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LEAD INDUSTRIES ASSOCIATION, INC.

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LEAD IN PLASTICS — WHAT THE FUTURE HOLDS*

G. V. Michael

Editor, Plastics Design & Processing

One of the most exciting phases of the fantastic technological growth this country has experienced since the end of World War II has been the emergence and growth of synthetic materials — plastics as they are more commonly called. Certainly, these materials have contributed much to the economic and technological advances made in this country in the past decade.

We, in the plastics industry, like to think that our industry has just emerged from the infancy stage — that it is still a vigorously growing child with the world at its feet. True, we have been dealt a number of setbacks; intracompetition has become a fierce thing, but you still can't consider us a mature industry: There is still so much to be learned about plastics in general, so many new types of polymers to be discovered, so many new ways to upgrade present plastics have yet to be tried, so many manufacturing and processing techniques have yet to be perfected or invented.

Let's take a look and see how this "wonder" child has grown (Figure 1). As you can see by these figures for the production of synthetic plastics and resin materials, the growth has been phenomenal. Back in 1922, the total production wasn't quite six million pounds — the industry was producing only two major products — phenolic (or "Bakelite") and cellulose nitrate. The development of the vinyls in 1927 started the push toward the discovery of other plastics — urea-formaldehyde, acrylics, cellulose acetate, nylon, melamine, Saran — until the total production amounted to some 428 million pounds in 1941. The war years saw the development of some of the important plastics of today — polyethylene, polyester, and fluorocarbons — all for the war effort. Production hit a high of 818 million pounds in 1945. The first billion pound mark was made in 1947, and the growth has been slightly more than terrific ever since.

In 1962, the total production of plastics is estimated to be 7.8 billion pounds — the increase over 1961 is almost equal the total production for the year 1947. The industry is expected to show a growth of at least 10% in 1963 to a total production of more than 8.5 billion pounds. (It might interest you to know that on a related volume basis this would be equivalent to 48.7 million tons of lead!) A total production of 10 billion pounds should be reached by 1965.

Consumption has paced this production very closely, ranging from about 93% to almost 100% or over, in some cases, because of imports. (Figure 2).

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Look Ahead with Lead

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WHAT ARE PLASTICS?

In this brief introduction, I have been throwing out a variety of terms such as polyethylene, polyester, acrylic, etc. Since I will be using these terms more and more throughout this talk, I think I should digress here a little and give a short explanation of just what the important plastics are, where are they used, and why they are important (Figure 3).

Here is another chart that tells what the various types of plastics are and in what volumes they are being produced. I have projected the figures to 1965 to show you which ones are considered to have the greatest growth potential. As you can see, polyethylene — a war baby with a fantastic growth record — leads the list. This is the plastic that you are all familiar with, as it is used to make film, housewares, wire and cable insulation, toys, detergent and bleach bottles, and pipe.

Next are the vinyls, very versatile materials, and the family of most interest to you. You are familiar with them because of their use in floor tile, appliance and building wire insulation, wall covering, synthetic leather, etc. Generally, vinyls are divided into two groups — plasticized and unplasticized (rigid). Because they are naturally hard, rigid materials, vinyls have to be compounded with plasticizers to increase their workability and impart flexibility and other desirable properties. The unplasticized vinyls produce strong, rigid materials that are today attracting much attention.

The third major group comprises the styrenes. This family consists of a number of polymers, copolymers, and terpolymers, all designed to handle specific jobs. General-purpose polystyrene is a common material for toys, decorative jewelry boxes, housewares, wall tile, and refrigerated food containers. The copolymers are used for TV and radio housings, and the terpolymer based on styrene-acrylonitrile-butadiene is a commonly used plastic in appliances and autombolies (generally metallized, so that most people don't even know it's a plastic).

These three types of plastics you are familiar with because they are common household items. As you can see, there are a variety of other ones that, even though used in lesser amounts, are equally important. Of particular interest are:

<u>Phenolics</u> — versatile liquid resins that are used to make moldings (the familiar "Bakelite") when combined with fillers such as wood flour, chopped fabrics, asbestos, and glass fibers; adhesives; paper and cloth laminations ("Formica" and "Micarta"); and glass fabric moldings (reinforced plastics) for rockets and missiles.

<u>Alkyds</u> — liquid resins for use in coatings and molding electrical parts.

<u>Melamine and urea formaldehydes</u> — similarly used in coatings; molding electrical parts, knobs and handles; dinnerware; adhesives; and "Formica" countertops.

<u>Polyesters</u> — liquid resins for castings or for use with glass fabrics to make reinforced plastic boats, car bodies, luggage, and building components.

<u>Polypropylene</u> — akin to polyethylene, but having some improved properties. Used in appliance and automotive parts, housewares, medical supplies, and pens.

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Urethanes — hard, abrasive coatings such as those found on bowling pins. Urethane foam is causing minor revolutions in the furniture and building fields.

Acrylics — clear plastics used for housings, signs, sheet goods, contact lenses, coatings, hair sprays, and industrial parts. Familiar as "Lucite" and "Plexiglas." About 200 million pounds in 1965.

Cellulosics — clear plastics derived from cellulose material (cotton or wood). Familiar uses include playing cards, steering wheels, telephone housings, eyeglass frames, pens, pencils, and tool handles. About 170 million pounds of these materials will be produced in 1965.

Epoxies, silicones, and diallyl phthalates — liquid resins for coatings, reinforced plastics, electrical and electronic insulation. The epoxies produce particularly strong adhesives for bonding all types of materials.

Nylons, acetals, fluorocarbons, and polycarbonates — engineering plastics having some properties approaching those of metals. These materials are finding use in a variety of applications that were once the exclusive property of brass, zinc, or aluminum. 1965 production of these materials is expected to be four times the 1962 figures.

Now that I have overwhelmed you with all these facts and figures about plastics, I am sure that many of you feel that you are in the wrong business. Don't be disheartened, because I haven't told you the important half of the story yet — the part where you are needed by the plastics industry.

As you may have noticed in my discussions of the various types of plastics, a number of different materials — paper, glass, cotton — play a very important role in their use. In fact, the list of materials that are needed by the plastics industry is more impressive than any listing of plastics. Why? Because, there is hardly a plastic on the market that is worth anything in its 100% pure form. For strength, they need to be reinforced with paper, glass, and cloth. Because many of them will degrade in the presence of light and/or heat, they need stabilizers and ultraviolet light absorbers. Others are too rigid, and they need plasticizers to loosen them up a bit. And they all use pigments. Other ingredients used in plastics range from powdered metals to waxes and lubricants, solvents, and flame retardant additives.

And these are not the only areas where plastics are used in conjunction with other materials. Today, plastics are giving more common-place materials a new lease on life. Coatings and laminations of film on metals have put a number of steel producers right into the plastics processing business. The plywood industry, working very closely with a number of plastics producers, is coming up with low-price, quality products that are attracting much interest in the construction field. In addition, there's an awful lot of steel and other metals going into the machinery, molds, and dies that are used to manufacture both the raw material and the finished plastic product.

Frankly, the plastics industry needs people such as you. Your products are being used by the industry in a variety of ways — as stabilizers for vinyls, as catalysts, pigments, and fillers, just to name a few. As I will point out in discussions of these various uses, there are some important areas where you're going to

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meet some stiff competition from other non-plastic materials. This fast-growing plastics industry can be pretty fickle, and it's going to buy the products that can do a better job more cheaply. Up to now, much of the research has been done by the plastics producer. Much more can be accomplished in the research labs of companies supplying materials to the plastics industry.

WHERE LEAD IS USED IN PLASTICS

A variety of lead compounds as well as some forms of metallic lead are used in plastics. In decreasing order, these lead applications are:

1. Stabilizers
2. Pigments
3. Catalysts
4. Fillers

STABILIZERS

The largest use for lead is as stabilizer compounds in polyvinyl chloride and other chlorine-containing polymers such as "Saran" (polyvinylidene chloride). Under exposure to heat and/or light, these plastics tend to release hydrogen chloride leaving a weak spot in the polymer chain susceptible to attack by oxygen. This attack causes degradation and embrittlement of the product. The addition of certain compounds, such as lead carbonate or sulfate, in concentrations of 3 to 10% will prevent such breakdowns under normal usage.

The incorporation of stabilizers is necessary to meet the requirements of an application as well as those posed by processing and storage. During processing, a vinyl resin may be heated to rather high temperatures several times: it has to be first compounded with plasticizers, pigments, fillers, etc., before it can be molded, extruded, or calendered — processes which have to be performed under high heat conditions.

The exact mechanism of the stabilizing effect is not exactly known. It is thought that the stabilizer absorbs any small amounts of hydrogen chloride formed and prevents the development of an acid condition in the resin — which would cause further degradation. In the case of ultraviolet attack, a material is needed to block out or absorb the UV rays. To qualify as a stabilizer, a material must easily absorb the HCl without detracting from the water resistance of the compounds.

Vinyl stabilizers can be divided into five main groups:

1) Lead salts or soaps
2) Barium, cadmium, zinc, and calcium salts or soaps
3) Organo-tin compounds
4) Organic (epoxies and phosphites)
5) Mixed stabilizers

At the present time, lead compounds comprise about 35% of the total amount of stabilizers used. They are lowest in cost and have many good properties. The other

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types generally are more expensive; however, for a number of applications, stabilizer cost is not a major factor and they do become very competitive with the lead materials.

The lead stabilizers offer good all-around properties; they are best in electrical properties and very effective in blocking out ultraviolet light. Disadvantages are that they cannot be used where optical clarity is essential, or where sulfide-staining presents a problem.

This problem of sulfide-staining, you will find, is becoming increasingly important. Many of the up-and-coming vinyl applications are in consumer areas where plastics have "to wear their best dress." Staining from industrial fumes, sulfur-heavy water, or other sources, such as fungicides or bacteriostats added to the vinyl compounds, cannot be tolerated.

Used alone, the barium, cadmium, calcium, and zinc materials do not give all the properties that are obtained with the lead stabilizers. Therefore, quite a technology has been developed in regard to the use of complex formulations of these materials. For example, Ba-Cd gives satisfactory electrical and clarity properties; Ba-Cd-Zn is good for sulfide stain resistance, and Zn-Ca is FDA-approved for food packaging uses. The Ba-Cd complexes are the most widely used.

More expensive are the organo-tins. They are considered best for rigid and clear vinyl products. The organics are not generally used alone, but in conjunction with other stabilizers. In the organic group are the epoxidized oils and esters which offer some heat and light stability. The phosphite stabilizers minimize color development and inhibit cloud formation.

As applications for plastics become more and more varied, there is a trend toward developing materials tailored for specific applications. Therefore, mixed stabilizer systems are becoming increasingly common. For example, a complete stabilization system may often contain a barium compound, a cadium compound, a zinc compound, a phosphite, an anti-oxidant, an epoxy, and an ultraviolet absorber.

The most widely used lead stabilizers are lead carbonate, lead silicate, lead sulfate, and a silicate-sulfate complex. Next are the dibasic lead phthalate and phosphite. Other lead stabilizers are chlorosilicate complexes, fatty acid salts, salicylate, and maleate. Their particular forms and properties are listed in this chart.

Figure 4

LEAD STABILIZER	PROPERTIES	USES
Basic lead carbonate	Good, all-around; low-cost Will gas at high temperatures	Electrical, plasticized extrusions, some rigid where processing temperatures are not too high
Tribasic lead sulfate	High heat stability; works well with most plasticizers; disperses easy in powder mixing operations	Electrical, plasticized and rigid extrusions and moldings

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LEAD STABILIZER	PROPERTIES	USES
Basic lead silicate-sulfate	Low specific gravity, good electrical properties, good moisture repellency, difficult to disperse in powder mixing	Electrical insulation
Dibasic lead phthalate	Good light fastness, excellent heat stability	High-temperature electrical insulation, opaque film and sheeting, some foam
Dibasic lead phosphite	Ultraviolet screening, anti-oxidant, good heat stabilizing, good dispersion properties	Plastisols, organosols, paints, foams
Lead ortho-silicate-silica gel	Gives good translucency, absorbs exudates	Translucent film, sheeting and upholstery stock
Lead chloro-silicate	Low cost, good electricals	Electrical insulation tapes
Lead chloro-phthalo-silicate	Low specific gravity, good electricals	Wire insulation
Lead salicylate	Ultraviolet light stabilizer, prevents development of blue color (because of iron impurities) in asbestos-filled formulations	Used with other stabilizers in floor tile
Lead stearate	Lubricating properties	Costabilizer for extruded calendered, and molded products
Lead salts of mixed fatty acids	Lubricant, heat and light stabilizing	Phonograph records, co-stabilizer in insulation
Tetrabasic lead fumarate	Heat stabilizing	Electrical grade plastisols, phonograph records, high temperature insulation
Tribasic lead maleate	High heat stabilizing, UV screening	Heat stable compounds, translucent stock

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You can see from this brief description of the various types of lead stabilisers available to the vinyl people that electrical insulation presents the biggest market, with phonograph records second, and floor coverings, film and sheet, and protective coatings running a close third.

I have broken down the PVC use into those areas of interest with an attempt to give some idea of the amount of lead going into each use (Figure 5). This has been a pretty hard thing to do. My discussions with the various manufacturers of vinyl compounds brought out some rather conflicting information in many areas of use. The amount of lead stabilisers being used in a particular application depends on whom you're talking to. One company says they don't use any, while another says they use quite a bit. About the only area, where there was any agreement, was in the wire insulation field.

Lead stabilizers are very important here because of their very desirable electrical properties. Besides flexible insulations and tapes, they are finding use in rigid vinyl conduit and molded and extruded electrical devices. All 1965 figures in Figure 5 are based on present usage and an anticipated rate of growth. At the present time, they are believed to be reliable estimates based on today's trends and the growth of the national economy. However, if you listen to the polyethylene people, vinyl is in for some stiff competition, particularly in electrical wire insulation. They point to the fact that the present price of vinyl resin (about 14¢ per pound) is about the lowest it can get. This resin price reflects an electrical insulation compound price of about 18¢ per pound. The most that could happen in the next few years would be a drop of about 2¢ per pound for compound. At 16¢, the price of a cubic inch of vinyl compound would be 0.7¢. Now, conventional polyethylene, which currently costs 21.5 to 25.5¢ per pound, could easily drop to 13 - 15¢. At these prices, a cubic inch of polyethylene would cost about 0.5¢ — a lost less than the vinyl. Of course, there are some areas where conventional polyethylene will never replace vinyl such as in building wire where flame retardance is a factor. But these same people point out that a new form of polyethylene — cross-linked polyethylene — has received UL approval and makes a very good building wire. At an expected future price of 18.5¢ per pound, it would still cost less on a volume basis than the lowest possibly priced vinyl. Some authorities predict that even a much higher-priced cross-linked polyethylene will reduce the vinyl building wire usage at least a third by 1965.

This price picture not only concerns the vinyl insulation business,but quite a bit of the other areas where vinyl is now the leader. That is one reason why the vinyl producers have recently concentrated their research and development on a higher-priced engineering version — the rigid vinyls. At the present time, rigid vinyl is causing quite a bit of excitement in the industry as it is expected to really pave the way for the use of all plastics in the construction field. These rigid vinyl materials are being used for such applications as pipe, building panels, gutters and downspounts, storm windows and doors, siding, weather-stripping, non-breakable windows and skylights, and roofing. At the present time, about 40 million pounds of rigid vinyl are being produced. By 1965, the volume could range anywhere from 100 to 300 million pounds, and go up to 500 million pounds by 1967.

Since the rigids are being aimed at a number of outdoor or high heat applications, much emphasis is being placed on the proper use of stabilisers. Rigid vinyl pipe, which amounts to almost 20 million pounds, is finding much use in non-

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potable applications such as conduit and drain-waste pipe where lead stabilizers are of value. At the present time, these applications comprise about 20% of the total rigid vinyl pipe produced. Nevertheless, there seems to be a hesitancy on the part of vinyl producers to use any lead at all in pipe compounds for they fear the possibility that as the market grows there will be the danger of lead-stabilized pipe accidently being used for potable water. Several producers, however, don't believe that this is really a problem. They point out that almost 75% of the rigid vinyl pipe produced in Europe contains lead — a fact that leads them to believe that it is safe to use potable water pipe stabilized with lead in this country. They're willing to produce such stabilized materials, but they're not going out and secure approval to do so. It's going to be up to you people to make the push toward investigating this application in this country, and securing necessary approval.

You're going to have to exhibit some more leadership, too, if you want to capture a sizable part of the market for rigid PVC going into outdoor applications. It is this area that makes the future for rigids so attractive. At the present time, the thinking is that lead can only be used in the manufacture of opaque, industrial-type products where there are no problems of toxicity and sulfide staining. Therefore, you'll find that Ba-Cd is claiming the lion's share of the market. Ba-Cd systems have to include a phosphite stabilizer, an ultraviolet absorber, and an epoxy to be really effective, but they do produce highly stable products (both clear and opaque). There are leads today that produce suitable translucent products with both heat and light stability equal to or better than the Ba-Cd systems. If you can beat this problem of color control and sulfide staining, you will find unlimited opportunities in this new and exciting field.

Of course, this big "if" is just as applicable to the other vinyl applications. Floor tile was once a big user of lead stabilizers. The switch to light-colored, high-style vinyl flooring has caused a trend away from lead during the past few years. The main objection here is that the sulfur in rubber shoe heels causes staining which pretty much restricts lead's use to dark-colored flooring. It is estimated that less than 10% of all types of flooring now uses lead. The market may open up again with the development and increased use of other materials for shoe heels and soles — lead stabilized vinyl being one such material.

Foam, which at one time looked particularly promising for lead (the stabilizer helps to promote the foaming reaction), is also moving into high-style areas such as outer-wear clothing. The best estimation is that about only 5% of the vinyl foam today uses lead (several years ago, lead was almost exclusively used); however, there is no reason why the usage couldn't increase in the next few years. The sulfur-staining problem can be easily eliminated through the use of stain-resistant skins. Competition here is from the Ba-Cd and Ba-Cd-Zn systems.

Vinyl protective coatings offer a particularly good market. On the industrial side, lead-stabilized pastisols are finding such good chemical-resistant applications as lining tanks and coating electroplating racks. Fluidized bed coating — an increasing popular method consisting of applying dry powdered coatings on metal — will boost the use of vinyls. Here again, lead stabilizers can be used, but the choice depends upon the application — many of the fluidized bed coating applications include such non-lead usages as food-handling equipment, decorative furniture, outdoor building components, and dishwasher and refrigerator components.

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PIGMENTS

With the present trend to high-style, decorator colors, it is pretty hard to predict what's going to happen in the field of plastics coloring. However, there has been reported a trend back to the yellows and oranges after a couple of years of the greens (bronze and pistachio, for example). This should certainly help the cause for some of the lead compounds used as pigments in plastics.

With lead pigmentation, of course, we are faced with the old problem of sulfide-staining — a problem, pigment people have run into in areas other than plastics. Nevertheless, several lead pigments are widely used in applications where this is not a factor.

The most commonly used lead pigments are chrome yellows and oranges (basic lead chromate and lead chromates) and molybdate orange (a coprecipitated mixture of lead chromate, lead sulfate, and lead molybdate). Both of these are used in the vinyls because of their compatibility with lead stabilizers. Other plastics for which they are suitable include most of the thermosets — phenolic, melamine, urea, polyester, alkyd, polyurethane, and epoxy. Use in other plastics such as polyethylene, polypropylene, and polystyrene is limited — the pigments can be very incompatible in certain applications of these resins.

Molybdate orange is considered to be unique among the inorganic pigments as it possesses good brightness and high coloring strength. It is often used with red pigments to produce relatively low-cost, bright red colors. The chrome orange pigments are particularly susceptible to sulfide-staining, and therefore, they are being replaced by blends of chrome yellow and molybdate orange. Competition, in these areas, is from the cadmium sulfide yellows, yellow titanium pigments, ceramic yellows (antimony, titanium-chrome oxide), and the cadmium mercury and cadmium sulfo-selenide oranges.

White lead is chiefly used in the vinyls to give stabilization, in addition to coloring. This material is a good, white pigment with moderate tinctorial strength. However, most of the white pigment used in other plastics is titanium dioxide; some zinc oxide and zinc sulfide are used for specific applications.

An interesting group of lead pigments are the light-stable, synthetic pearlescents. About 300 to 400 tons of lead are used a year for pearlescent pigmentation, the majority of which is in conjunction with plastics materials. They can be dispersed in plastic-base lacquers or enamels for application on both plastic and non-plastic substrates. They are mixed with casting resins, such as polyesters and acrylics, to produce attractive sheeting, jewelry, buttons, compacts, and knife handles. Because of their high heat stability, they are easily incorporated into molding and extruding compounds — polystyrene, polyethylene, polypropylene, cellulose acetate, acrylic, and vinyl — to produce a wide range of attractive products.

Some of these synthetic nacreous pigments can be compounded and used to give an interesting play of colors in plastics. In the form of thin, platelike crystals that behave like conventional pearl pigments, these materials have twin inherent colors — one being observed by reflected light while the other is seen by transmitted light. Incorporated in transparent plastic film or sheet, they produce interesting optical effects such as red when viewed in one light and green when viewed in another.

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CATALYSTS AND CURING AGENTS

A number of elastomeric polymers, namely polysulfide rubber, neoprene, chlorosulfonated polyethylene and urethane, are cured with the aid of lead oxides or organic salts. In some cases, lead is used because it alone will give the degree of cure needed for most applications. With other elastomers, the use of lead curing agents produce materials having other improved properties, such as moisture resistance.

Polysulfide rubbers are cured almost exclusively with lead dioxide, and consume approximately 200,000 pounds of this material each year. The lead material is the only common chemical that provides the type and degree of cross-linking required for such polysulfide uses as non-hardening caulking materials and belting. The polysulfides are important materials to plastics processing, too, as they are widely used for making plastic molds and dies. The 1962 production of polysulfide rubbers amounted to 7.0 millions pounds; it is expected to reach 9.0 million by 1965.

Like polysulfide, neoprene rubbers can be vulcanized by metallic oxides and organic salts. It has been found, however, that litharge or red lead gives products having much improved moisture resistance. When cured with non-lead chemicals, neoprene swells 20% on exposure to water. Cured with litharge, the swelling is in the range of 0.1%. A red lead cured material is capable of withstanding intermittent sea water immersion and intense sunlight for years without any loss of toughness or soft sealing properties. Present production of neoprene amounts to about 270 million pounds per year. Losing out to some of the newer materials in many applications, it isn't expected to show much of a production growth over the next five years — only about 10 million pounds increase by 1967. Major applications include: tire and tire products, wire and cable jacketing, mechanical goods, adhesives, and shoe heels.

Chlorosulfonated polyethylene, better known as "Hypalon," is frequently cured with tribasic lead maleate or tetrabasic lead furmarate to arrive at the highly stable properties for which it is noted: resistance to oxidation by sunlight, weather, chemicals, high temperatures or ozone. Having unlimited coloring ability, as well as high resistance to abrasion and compression set, it is a good material for cable jacketing, seals and gaskets, floor tile, calendering rolls, shoe heels, corrosion-resistant hose, roofing, and coatings. Production in 1962 amounted to some 13 million pounds. Some predict a bright future with close to 80 million pounds being produced by 1967.

METALLIC LEAD FILLERS

Many of the plastics can take advantage of metallic lead's unique properties to produce some rather interesting and unusual products. In spite of the higher density, lead powders blend more easily with liquid plastics than other metals do, and a greater volume percentage can be introduced into the formulations. For a given viscosity starting with the same liquid resin base, a greater volume of lead can be incorporated than with other metals such as iron, copper, or aluminum.

Plastics can make great use of the radiation shielding properties of lead. For example, lead-loaded vinyl sheet is a most convenient material for X-ray aprons, gloves, and radiation suits. Lead-filled epoxies, polyethylenes, silicones, urethanes,

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and polyesters represent good materials for formulating shielding materials. Cast lead-filled radiation shields are more economical than machined or fabricated structures, or other structures surfaced with lead. As an example, a combination radiation shield recently developed by the AEC uses powdered lead mixed with paraffin polyethylene waxes. The lead particles distributed homogeneously throughout the wax matrix block the propagation of gamma and X-rays. Neutrons are absorbed by the light atoms of the organic material. The mixture is easily cast like metal at a low temperature of 260°F. It makes little difference if elemental lead is in the form of a massive, monolithic shield or distributed as a finely divided powder in a plastic matrix — what is important is the number of lead atoms in the path of the gamma radiation. Lead-filled silicone rubbers produce flexible radiation shields suitable for service at temperature extremes of -90° to +600°F.

Another big area is the use of lead/plastic or lead/rubber mixtures for noise control. Galena (lead sulfide)-loaded urethanes and lead-vinyl combinations are very effective in soaking up sound. They are applied directly to surfaces that would otherwise radiate noise. I believe you have witnessed the excellent demonstrations of these acoustical materials at the exhibits put on by your Association. These materials are specified on certain naval installations, in helicopters and jet aircraft, and for covering noisy pipes and machinery. Leaded plastic curtains are very effective flexible sound barriers, and troweling compounds reduce vibration in partitions, ductwork, metal panels, and machinery members. At the present time, there are about ten suppliers of lead-loaded vinyl or rubber sheet materials, four manufacturers of leaded vinyl or rubber coated fabrics, and an additional four manufacturers of lead-filled casting or troweling compounds based on either epoxy, urethane, or silicone materials. Another application of lead-filled plastics is in the production of dense cast products useful as ballasts or in small flywheels where mass must be concentrated on the outside periphery.

Leaded epoxy can be used in much the same way as aluminum or iron filled formulations for making precision dies used by both the plastics and non-plastics industries. Lead powder of very small particle size is mixed with the resin and cast into a block from which dies are formed by sculpting, grinding, and polishing by hand. The lead particles act as chip-breakers within the plastic and prevent gouging by abrasives. In final polishing, the lead smears out to a mirror-like surface, which is essential for good reproduction from the die. However, such lead-based dies are pretty unique items from a plastics tooling standpoint. They produce tools that are heavy; heat transfer is poor compared to the use of other metals; and they can only be used for low volume production because of their lower strength. Aluminum, iron or steel filled epoxies make much better tooling materials for most applications. The one major advantage of using lead — softer surfaces — can be accomplished by varying the epoxy formulation when using other metals.

As you can see, all these applications for metallic lead fillers are unique. In some cases, competition from other metals or materials is high. I wouldn't attempt to give forth with any ideas on the future in any of these areas, but I would say that if you want to capture your deserved share of these markets, you're going to have to continue your fine promotional programs to convince the plastics people that there's a need and a future for lead-filled products.

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SOME BLUE-SKY THINKING ABOUT THE FUTURE

Throughout this paper, I have tried to be as realistic as is possible depicting what the future of the plastics industry holds for lead. In certain areas, I have had to present somewhat of a pessimistic picture — such as the future of vinyl for electrical insulation. As I said then, there is a good possibility that other plastic materials could capture much of the insulation business away from the vinyls. Whether or not it will happen is anyone's guess. The way things are happening today in the plastics industry it isn't hard for one material to become obsolete overnight. On the same basis, new developments in an older plastics family could easily put this material back on top — and new developments involving both old and new plastics are happening everyday.

Generally speaking, it's obvious that as more and more plastics move into consumer items, lead is going to take a beating, and it is other types of applications — industrial and defense — where lead because of some of its unique properties can aid plastics in capturing more of the market. It is in this realm that I would like to do some blue-sky thinking about possibilities of developing new lead/plastic materials. I may be way-off-base with these ideas,but I hope they will provide some food for thought.

One real hot phase of the plastics industry is that of reinforced plastics. In 1962, it was estimated that over 280 million pounds of reinforced plastics were produced; predictions put 1963 sales at 300 million pounds. Total consumption could easily jump to 500 million pounds by 1965. Of these weight figures, you can roughly estimate that 40% is glass. Now, as far as I know, there are no lead glass fibers being used for reinforced plastics. For one thing, the specific gravity is higher, softening point is lower, and tensile strength is less than that of the commonly used borosilicate glass. But, lead glass does offer the distinct advantages of some radiation absorption, as well as desirable electrical properties. These properties could very well make lead glass fiber reinforced plastics important products in certain industrial and defense areas.

At the present time, the strength-to-weight properties are what make reinforced plastics so attractive, and that is why most applications are as structural materials in boats, rockets, cars, construction, pipe, aircraft, and electrical apparatus. I can foresee future use in numerous areas where the designer is willing to sacrifice some strength properties for, say, X-ray shielding or increased dielectric constant. Who knows? Perhaps, more research on lead glasses will produce a range of products that could offer a number of additional advantages.

Along this same line is the possibility of producing lead ceramic fibers for reinforcing plastics. One company has already developed zirconia fibers that promise to become important reinforcements for rocket nozzles. In the future, these same fibers are expected to invade industrial reinforced plastics where their high-temperature properties can be used to advantage. It's possible that some of the lead ceramics could produce comparable or better materials.

A third interesting possibility is the development of a lead polymer. At the present time, there is much activity in the field of metallic or inorganic polymers. It is generally acknowledged that the Russians are way ahead of us in this field,

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and that their inorganic polymer developments have enabled them to perform some of their more spectacular space feats.

The purpose behind this work is to come up with practical plastic materials having increased high-temperature stability over today's organic polymers. Two basic types of metallic polymers currently being investigated are: 1) those which have no carbon-carbon bonds in their backbone, but have them in their side chains; and 2) those which contain no carbon-carbon bonds whatsoever. (Figure 6). These, of course, differ from the conventional plastics which have carbon-carbon bonds in their backbone.

The first classification is not particularly new, as the silicones fall into this category. Much of the work being done by both us and the Russians is aimed at developing similar polymers where either part of, or all of, the silicon atoms are replaced with other elements. Other work is devoted to producing similar polymers based on elements closely related to silicon and oxygen in chemical functioning.

So far, attempts to make practical, non-carbon polymers have not been successful. While thermally stable at temperatures considered maximum for commercial "high-temperature" organic polymers, these materials, based on such compounds as boron nitride and phosphonitrilic chloride, generally lack resistance to moisture and oxidation.

As you can see by some of the types of polymers already developed, the field is wide open for metals. Aluminum, boron, tin, arsenic, beryllium, and chromium are represented in work currently being done, and, as far as I know, lead hasn't been considered as a possibility at all. You won't know what kind of a polymer it could produce until it's been tried!

CONCLUSIONS

The plastics market is certainly a good one for the producers of non-plastic materials to latch onto. It has had a tremendous growth that shows no signs of leveling off for the next 10 to 20 years. In fact, with the development of new and improved plastics, the overall growth of the industry could reach quite fantastic proportions.

Overall, I would say that the future for lead in plastics is good, although present trends indicate its growth will not be as great as it should be. This is due mainly to the fact that leaded plastics are being replaced by other plastics in which lead compounds are not needed.

I would also say that you have a good opportunity to develop new uses for lead, particularly in some of the higher volume plastics that are not using your materials at the present time. In the next ten years, new markets for plastics are not going to just happen as has been the case so many times in the past. They're going to be painstakingly developed by plastics producers. The markets for lead and lead materials in plastics will have to be developed in a similar, concentrated fashion.

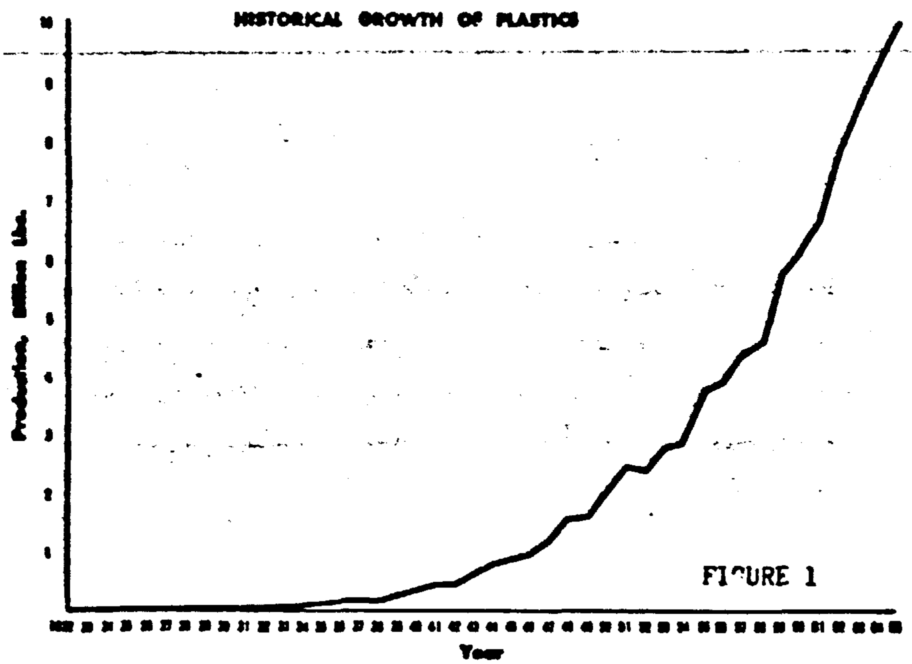

FIGURE 1

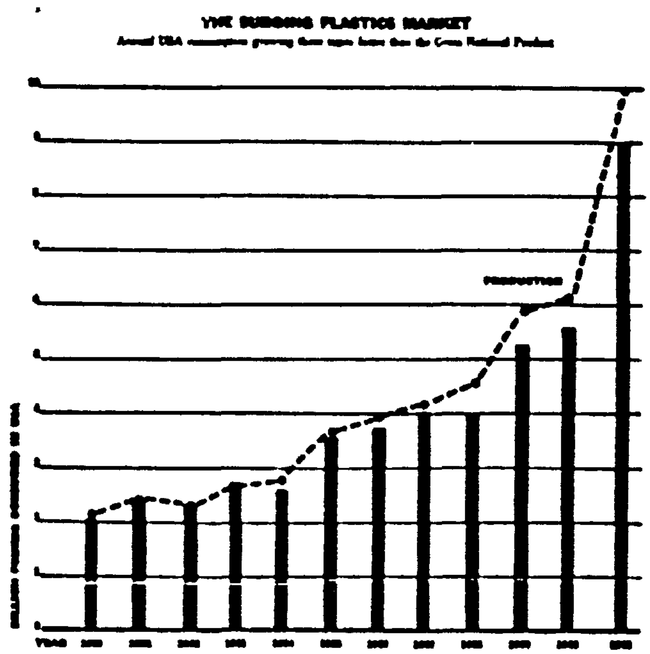

FIGURE 2

ANNUAL PRODUCTION OF PLASTICS

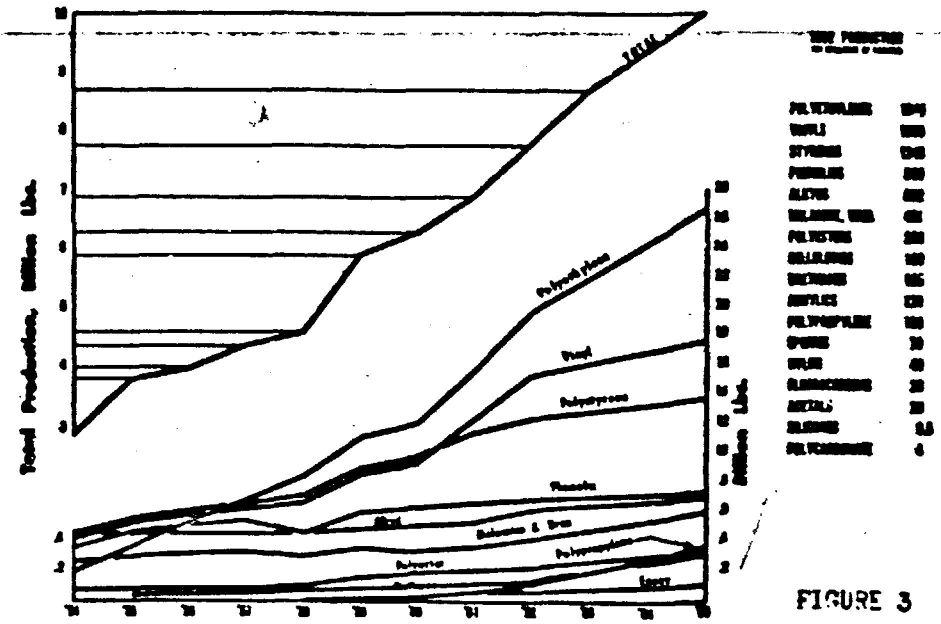

FIGURE 3

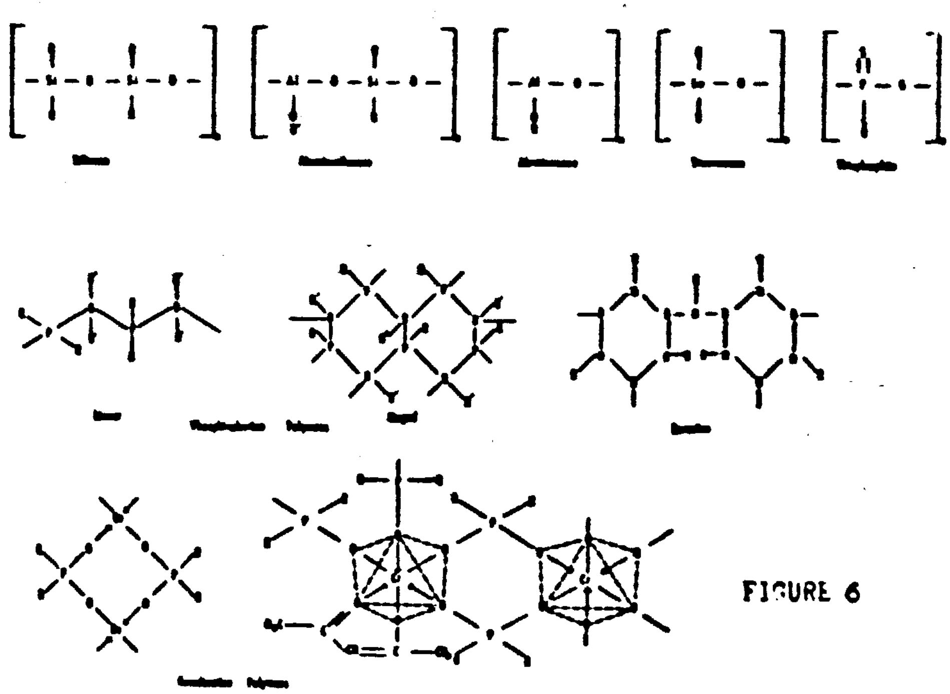

FIGURE 6

Figure 5

CONSUMPTION OF VINYL AND LEAD STABILIZERS

(all figures in millions of pounds)

	Applications of Vinyl		Consumption of Lead Stabilizers	
	1962	1965	1962	1965
Total Vinyl	1535	1700-1900		
Total PVC	1120	1350-1550		
Wire Coating	176	203	8.30	9.50
Records	68	80	1.00	1.20
Rigid Pipe & Shapes	46	100-300	0.50	3.60
Floor Coverings	230	250	2.20	2.00
Film & Sheet	250	350	1.25	1.20
Foam	18	35	0.05	0.10
Protective Coatings	50	100	0.60	1.20
Other	282	232	5.00	5.00
Total Lead Stabilizer			18.90	23.80