THE FUTURE OF ENGINEERING PLASTICS

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Plastics have evolved considerably since the first natural plastics, celluloid, was developed over a one hundred years ago in the United States as a substitute for ivory in billiard balls. It is safe to say that the consumer revolution of the past thirty years is basically a plastics' revolution. Without plastics, consumers could not afford or even get, many of the products that are on the market today.

Just think, last year in Japan almost the same volume of plastic resins were made and used than all of the steel, aluminum and copper combined. Total plastics produced in Japan in 1987 exceeded 10 million tons. Total production of steel, aluminum and copper was about 76 million tons. Using the different specific gravities of these materials, volume is almost the same. So I think you can see that plastics have become a very important material for use in Japan and throughout the world.

Unlike metal, plastics come in many different varieties and almost an infinite number of performance possibilities from rubber like materials to those having a stiffness to weight ratio approaching that of steel.

You already know that we divide plastics into two generic categories: Thermoset and Thermoplastic resins. Thermoset resins can be formed only once. While, Thermoplastics can be reheated and reshaped many times. Further classification of these two generic types would include commodities and engineering plastics. Commodity plastics serve non-structured applications, usually produced in high volumes such as shower curtains, trash containers, credit cars, ball point pens, cups and packages, etc. Among commodity plastics are polyethylene, polypropylene, polystyrene and PVC. In Japan commodity plastics comprise about 95% of the total volume of all plastics sold, but only about 80% of the total value, because of their generally lower prices.

In contrast to commodity plastics, engineering thermoplastics are high performance materials that offer prolonged use in more demanding and structured applications because they are outstanding in high stress chemical, electrical,thermal and mechanical environments.
They can also be produced to provide additional advantages in dimensional stability, high heat resistance, flame resistance and self-lubricating properties. Today, Engineering plastics represent less than 5% of all of the plastics being used in the world. But because these engineering plastics, more than any other materials, can help drive the major changes that are occurring in world industries, the use of these materials will grow enormously in the coming years. High performance engineering thermoplastics provide productivity design, productivity in manufacturing, and productivity in recycling. When properly formulated, engineering plastics can be fabricated into mechanically functional, precision parts with structures similar to metal --- but with other advantages that make them superior to metal in many important features. Compared to metals, engineering plastics do not corrode or rust. They are easier to fabricate and color. They can provide equal strength and durability and less energy is needed to produce a finished part versus a similar part made of metal. Throughout history metals have been extremely energy-intensive materials, requiring 00massive amounts of energy to mine, transport, refine and fabricate. Engineering plastics save energy.

Engineering plastics include a variety of high performance materials ranging from large volume plastics to relatively new , low volume, high cost specialities such as polyimide, liquid crystal polymers, polyetherketones and aramid fibers. These speciality materials will become more important in the future, because they are growing at more than 15% per year as end-user requirements increase and manufacturing techniques are altered or developed for their use. The needs of the aerospace and electronic industry are increasingly being met by these materials. At GE PLASTICS we are participating with ultem polyetherimide, supec polyphenylene sulfide, while LCPs and other new products are being developed in our laboratories.

Today, however, I will limit my discussion to higher volume engineering thermoplastics which will continue to grow at a rapid rate from a much larger volume base. Among these materials I include polyacetal, polyamide, polycarbonate, polyphenylene ether and molding grades of thermoplastics polyester, PBT and PET.

POLYACETAL

Acetal is a highly crystalline resin based on formaldehyde polymerization technology. The original polymer was introduced in the 1940's by Dupont.

Low friction and good wear resistance are major factors in selecting this product for dynamic applications such as gears and bearings. Acetal's toughness, abrasion resistance, and moisture, heat and solvent resistance have made it a preferred material in plumbing fittings.

Sales of Acetal resins are larger in Japan than in the U.S. In fact, Acetal is the highest volume engineering plastics in Japan with over 100,000 tons sold in 1987. This probably results from the fact that Acetal's low friction levels and lubricity enable it to be widely used for internal components in a wide range of consumer electronics products, a largely Japanese based industry. The leading producers of Acetals are Dupont, BASF, and Hoechst Celanese.

POLYAMIDE OR NYLON

Nylons are the oldest of the engineering thermoplastics, having been introduced in 1938 as the world's first synthetic fiber. It has the largest engineering plastic tonnage in Europe but in the U. S. It is second to polycarbonate. In Japan sales were about 80,000 tons in 1987. The most widely used Nylons are Nylon 66 and Nylon 6. Specialty grads, Nylon 11, Nylon 12, Amorphous Nylons, etc., have also been developed for specialty applications.

Nylons are mostly crystalline polymers which have excellent fatigue resistance, low coefficient of friction, good toughness and good chemical resistance. Nylons find their largest volume use in the automotive industry in mechanical and electrical hardware and under-the-hood applications. The introduction of impact modified (super though) Nylons in the 1970'S added to Nylon's growth and opened up new market opportunities. The major producers of Nylons are Dupont, Homechst Celanese, BASF, UBE and Asahi.

POLYCARBONATE

Polycarbonate has become the largest volume Amorphous Engineering Thermoplastic in the world. Its key properties are exceptional impact strength, toughness, transparency, high heat resistance, flame retardance, and dimensional stability. Applications range from Glazing of windows to compact discs to clear water bottles. The high degree of compatibility with other materials has resulted in many blends which have expanded market acceptance. Combinations with Polyesters have resulted in tough, chemical resistant products used in automobile bumpers. Ford Taurus and new Cadillac Models are using this material for bumpers in the U.S. In Korea, Hyundai has become a major user. Combinations with ABS are being used in business machines and automotive applications. About 80,000 tons Polycarbonate are General Electric, Teijin, Bayer and Mitsubishi Gas Chemical.

MODIFIED POLYHENYLENE ETHER

The combination of high impact polystyrene and polyphenylene ether produces an alloy with a broad property profile and good processability at reasonable cost. The properties vary with the quantities of each ingredient but generally, these products have excellent impact strength,toughness, dimensional stability and good hydrolytic stability,flame retardant grades find use in business machine applications, appliances, and electrical/electronic parts. Other grades are used in automotive applications due to excellent low temperature impact strength and retention of properties after repeated temperature variations.

Various fabricating processes, such as foam molding and blow molding, have expanded the use of these products, particularly in business machine applications. Over 70,000 tons per year are sold in Japan. Recent introduction of PPE/Nylon Blends, which have excellent dimensional stability, chemical resistance, and toughness, open new market opportunities such as automotive body panels. GE is the leading producer with over 80% share worldwide.

THERMOPLASTIC POLYESTERS

Thermoplastic polyester molding compounds are crystalline polymers with good chemical resistance (especially to organic solvents and oils), toughness, high heart resistance, and Dimensional stability. Polybutylene terephthalate (PBT) has received the most market acceptance compared to polyethylene terephthalate (PET) due to improved processing and electrical properties of the former material. However, the higher heat resistance of PET is desirable for some applications. Large markets include electrical/electronic application (such as intricate connectors) and automotive parts (such as distributor caps). About 70,000 tons per year are sold in Japan.

The title of my talk is "The Future of Engineering Plastics", so let me now describe what we at GE Plastics consider to be major trends for these materials in the future.

THE FIRST TREND IS THAT CONSUMERS AND MANUFACTURES ARE RECOGNIZING PLASTICS TO BE, IN FACT, HIGH QUALITY MATERIAL.

The old public image of plastics being cheap substitutes is giving way to a new image of plastics as high performance materials that enhance the design, function, manufacturability and general competitiveness of products. Because engineering plastics represent functional replacements of traditional materials, the polymers are providing high quality performance that equals and, in many cases, surpasses the materials being replaced.

For instance, with regard to applications most used by consumers, there are today in the marketplace products such as blenders and toasters made of plastics that are preferred over their metal counterparts.

Because consumers' perceptions of plastics are changing, their expectations of plastics are changing too. Being more comfortable with plastics, consumers are demanding, and will continue to demand, more sophisticated performance from plastics. In turn, the fulfillment of these demands by plastics suppliers will enhance the high quality image of plastics even more.

THE SECOND TREND IS THE INCREASING RECOGNITION BY MANUFACTURERS OF THE COMPETITIVE IMPORTANCE OF DESIGN.

A recent article in business week noted: "After relegating design to the backseat in the 1970s, U. S. manufacturers are once again discovering that it is key to industrial competitiveness. Design, they are learning, is more than skin deep. It's the very heart of a product. A good design appeals to the eye, but it also must be reliable easy, and economical to operate and service. It should also be simple to manufacture." In short, design not only enhances product appearance and function but it also drives manufacturing productivity.

Plastics, especially engineering thermoplastics, are especially suited to enhancing the power and scope of design. First, designing with engineering thermoplastics drives product quality advances. Quality is defined in one place only, the marketplace, and by one person only, the customer. Because the marketplace is constantly changing, because customers' needs are constantly changing, quality is constantly changing. So quality and change in the marketplace are not separate but interrelated. Using engineering thermoplastics offers the quickest and most efficient and effective means of adapting to and driving quality and change in the marketplace. Quality is enhanced through the use of engineering thermoplastics because designers have much greater freedom than when using metal, wood, glass or paper. Because suppliers can provide design and engineering expertise along with materials, new advances in materials performance and processing can be more rapidly incorporated into product development. New products, products directly linked to fulfilling consumer needs, can be more quickly cycled into the marketplace, usually at lower costs. Total cost incorporates not just materials' costs but manufacturing costs. Because the total manufacturing costs of a product usually breaks down to one third materials' cost and two thirds assembly costs, manufacturers must take a more comprehensive view of cost requirements. Engineering thermoplastics may be more costly on a per kilo basis, but their use can actually lower total manufacturing costs.

Designing with a broad range of performance offerings, designing for the combination of aesthetics and functionality, designing for serviceability, designing for manufacturability, designing with new materials and new processes, designing for quick cycling of products into the marketplace ----- all these design activities, that are enhanced by engineering thermoplastics ----- serve to make products less costly.

THE THIRD MARKETPLACE TREND THAT WILL ENHANCE THE GROWTH OF ENGINEERING THERMOPLASTICS IS THE MOVEMENT OF THE MARKET TOWARD LARGE PLASTIC PARTS.

For the first time since plastics were invented, the advent of new materials, new processing techniques and new conversion equipment is enabling engineering. Thermoplastics to be incorporated into large parts. In the early 1970s, the largest lexan polycarbonate injection molded part was a 10 kilogram snowmobile hood. Injection molding is an inherently slow process compared to metal stamping. Furthermore, the modulus of thermoplastics was not adequate for large part configuration. So large, infection molded parts, were impractical.

Before the development of high performance thermoplastic composites, like polyester/glass, manufacturers of large parts could choose either thermosetting composites, like polyester/glass, or stamped metal.
It was a limited choice. Both materials involve labor and time intensive processing. They require large amounts of floor space and very large machines. In addition, stamped metal requires expensive tooling and has limited functionality and design flexibility. But the development both of high modulus, engineering resin and glass mat composites <u>and</u> new conversion techniques, such as flow forming, is enabling engineering thermoplastics to be made into large parts. Composites combine a heterogeneous mixture of one or more polymers and reinforcements, providing a high modulus, though, lightweight material that is the functional equivalent of steel. They can be flow formed through a process that involves filling tools with preheated blanks of thermoplastic composites. Since the tools can incorporate functional components, large parts can be formed with such features as bosses, ribs, and inserts. Think of it: large, highly functional thermoplastic parts, flow formed in one operation.

These advances are leading to striking new innovations in the use of engineering thermoplastics in large parts, not just large parts for industrial applications, such as automobile seat shells, hoods, body and under body panels; large appliance fans, dryer tubs, bases and panels; construction modular flooring, to name just a few.

THE FOURTH TREND THAT WILL DRIVE ENGINEERING THERMOPLASTICS' GROWTH IS MATERIALS' RECOVERY.

Recovery of materials, or recycling, is becoming a paramount social issue, also of importance here in Japan. But equally important are the business issues associated with materials' recovery. Recycling can be a productive and profitable undertaking. The metal industry has proven that point. Just as metals can be re-used, so high performance engineering thermoplastics can be profitably re-used as well. In a recent study, GE plastics found that engineering thermoplastics retain almost 100% of their properties even after 10 years of weathering on first use applications. Materials that ROT, RUST and CORRODE are simply unproductive.

Indeed, Materials that cannot be used twice are also unproductive and are likely to become obsolete because they cannot provide the economic advantages to be used once. For instance, recycling ¥140 per kilo commodity plastics is not productive. Cleaning them, reconverting them, repacking and reshipping them is not worth the original cost. But recovering high value, high performance engineering thermoplastics costing ¥500 or more per kilo not only provides a significant value to recover, reconvert and reuse them, it also provides materials stripped of original manufacturing costs. In addition, using high performance engineering thermoplastics twice can drive out lower value materials that are used only once. Just think of it, when plastics are recycled, up to 60 percent of the energy required to make the same product is saved.

THE FIFTH TREND IS THE MOVEMENT OF ENGINEERING THERMOPLASTICS INTO THE BUILDING INDUSTRY.

As the cost of land, labor, materials, and capital continue to rise around the world, engineering thermoplastics will provide greater economies in manufacturing and building houses. Compared to traditional materials of metal, wood and glass, engineering thermoplastics can be more effectively designed for simplified assembly procedures, they can be more effectively integrated into automated and robotized production. And they can more effectively incorporate functional features. And houses built of engineering thermoplastics need not upset tradition. Such houses will offer function, efficiency and beauty, with old and new materials working side-by-side: the technology of the new combining with the wood, stone, and glass of tradition. GE plastics is making a strong commitment to bring engineering thermoplastics to the housing industry by building a polymer house, which will open next September in Pittsfield, Massachusetts, U.S.A.

THE SIXTH TREND IN THE FUTURE OF ENGINEERING THERMOPLASTICS: OOBLENDS AND ALLOYS.

Polymer blends -- which are outgrowths of two other well-established composites, filled and reinforced plastics -- are achieving high growth for two reasons. One is that resin suppliers can longer afford to make the big investments needed in high research costs, long development times and marking uncertainties to develop and market new molecules. The only cost effective way to develop new materials is by blending.

The second reason is that suppliers, consumers, molders and extruders are increasingly developing new applications for engineering resins, requiring that materials be blended to fit specific market needs. Upgrading plastics performance is thus an optimization process that reinforces selected properties with due consideration to the established production and process specifications and to cost factors.

Blends are mixtures of two or more polymers that become a unique material. But blending is not simply mixing A & B to get C. Instead, it is a sophisticated effort that involves the utilization of a great deal of proprietary, specialized technology to create a chemical mix that will enhance the marriage of A & B. For example, Polymer "A" has excellent chemical resistant properties -- and Polymer "B" has high heat deflection temperature values -- but neither has both. By blending these resins, the polymer alloy will have both excellent chemical resistance and high heat deflection temperatures -- and consequently deliver the levels of performance the materials need to do the job effectively.

Today, there are numerous polymers alloy blends available in both commodity and engineering plastics. One of the original and most famous of the engineering blends is General Electric's MPPE or Noryl Resin. Polyphenylene ether itself had been of limited usefulness, until GE added polystyrene in the MID-1960s. The alloy was more processable than the basic resin. At the same time, the alloy retained the desirable physical properties.
With Noryl Resin, General Electric has served the low end of the engineering plastics market for years, filling the GAP between ABS and the higher-priced polycarbonate resins.

Examples of other blends produced by GE are: PC/ABS under the name cycolloy; PBT/ELASTOMER CALLED LOMOD. PC/PBT CALLED XENOY.

THE SEVENTH TREND IS IN PROCESSING TECHNOLOGY.

The principle method of forming thermoplastic materials is through injection molding. But recently some interesting new technologies and new ways of using old techniques have emerged.

For example, layering. In layering, different plastics each providing its own unique qualities, are combined during extrusion into a single structure capable of performing multiple tasks such as blocking the passage of light, flavor, moisture of gases such as oxygen or carbon dioxide. Engineering resins in general can be deficient in specific properties when used alone. For instance, Pet cannot be hot-filled; Polycarbonates have poor barrier and chemical resistance properties. Virtually all of these disadvantages of single polymer systems can be solved by layering technology. So a multi-layer film using PRT and Polycarbonate can have good barrier properties AND be hot-filled.

But advances in processing are not only keyed to new technologies but also to old technologies used in new ways. For example, Blow molding is a fifty year old method of forming plastics, mainly for bottles. Today, it has taken on a new aspect. That is compression blowmolding, a form of extrusion blowmoling accompanied by tacking off or squeezing together both walls of the parison, and producing parts with structurally enhanced characteristics. Structural blow molding produces double-walled configurations with extremely high stiffness-to-weight rations in large-sized parts. From an economy/performance standpoint, structural blowmolding fills a need for applications requiring fewer parts than would justify expensive tools for injection molding.

THE EIGHT TREND: THE INVENTION, DEVELOPMENT AND MANUFACTURING OF ENGINEERING RESINS REQUIRE SUBSTANTIAL INVESTMENT.

Despite the growth and profitability of engineering resins, it is quite difficult for new manufacturers to participate in this segment of the industry. First, the engineering resin producer must make strong commitments to a comprehensive marketing program and technology base from which product improvements will arise.

Second, the successful engineering resin producer must have the technological and financial strength to enter the market and the staying power to persist until financial results turn positive. These long payback periods result largely from the high cost of engineering resins capacity. The cost per unit capacity of an engineering resin plant is higher than that of the usual commodity facility for three reasons: First, engineering resin facilities are almost always smaller than commodity resin plants, and therefore, do not benefit from economies of scale to the same degree. Second, many engineering resins are produced VIA relatively complex syntheses which may require unusual or exotic and, therefore, expensive equipment. A third factor results from the typically rapid growth rates of engineering resins, which require that the manufacturing plants often be built to anticipate higher demand. This tends to cause initial low capacity utilization levels, which increase unit fixed costs.

So any company desiring to participate in the engineering plastics industry must be prepared to make very large investments, up front.

In conclusion, worldwide manufacturing is undergoing significant changes; changes in globalization, in technologies, and in materials. The most powerful change is that involving materials. And the materials that will be driving that change are high performance engineering thermoplastics. These materials provide productivity in design, manufacturing, cost reduction, lower energy requirements and materials' recovery. Engineering thermoplastics, thus far, have grown mostly through metal substitution. The fact that our industrial society is still predominately a metal-oriented society means that the growth of engineering thermoplastics has only just begun. Having only achieved a small fraction of its growth potential, the engineering thermoplastic industry is young, vibrant, and on the move.

Only strong companies can prevail in today's changing industrial environment. In addition, the successful producer of new materials must have a clear and comprehensive marketing vision and an abiding commitment to innovation and prudent risk that will turn that vision into profitable realities.

By the beginning of the next century, engineering thermoplastics will be so commonly used in so many different ways that their name will no longer be associated with exotic polymers, only playing a marginal role in manufacturing, but will be as common as the names: steel, glass and wood.