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POTENTIAL PLASTICS APPLICATIONS FOR FABRICATORS IN DEVELOPING COUNTRIES[1/]

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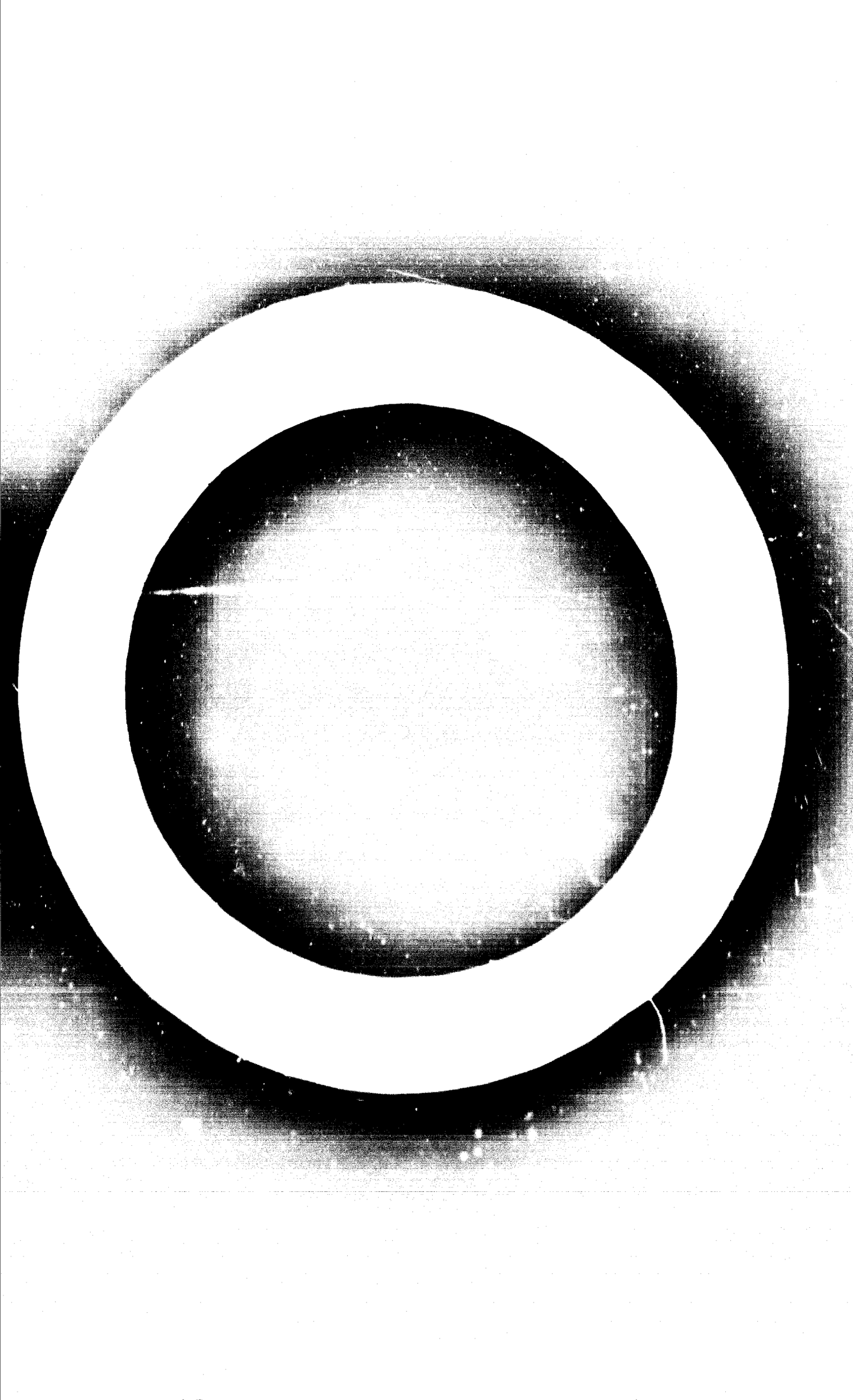

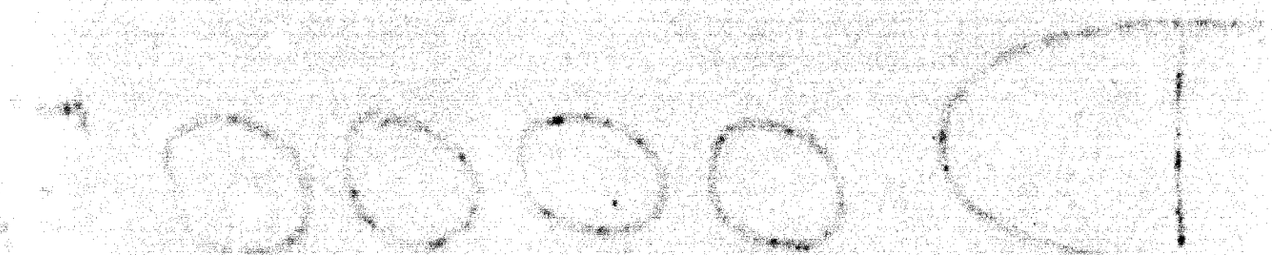

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CHAPTER I METHODS FOR PROCESSING PLASTICS

1. Plastics are man-made materials. According to the American Society of the Plastics Industry, Incorporated, an accepted definition for a plastic is a material "consisting wholly or in part of combinations of carbon oxygen, hydrogen, nitrogen and other organic and inorganic elements which, while solid in the finished state, at some stage in its manufacture is made liquid, and thus capable of being formed into various shapes most usually through the application, either singly or together, of heat and pressure".

2. Within the framework of this definition, plastics are either thermoplastics which become soft when heated and hardened when cooled, or thermosetting resins which set into permanent shape when heat and pressure are applied to them. Because of this basic difference in physical properties, different techniques for handling and processing thermoplastics and thermosets have been devised.

Thermoplastic processing

3. Injection moulding is an important method for forming objects from thermoplastic products. During this process, the resin is fed into a hopper (see figure 1) which leads into a heating chamber. The plunger pushes the plastic through the heating chamber and the previously hard pellet or powder softens to a fluid state. A nozzle at the end of the chamber injects the fluid plastic under pressure into a cooled mould. While travelling through the mould, the fluid material solidifies rapidly and is ejected from the mould automatically or is ejected by hand from less sophisticated equipment.

4. Blow moulding also requires the use of thermoplastics. It was developed in order to solve the problem of fabricating bottle-shaped objects. In essence, the process as illustrated in figure 2 consists of extruding a semi-molten tube (parison) between two matched moulds. The moulds are then closed and a stream of air stretches the parison to meet the configuration of the mould. (An analogy would be the insertion of a limp balloon into a bottle, followed by the addition of air into the balloon. The balloon stretches until it hits the confining wall of the bottle.) The solid bottle, or other complex shape, cools in the mould and is ejected.

Figure 1

Injection moulding

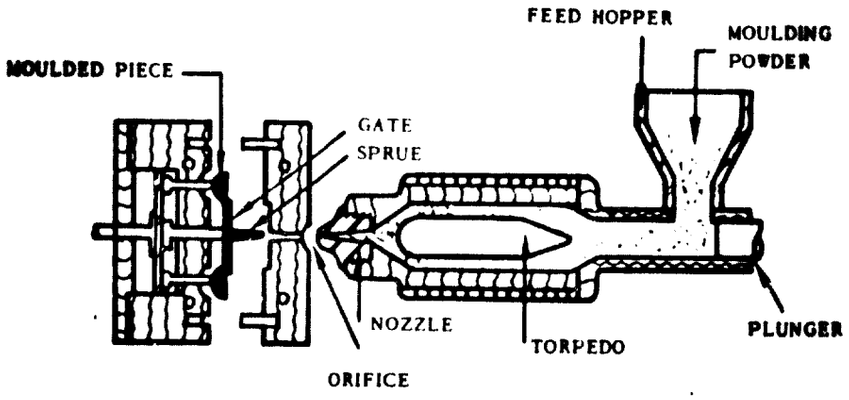
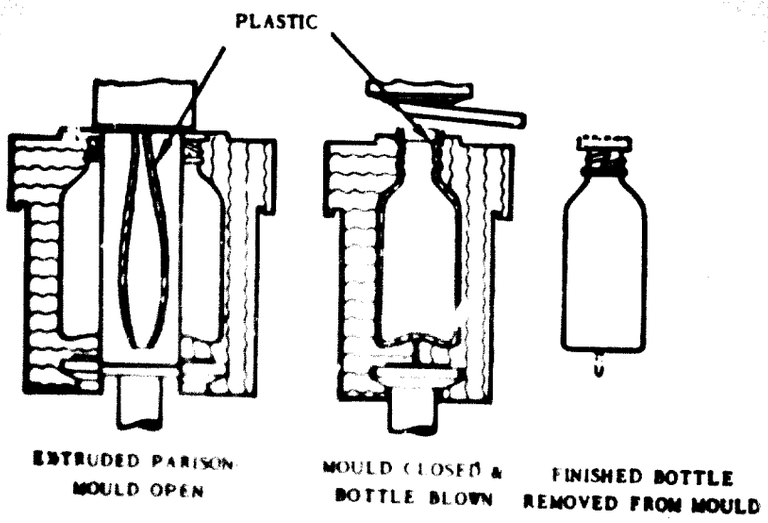


Figure 2

Blow moulding



5. Extrusion is used to form thermoplastics into continuous shapes such as film, sheet, rod, tubes, profiles and filaments. Extrusion is also used to enclose wire with a thermoplastic. The major difference between extrusion and injection moulding is that in the former process the fluid plastic is forced through a die which is in the shape of the desired object. Often the extruded object is cooled by passing it through a quench bath. Or, it is fed onto a moving belt which results in air cooling of the extruded object (see figure 3).

6. Thermoforming, another important process for thermoplastics, is the method of forming shapes from hot plastic sheets. There are many methods of thermoforming, e.g. cavity forming, plug-assist forming, plug-and-ring forming, and slip forming. The process involves heating a thermoplastic sheet over a cavity and applying suction or pressure to the sheet, an act which forces the semi-rigid sheet into the configuration of the mould. The same end result can be achieved by using a male and female mould rather than applying pressure or suction.

Thermoset processing

7. Compression moulding is the most common method of shaping thermosetting resins. This process consists of forcing the resin into the desired shape by applying heat and pressure to the material in the mould (see figure 4). A trio of critical factors, temperature, pressure and time, causes the thermosetting resin to undergo a chemical change in which the resin solidifies into permanent shape.

8. Transfer moulding differs from compression moulding in that the thermosetting resin is heated to the plasticity point before it reaches the mould and is then plunged into a closed mould. This method was devised to ease the fabrication of complex shapes with deep holes or metal inserts. The liquefied plastic flows around metal parts without resulting in the metal shifting position.

Other processes

9. Casting consists of pouring a fluid plastic composition into an open or closed mould. The mass is then cured at a different temperature depending on

Figure 3

Extrusion moulding

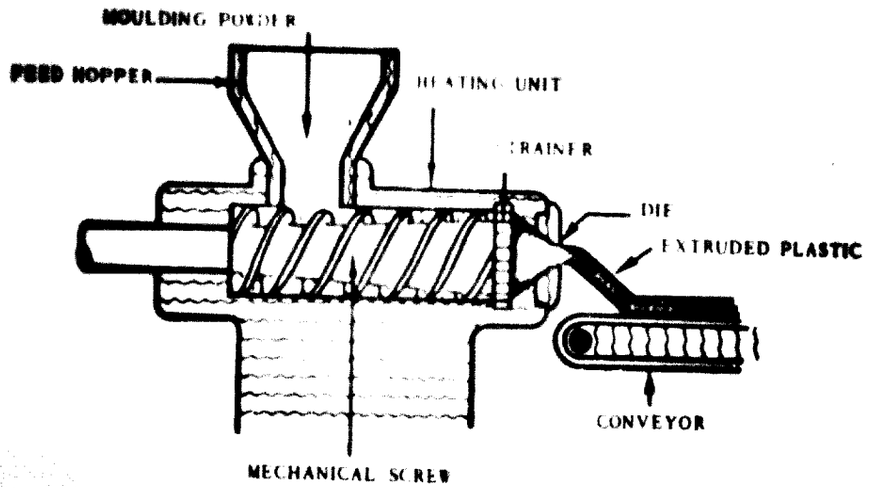
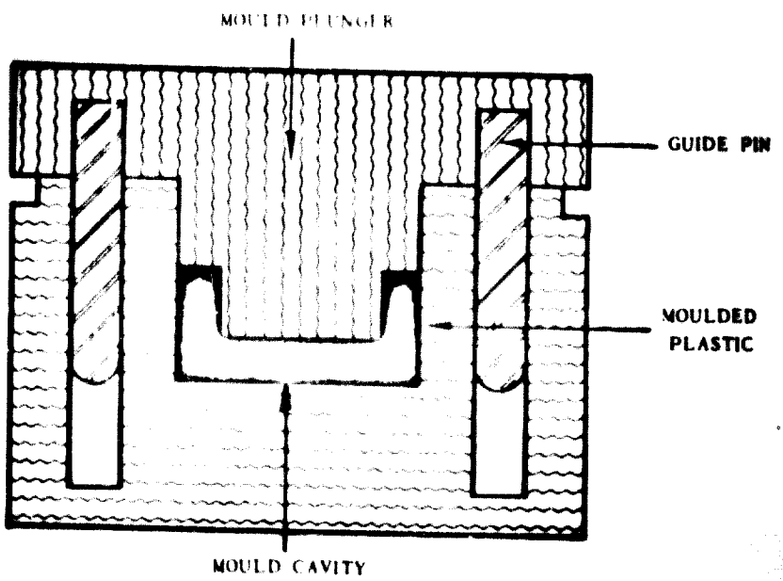


Figure 4

Compression moulding

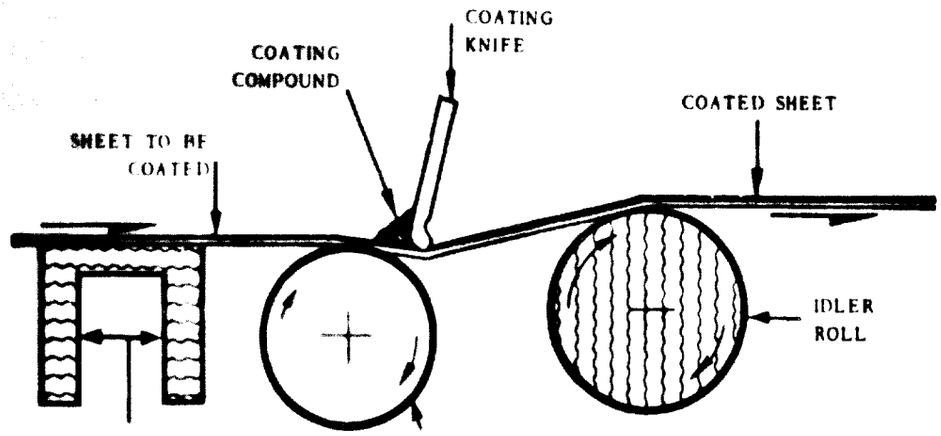


the particular plastic cast and is removed from the mould. Most often, casting is used to produce a precise thickness of film and/or sheet. Plastics can also be cast onto moving drums or belts and then stripped off.

10. Coating is used to apply a plastic to the surface of another material such as wood, paper, metal or fabric. The methods used consist of knife or spread coating (see figure 5), spraying, brushing or roller coating.

Figure 5

Coating



Spread coating allows the material being coated to pass over a roller and under a blade. The plastic is placed on the material in front of the blade and is spread over the substrate surface. Thickness is controlled by the speed at which the substrate is drawn under the knife and the position of the knife.

11. Calendering is used to process thermoplastics into film and sheet or to apply thermoplastics to fabrics or textiles. Calendering consists of passing the thermoplastic between rollers which squeeze the plastic into a sheet or film. The thickness of the film or sheet is controlled by the space between the rollers. Surface effects can result by modifying the roller surface.

12. The previous section dealt with the various important methods for manufacturing plastic products. The following list indicates the typical

fabricated products which can be manufactured using these processes.

Process	Representative fabricated products
Thermoplastics	
Injection moulding	Pipe fittings, plumbing fixtures, dishes, lighting fixtures, gears, bottle caps, beverage cases, small containers, shoes, shutters, valves, vials, toys
Blow moulding	Bottles, toys, ducts, carrying cases
Extrusion	Pipe, conduit, tubes, wire covering, window frames, films for food wrap, sheet for sacks, strapping
Thermoforming	Cups and lids, blister containers, shoe uppers, trays, signs
Thermosets	
Compression and transfer moulding	Handles, switch gears, vacuum tube bases, coil housings and bobbins, resistors, terminal boards, connectors, dishes, closures, buttons
Other processes	
Casting	Large gears, heavy sheet
Coating	Sanitary foodboard, protective papers, impregnated textiles
Calendering	Table cloths, shower curtains, rain coats

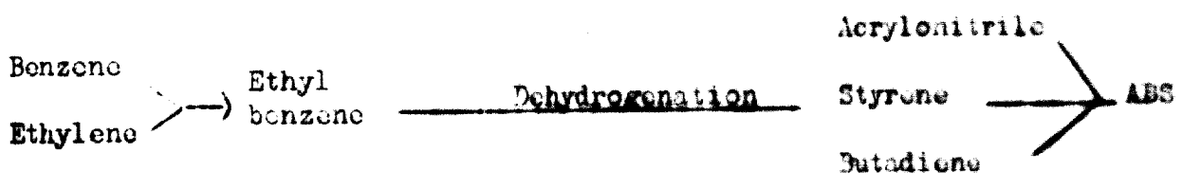
CHAPTER II RAW MATERIALS FOR PLASTICS

13. This section discusses briefly the wide range of plastic materials available, and the key properties, applications, and major world-wide suppliers of each.

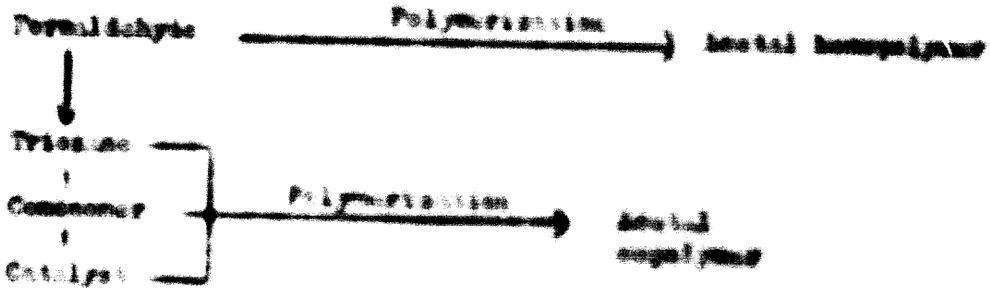
14. Currently there are almost 40 major plastic materials being utilized. Many more are being developed in research laboratories and as yet are too exotic for commercial exploration. Because many of the so-called "common core materials" are difficult to process, require special technology, highly skilled and experienced personnel, and high capital investment in processing equipment, the emphasis in this section will be placed on the plastics that would most likely be utilized in a developing country.

Thermoplastics

15. Acrylonitrile-butadiene-styrene (ABS) was developed in 1948. It is a tough material with outstanding impact resistance combined with high mechanical strength and dimensional stability. It also possesses excellent heat resistant qualities, from 60°F to 175-212°F. Typical uses include pipe and pipe fittings, automotive parts, tote boxes, telephone housings, and appliance cases. The chemistry of ABS is as follows:



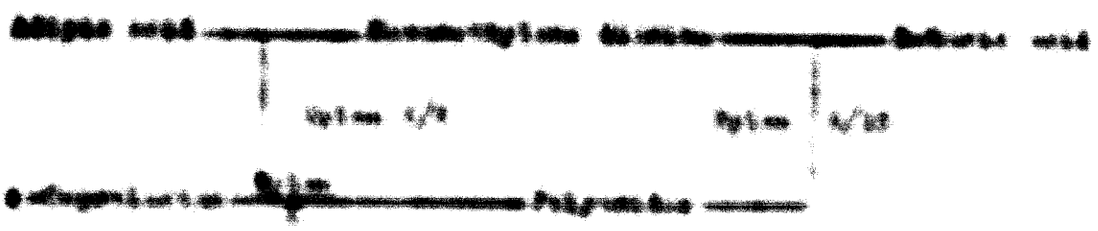
16. Acetal resins is a material developed in 1956. It is a very rigid plastic without being brittle which retains its rigidity under a wide variety of conditions. Other outstanding properties include great strength, excellent dimensional stability and resilience. Repeated impact loading usually does not affect the acetal resins. This balance of properties has caused considerable development of acetals as a metal-replacement plastic. Typical uses include plumbing parts, automotive assembly parts, terminal blocks, gears and bushings and valves. The chemistry of acetals is as follows:



17. Acrylic was introduced on the United States market in 1936. The outstanding properties are exceptional clarity and light transmission in combination with strength, impact resistance and resistance to weathering. Typical applications include glazing, sign faces, instrument lenses, skylights and pois-of-purchase displays. Acrylic resins are manufactured by polymerizing methyl methacrylate monomer in the presence of a catalyst and heat.

18. Cellulosics are some of the earliest materials developed in the industry, although they are not a true "plastic" material since they are based on cellulose, a natural material. There are several types of commercial cellulosic resins, cellulose acetate butyrate, cellulose propionate and the less commonly used ethyl cellulose. Their outstanding properties include great degree of toughness (perhaps the toughest in the plastics family), durability, transparency, ease of colourability, and good electrical properties. Typical applications include automotive steering wheels, pens, eyeglass frames, shoe heels, gun and pistol grips, brushes, caps, film and foil. Cellulosics are custom-blended to suit each individual requirement for the application. The compounds are made by compounding plasticizers, additives and cellulose ester flake.

19. Nylon, which was commercialized in 1938, is one of the most mature of all the thermoplastics. Its important properties are toughness and wear resistance, chemical resistance, good electrical properties and lubricity. Typical applications include zippers, gloves, bushings, bearings, specialty wire insulation and in filament form, fishing line and brush bristles. Nylon types include 6, 6/6 and 6/10, as well as specialty grades and nylons in combined forms. The major types are produced as follows:



[illegible] Polyurethane

[illegible] Nylon 6/6 Nylon 6/10

[illegible] Polyurethane

[illegible] Polyurethane

[illegible] Polyurethane

[illegible] Polyurethane

24. Polyurethane is a major material in the field of foamed plastics, available in rigid and flexible forms. Key properties include toughness and abrasion resistance, adhesion, chemical resistance and insulation characteristics. Typical uses include cushioning, clothing and appliance insulation, padding, structural parts and toys. The urethane family is produced from the reaction of a polyisocyanate with reactive hydrogen-containing compounds, e.g. polyols.

25. Vinyls are another large volume commodity type of thermoplastics first introduced in 1927. They are strong and resist abrasion, offering a wide range of colour. They also have excellent electrical properties and are resistant to weathering. The uniqueness stems from their ability to be manufactured in many forms: flexible (elastomers), rigid or foamed. Typical uses (based on the most important in the plastic group, polyvinyl chloride) are toys, flexible film and sheet (e.g. raincoats and shower curtains), phonograph records, floor tiles, garden hose, pipe and plumbing fittings and wire and cable insulation. The properties of polyvinyl chloride (PVC) are varied by the amount of plasticizers added or the amount or type of copolymer used. PVC is produced by the polymerization of vinyl chloride monomer.

Thermosets

26. There are five major thermosetting resins used for moulding parts. These resins are alkyds, diallyl phthalate, phenolics, melamine and urea. With the exception of melamine, which is primarily used in moulding house-ware dishes, thermosetting resins are used mainly for electrical and electronic applications. In terms of widest usage, the most important resins are the phenolics discussed below.

27. Phenolics are the largest volume thermoset resins and among the earliest plastics developed (1909). Phenolics are strong, hard resins which perform continuously at temperatures exceeding 400°F. Phenolics are also chemical resistant and are known for their excellent insulating properties. Typical applications are automobile distributor heads, appliance handles and knobs, radio cabinets and moulding machine agitators. Phenolic resins are often customized for their applications. This is accomplished by loading the resins with various fillers such as wood flour, cotton flock, asbestos,

glass fibre and paper. Phenolic resin is produced by the condensation reaction between phenol and formaldehyde in the presence of a catalyst.

28. Many of the key elements of the previous discussion are summarized in Annex 1 which brings together raw materials and their relative costs, processing methods and suppliers.

CHAPTER III AGRICULTURAL USES

29. The use of films in agriculture represents a potentially important application for plastics. Moreover, the use of plastics in agriculture has been used as a means of improving farm efficiency. This is particularly important with reference to developing countries, since (a) agriculture is very often the only major industry in the country, (b) the major "cash" export is produce, and (c) food production in the country is of highest importance for the sustenance of the population.

30. The important role that plastic plays in agriculture has been emphasized by the many "plastics in agriculture" conferences which have taken place throughout the world -- nine in France, one in Eastern Germany, three in Italy and seven in the United States of America.

31. Mr. F. Buclon, General Secretary of the Comité des Plastiques en Agriculture in Paris, France, has indicated that in 1965, 130 million French francs were spent on plastics applications in the agricultural field. Of this amount, 75 million was for packaging (see Chapter IV) and 35 million francs for agricultural covering materials. Since many agricultural problems are common to developed countries as well as developing countries, we will examine the successful applications in the former to gain insight into possible applications for the latter.

32. The main agricultural objective is to maximize yields at the lowest possible cost. In order to accomplish this goal, the plant environment must be balanced in such a way as to bring about the desired results. Therefore, the environmental factors of soil, water, light, temperature, nutrients and carbon dioxide must be in proper alignment. Plastics can help maximize the balance of these factors.

Reservoirs and liners

33. The use of plastic for reservoirs and liners has been successful in the United States and Israel. The objective of the application is to reduce seepage and leakage from ponds and irrigation ditches. The materials usually employed are PVC or polyethylene sheets of 10-20 mm thickness. The United States

has used approximately four million pounds of these films for this application. Another use has been for water "traps" in arid areas. (Many have promoting butyl rubber for this purpose.) The polyethylene used is, of course, cheaper than PVC, and has been found in some instances to be unsatisfactory. The polyethylene formulation requires a carbon black content.

34. For large areas such as ponds, sheet widths are too narrow and the desired size must be built up from sections sealed together. This requires a certain amount of skill on the part of the labour used.

35. In spite of the various problems cited, these applications represent a possible venture for a PVC calendering operation or polyethylene film extrusion operation. The viability would depend on the marketing opportunities within the country, as well as export possibilities in neighbouring lands, e.g. Africa.

Soil mulching

36. Polyethylene sheet of 0.15 mm is used to cover soil which has been treated with soil fumigants. The objective is to maximize the retention of the fumigant volatiles. This application would siphon off "off-grade" film manufactured for more demanding applications.

Animal shelters

37. Animal shelters can be constructed from films and sheets so as to help reduce fatalities among younger animals. This would be another outlet for scrap material. Any kind of film, e.g. polypropylene, PVC, polyethylene, could be utilized.

Tunnels and greenhouses

38. Glass coverings have been used to protect crops of soups and to extend crop seasons. Glass, however, does not have the same flexibility in terms of plastic films nor does it supply adequate thermal protection. PVC and polyethylene are beginning to act as a glass substitute. Although PVC retains infra-red rays better than polyethylene, the latter can be produced in larger widths. Therefore, polyethylene is more commonly used. Numerous experiments have proven that the PVC can be stretched with considerable economy. The French and Italians have also been producing tubes mainly PVC using extrusion blowing equipment which is less expensive than calendering.

39. The tunnel row coverings have been successfully applied in France, the Union of Soviet Socialist Republics and the United States. The French farmers in the Nantes region have evolved out a system ("tunnel nantais") where a continuous sheet is extended over rigid wooden arches. This system has been also successfully implemented in Israel. For example, at Ein Zeyrim, tomatoes and other-species have yielded earlier and other crops. The Israel Agriculture Ministry now recommended the full-scale usage of tunnel row coverings. A major improvement is the reduction of weeds evil when these tunnels are installed (mainly in order between tunnels). Japan is the largest user of these tunnels, using primarily PVC, while the use of polyethylene predominates in France, Italy and the United States.

40. The use of greenhouses is associated with latitude. Development of plastic greenhouses is economic at latitudes under 40° N latitudes higher than 40°, there is need because of low light intensity. At latitudes below 30°, crops can be grown without shelters.

41. In Italy and in United States, greenhouse farms are built by the farmers. Self-farmers greenhouses were the purpose by using plastic covered shelters spheres of wood and heavy steel. These areas have plastic greenhouses covered such a way and equipped with heating, ventilation and evaporative greenhouses in Southern Italy range from 0.1 to 0.5 per square meter. In the hands of this range farmers adopts, plastic tunnel and ventilated glass greenhouses range of 1 to 10 per square meter, depending on the design.

42. When poly ethylene is used in greenhouses, double layers are common. The two layers by an inflow using when reinforced with nylon net sewing. Such films are available from Israel and Cyprus. Polyvinyl Fluoride produces a PVC film called "Tedlar" which is also available for these purposes. Table 1 summarizes the film types used in Mediterranean countries.

Table 1

Distribution of film type for plastic greenhouses in four countries

Film type	USA	France	Italy	USSR
		Distribution (per cent)		
Polyethylene	90	45	86	100
Polyester	10	10	7	
Rigid PVC		45		
Reinforced PVC			7	
Plasticised PVC				Some
Nylon				

Source: Paulsen, P. (1966) Proceedings of the Seventh National Agricultural Plastics Conference, University of Kentucky, United States of America.

43. Recently a new type of greenhouse was founded by Austrian engineers. They have designed a high-rise structure consisting of steel, glass and polyester film. A continuous conveyor carries the seedlings through a routine of sprays and nutritive applications under controlled climate conditions. For the last four years, Canada, Norway, Sweden, Switzerland, the Federal Republic of Germany and Austria have experimented with this system. The firm responsible for the development is the Eschenau Company (Vienna, Austria).

Mulch

44. Mulch is used to reduce moisture evaporation from the soil, increase soil temperature, control weeds, accelerate plant maturity and reduce nutrient leaching. Straw is still used for this purpose, but experience in the United States has shown that vigor polyethylene film mulch has reduced disease and promoted growth.

45. One of the most important laying plastic film mulch is in the row material rather than the labour. Labour costs are often because of the reduction in weeding and hoeing. Special tractor attachments for laying down the mulch have been developed by both Shaw Institute and Gulf Oil (formerly Spencer Chemical). Subsoils and soil fumigants to increase the necessary techniques are required. Plastic mulch is very used commercially in Europe. A hectare entails a cost of [illegible] per acre, and this seemingly high cost is compensated by greater yields and higher profits for the farmer. The most common material is

30-50 micron polyethylene film, grey or black. The quality of the film is not demanding and thus makes an ideal potential fabricated product for a developing country oriented towards agriculture.

Silage covers

46. Silage covers made from black polyethylene film 0.05-0.25 mm thick are used in Europe and the United States. The investment required for these silage containers is much lower than that for permanent silo structures. British Visqueen has developed a new technique called vacuum silage. In this process air is pulled from the haystack and the possibility of fermentation spoilage is reduced. Silage bags are also used on smaller farms.

Miscellaneous applications

47. Nursery wrap. A flat polyethylene film is used to wrap the bottoms of plants and flowers.

48. Water cisterns. Water cisterns are thermoformed from high-density polyethylene sheet.

49. Pots. Plastic pots can be used as a substitute for earthen products. Plastic is more desirable because the interior pot temperature is higher and the need for watering is reduced.

Sources of additional information

50. The use of plastics in agriculture has been developing rapidly because plastics help reduce labor costs and/or increase crop yields. Nevertheless, in order to convince the farmer of the advantages of plastics, it is desirable for co-operative efforts to be initiated between the fabrication interests and the agricultural ministries of the governments involved. Help is available from many willing sources, some of which are:

International Plastic Agricultural Committee
2, Rue Pixel
Paris 1le, France

Dr. Thrien
Dow Chemical
Milan, Italy

Pechiney St-Gobain
Courbevoie-la-Defense, France

Instituto Nazionale Studi Industrializzazione Agricultura
Milan, Italy

United Nations
Food and Agriculture Organization (FAO)
Rome, Italy

Israel Ministry of Agriculture
Tel Aviv, Israel

CHAPTER IV PACKAGING MATERIALS

51. Packaging is considered to be one of the largest markets consuming plastic materials. Various experts have estimated that approximately 2,500 million pounds of different types of plastic raw materials in a variety of forms covering 30 distinct compositions of matter were used by the American packaging industry in 1965. This is expected to grow to approximately 5,000 million pounds by 1975. Table 2 shows the different types of plastics on the market in the United States. By 1975 films are expected to lose some ground owing to the growth of plastics consumption in the area of rigid containers.

Table 2

Plastics on the United States packaging market, 1967 and 1975

Plastic	Distribution (per cent of total market) 1967	1975 est.
Containers	30	35
Films	45	40
Closures	6	5
Coatings	17	16
Foams	2	4

52. The plastic raw materials which will predominate in the fabricated products area are polyethylene, polypropylene, polystyrene, polyvinyl chloride, cellophane[2/] and Saran. These materials combined account for 92 per cent of the resin used for packaging in 1965 and will account for 88 per cent in 1975. (This indicates that the packaging market is served mainly by commodity-type plastics and that none of the new speciality engineering materials will be of importance in this field.)

Technical and marketing trends

53. In the developed world several major packaging trends are evident which have and will continue to have a major impact on the use of plastics in packaging. These trends are in both technology and marketing.

2/ Cellophane is based on a natural product (cellulose) and is in the strict sense not a plastic; nevertheless, most discussions on this subject include cellophane in the plastics sphere.

54. Among the technical trends, in-plant fabrication is playing an increasingly important role in the world-wide packaging industry, e.g. in-plant dairy packaging, vinegar and wine packaging.

55. Irradiation and freeze drying of foods (probably a common commercial process by 1980) will have a major impact on the kinds and forms of packaging materials used.

56. The marketing trend of mass merchandising (e.g. supermarkets) until recently limited to North America, is taking hold in many other cultures.

57. Promotion through various media such as television is having a marked effect on the use of all types of packaging materials.

58. Vending is already important and its popularity continues to grow as a means of automated selling.

59. The following sections will discuss various major packaging applications and an assessment of the likelihood of establishing profitable fabrication enterprises in developing countries with respect to the markets discussed.

Films for food packaging

60. The packaging markets in the United States, Europe and Japan have been using increasing amounts of film for both food and non-food packaging. The typical end uses for film in food packaging are:

Candy
Baked goods
Fresh produce
Meat, poultry and fish
Dry foods and snacks
Frozen foods

61. An examination of the above list of film uses in developed countries reveals only a few which might be considered potential opportunities for a developing country. Obviously, the appropriate applications are dependent on the cultural orientation and habits of the populace, food preferences and fetishes, and the degree of in-country production of the particular product. Each of the above product-packaging opportunities will be discussed in turn, with emphasis on those considered to be potentially feasible in developing countries.

Candy

62. In 1965 the market for candy in the United States was approximately US$2,000 million representing about 4,000 million pounds of various products. Candy-wrap materials are generally custom chosen for the particular packaging problem. The materials should be moisture-proof, abrasion resistant and grease resistant. In addition, they should transmit no taste to the candy. When films are used to package candy, many types of equipment and packaging methods are employed, for example, overwrap, direct wrap, form-fill and seal, strip packaging and vacuum packaging.

63. The overwrap of film has proven a good match for the properties of polyethylene and polypropylene films. The trend has been towards the use of stiffer (.926-.935 density) films in order to achieve cellophane-like handling on packaging equipment. The major films used for all types of candy products, including gum, nuts, candy bars etc., are cellophane, low-density polyethylene and oriented polypropylene film. The major manufacturers of overwrapping equipment are Battle Creek Packaging (Battle Creek, Michigan), Hayssen Manufacturing (Sheboygan, Wisconsin) and FMC Packaging Machinery Division (New York, New York).

64. Assuming that the volume is sufficient to warrant production, the establishment of a low-density polyethylene film extrusion operation is the likely choice for a developing country since the investment necessary for cellophane would be much greater. Naturally, it is doubtful that a small developing country could justify a film plant just to serve a small local candy operation. It is more likely that justification would come in a variety of end uses from different markets as described below.

Baked goods

65. Baked goods are packaged in order to prolong the freshness of the product and to keep it sanitary. Polyethylene has replaced cellophane and waxed paper in the United States as the preferred packaging material for bread. A recent trend to bagging bread loaves is also noticeable. USIC (United States Industrial Chemicals) and Kordite have also been successful in promoting the stronger and clearer polypropylene films for bread wrapping. The non-plastic packaging material suffering the greatest because of this transition has been waxed paper.

66. Bags are popular with the American housewife because of the convenience of opening and re-closing, the lightweight freshness of the product and the ability to see the bag. Machinery capable of automatically forming and loading the bag and twist-tying it is now available.

67. Since the plastic wood-wrap market was geared to cellophane, the polyolefin film suppliers went to great expense in persuading industries to use the longer polyolefins. In order to use polyolefins, cellophane equipment had to be modified at additional expense. A new bakery beginning today to plastic wrap their product would not encounter this problem. The bakery can purchase the proper equipment from Hayssen, Kettle Stone and Adams Pearl (London, England).

68. The least expensive packaging method for a bakery would be the utilization of plain or printed polyolefin bags. The critical factor centres around creating a new tradition for purchasing baked goods under sanitary conditions. This would require government co-operation and encouragement through mass media advertising.

Fresh produce

69. Low-density polyethylene film is used extensively for prepackaging fresh produce in the United States and this trend is on the upswing. Approximately 65 per cent of the produce is prepackaged by the distributors. This figure should increase [illegible] per cent by 1975. Of all the products so packaged, apples are the most popular prepackaged items (7[illegible] per cent by weight of all apples). Tomatoes are also prepackaged [illegible] per cent using to a great extent film and tray combinations. Apples, onions, citrus fruits, lettuce and potatoes are also pre-packaged. Most often, bags (.02-.05 mm) are used.

70. The key to success in this market is dependent on the kind of distribution methods used for the produce. Central terminals or grocer packaging operations easily lend themselves to prepackaging produce. Frontline marketing conditions do not. Consumer acceptance also determines the choice of packaging method. A plain or printed bag would suffice in many cases. Relatively speaking, low-level investments in machinery are required once an adequate internal or external film supply is established.

[redacted]

[redacted] and film

[redacted] and wrapping are used for fresh meat. In the United States, most meat sales are made in retail self-service stores where meat is prewrapped. The meat is placed on a [redacted] (paper, foamed polystyrene or transparent polystyrene) and overwrapped, or the meat is simply overwrapped with a film. In order to assure that the meat is properly film wrapped, the film must be:

(a) [redacted] and puncture resistant;
(b) [redacted] to moisture and oxygen transmission;
(c) [redacted];
(d) [redacted];
(e) Transparent and shiny and appetizing in appearance.

Cellophane is the dominant film for wrapping fresh meat because it has the best balance of the above critical properties. Improvements in cellophane have been made by coating it with either nitrocellulose or low-density polyethylene. There are currently [redacted] cellophane films which are custom-designed for particular meat packaging problems.

The packaging market has recently experienced a heavy demand for PVC because of the [redacted] of competition. PVC is more flexible than cellophane and [redacted] characteristics. The progress of PVC on the market has been [redacted] because of the lower cost compared to cellophane. It is predicted [redacted] film will predominate in the meat packaging industry. Polyester [redacted] cellophane and low-density polyethylene film. In addition, polyethylene trays will be extremely important in combination with films. This will be at the expense of paper pulp and coated trays.

Processed meats, [redacted], frankfurters, and bologna, require a different set of film property requirements:

(a) [redacted]
(b) [redacted]
(c) [redacted]
(d) [redacted]
(e) [redacted]
(f) [redacted]
(g) [redacted]
(h) [redacted] temperatures
(i) [redacted]

The films generally used for processed meats are polyester, nylon, cellophane, and plasticized PVC. Both nylon and polyester have good thermoforming draw properties. A combination of Saran-PVC-Saran has also been successfully promoted using automatic vacuum packaging machines (Flex-Vac made by Standard Packaging). Such equipment can cost as little as US$1,000 for manual types or US$35,000 to $45,000 for high-volume fully automatic designs.

74. Prepackaged poultry is sold either fresh or frozen. Fresh poultry accounts for 90 per cent of all poultry sold on the United States retail market. Fresh poultry is packaged in a combination of tray and film. Low-density polyethylene has become increasingly popular along with the traditional use of cellophane overwrap.

75. Cryovac L, developed by W. R. Grace (Cryovac Division), is an irradiated polyethylene film with shrink properties. This film in bag form is associated with frozen poultry processing. The bird is stuffed in the bag and is passed through a shrink tunnel. The film shrinks tightly around the bird and successfully resists puncturing. This is then followed by freezing.

76. Requirements for fish packaging materials are less critical than those for packaging meat or poultry. Low-temperature toughness is the essential requirement. Fish is usually overwrapped using a tray and film. In some cases, e.g. in the packaging of shrimp, the product is placed in a low-density polyethylene bag. Polyethylene bags and cellophane are the predominant films utilized.

77. Since food packaging and marketing usually require a rather advanced stage of development and the popular acceptance of supermarket retailing, meat packaging would not be a national investment for plastics fabrication for the foreseeable future in most of the African and Asian countries. However, in an economy having relatively large meat packaging plants, e.g. Argentina, the possibilities for using plastics should be investigated.

Dry foods

78. Cereals, macaroni products, sugar, flour, coffee, tea, salt etc., are generally classified as "dry foods". The consumption of these foods in developing countries is culture oriented and more often than not, these foods are sold in primitive packages. Even in the United States, large amounts of plastic film are not used for these products. For the most part, paper, glass, and cartons

predominate in the dry foods packaging market. Nevertheless, where products such as flour, salt and sugar are sold in open markets, plastic sacks could conceivably be used. In hot and damp climates, moisture barrier properties would be desirable, and in less industrialized countries, polyethylene sacks might be more practical than plain paper bags.

79. In the United States, where climate conditions are more varied and less severe than in many of the developing world, dry foods products require packaging materials which afford freedom from dirt contamination and moisture. Two thousand million units of several different types of sugar forms (powder, granulated, cubes etc.) are sold in the United States in either uncoated or coated bags or cartons. The main functions of the packaging used for dry foods is to protect the contents, and to carry an advertising message and establish brand identity.

80. Nevertheless, in countries where bazaar markets are common, the plain or printed bag could easily be produced and used for packaging. The investment needed for film extrusion and bag-making equipment is only a fraction of the huge investment necessary to produce paper and board products. For example, in Thailand in 1964, approximately nine million pounds of polyethylene film was manufactured, and most of it was used for bags. The bags were used for packaging a wide assortment of bazaar items. Previously, paper was used, but the Government decided to discourage this practice for sanitary reasons. Moreover, polyethylene bags are less expensive than paper bags.

Frozen foods

81. The number and types of foods that can be fresh frozen have grown to enormous proportions. In the United States and other Western countries, the refrigerator and/or freezer is taken for granted. Plastics, principally low-density polyethylene bags for vegetables and fruits, is an accepted mode of packaging, although, the major packaging material, current and future, is the plastic or wax-coated box.

82. Phillips Petroleum (Sealright Division) has been attempting to increase the demand for the high-density polyethylene thermoformed tray. However, this package has been only sporadically popular owing to many problems involved - cost, sealing, and the need for specialized equipment for filling and sealing.

85. Polyester pouches are used to package the precooked-frozen meals-on-tray foods. The United States frozen food market only consumes two million pounds of polyester film for this end use.

86. The area of frozen foods is a difficult one to recommend for plastics fabrication. There a market exists for frozen foods (i.e. where refrigeration with frozen food compartments are available) polyethylene might sometimes be justified because of the low temperature resistance used. This factor would have to be weighed against the total output of frozen foods. It is unlikely that any sizable demand for frozen food packages will develop in this area.

Films for non-food products

87. The following discussion will highlight some of the more important uses for films in non-food areas. The typical end uses are heavy-duty sacks and textiles.

Heavy-duty sacks

88. In 1960 the all plastics heavy-duty sack was introduced on the American market. The producers of these sacks (i.e. Union, Bemis Bro-Bag, Hall Pak) have been waging a sharp business battle with the paper bag manufacturers for a large share of the chemical and fertilizer market. The typical paper bag is a kraft paper construction with multiple plies reinforced by polyethylene film or coating + asphalt laminate. The all-plastic bag is available in five or eight millimetre thicknesses. From the many machinery plastic sacks presented problems. In addition to high cost, there were also difficulties in filling the sacks and providing strong seams. Many of these have since been reduced or eliminated. Semi-automatic and automatic sack-making and sealing equipment is required by the sack manufacturer and the chemical packager. Sources of sack equipment are Windmoeller & Hoelscher (Lengerich, Federal Republic of Germany) and Hesser (Stuttgart, Federal Republic of Germany) and Haensler and Schoeller (Westphalia, Federal Republic of Germany).

89. Low-density polyethylene is used to manufacture the bags, although more recently, blends of high and low-density resins are becoming more popular. With respect to balance, polyethylene appears to offer a better combination of properties than does plasticized PVC.

[illegible]

[illegible]

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a [illegible]

b [illegible]

[illegible]

[illegible]. The term "machine" usually refers to soft molds, e.g. sheets, extrusions, and [illegible]. Hard and stepping films are used to package machine parts and glass are extremely important film requirements. The United States market formerly [illegible] by polyethylene film and more recently vinyl polypropylene. It was found, particularly evident in the packaging of electronic equipment, to require the use of shrink films. This form of packaging is preferred because of the capability to seal and [illegible].

[illegible]. Since the consumption market for extrusion of polyethylene film is quite heavily low, the companies in engineering shrink manufacturers and machine machines might be induced to survey these packaging possibilities.

[illegible]

[illegible]. Plastic packaging is a growing business in the American plastics market. The sale of consumption packaging in the United States is estimated [illegible] billion out of a total packaging market of [illegible] billion. It is estimated that by 1975, the sale of consumption will grow to [illegible] billion. Before consumer-type packaging for [illegible], however, the material which will predominate in the market will be polypropylene using by the lower cost. Film technology and [illegible] is a principle producer and fabricator of polypropylene types. The major United States plant packaging producers consumption and the marketing opportunity for polypropylene, and most have begun producing it. The cost of resin is [illegible] per pound. Current American polypropylene packaging sells for [illegible] per pound, but will decline to [illegible] per pound by 1975. There is great value added opportunity in fabricating this product and many end use applications can be synthesized. For example, plastic packaging may result be used by cotton producers in a developing country which produces and exports textile products, as for the packing and shipping of cotton. The key to success in the ability to offer and create a complete system. Packaging machine is an extension of consumption, requires a device for sealing the cube together. Packaging engineers primarily design and offer such sealing devices and it seems likely that a fabricator of consumption packaging in a developing country would have to do the same. The Japanese are pioneers in a great extent in manufacturing and fabricating polypropylene packaging throughout the world.

[redacted]

[redacted] The use of blow molding technology with low-cost raw materials (polyethylene, polystyrene, [redacted] and [redacted]) has resulted in a demand for over [redacted] billion plastic containers in the United States. In spite of this tremendous growth over a short period of time, only a fraction of the potential market, commonly discussed by [redacted], has been exploited.

[redacted] Two secondary trends are taking place in this market sphere and both are evident in the United States and Europe:

(a) Development of high-speed and highly automated blow-molding machines for commodity products;

(b) Multi-cavity design and configuration of machines geared for low-cost custom blow molding in the workplace.

[redacted] On the low-cost market, the production of plastic bottles is dominated by packaging manufacturers which have moved into captive (Owens-Illinois, American Can, Continental Can), by resin producers which have moved into containers (Dow, Hercules, Monsanto, Amoco), and by smaller regional suppliers of custom-built containers. The major purchasers of containers exist in extensive consumer goods industries of household products, such as bleach, detergents, liquid drugs etc. A renewed trend towards the use of blow molding by the market has not taken place as yet. (There are notable exceptions, for example, Purex, [redacted] most of which is owned by Hills & Petroleum.) The reluctance to make this conversion can be explained by sheer competition among the blow molders, a fact that results in severe price concessions to major detergent producers. However, in order to avoid undue pressure, the bottle manufacturer must be assured of low and competitive resin supplies. Since blow molding is the largest single outlet by weight for high-density polyethylene resin the suppliers of these resins have made efforts to secure as large a portion of this market as possible. It becomes apparent, that in order to be successful at blow molding for packaging applications, a firm must either be able to obtain resin at favorable cost or be able to secure a stable outlet for its bottles. Firms such as Owens-Illinois are often able to do both. (Owens-Illinois and U.S.I. Chemical [redacted] have a joint polyethylene venture. Owens-Illinois is one of the largest American producers of glass containers.)

96. Several basic problems must be overcome before container blow moulding processes for developing countries can be considered. Manufacturers of conventional containers must be willing to consider plastic containers as a supplement to their product line rather than a competitive product. Moreover, packers must be willing to use plastic. This is easier said than done. The use of plastic often requires additional investment for new filling equipment.

97. Special problems will also exist. For example, in Israel, bottle deposits are a problem. Even corrugated cartons sometimes carry deposits, whereas plastic bottles are non-returnable. Non-returnable bottles are a convenience and generally carry a premium price to compensate the packer for the extra cost. Usually such a convenience comes after industrialization. An affluent society is willing to pay more for convenience, a luxury which a developing country cannot afford.

Blow-moulding raw materials

98. Polyvinyl chloride has been developed to large degree in Europe, whereas high-density polyethylene is the preferred material for blow moulding in the United States. In France, Lesieur and Fils (Paris and Le Havre) have developed PVC bottles for salad oil using single parison, six-station equipment. The Marrion process is quite unusual since it involves the extrusion of parison tubes and a subsequent resale to the bottle maker, where the tubes are reheated and formed in a Marrion multiple-station machine. Kautex Werke (Bargelar-Siegburg, Federal Republic of Germany) offers single or double mould machines suitable for processing PVC. Rigid PVC extrudes more slowly than polyethylene in order to avoid decomposition owing to overheating.

99. Another interesting development by F. Baumann A. G. (Zurich, Switzerland) which has been promoted in Israel is called "Vacuplace". It consists of folded PVC sheet which is welded into bottles as the web emerges as a continuous sheet. The bottles are being used for salad oils and dressings.

100. The resin most popular in the United States for blow moulding is high-density polyethylene (density over 0.950). Specially tailored grades must be used depending on the product being packaged. For example, if an improper resin is used, detergents will stress-crack the plastic bottle.

101. As a commodity resin for blow moulding, polystyrene has not been as successful as polyethylene because of higher cost.

102. Polystyrene (high-impact grades) is a minor blow moulding material but it can be easily processed. Use for it has been evident in the cosmetic and pharmaceutical fields.

Household chemicals

103. The largest single commercial outlet for plastic bottles is currently in the household chemical field. As cited earlier, this product line includes bleach, detergents, ammonia, waxes, and liquid starch. Many of these products find great demand in industrialized countries. In 1965, the American market consumed close to XX million pounds of high-density polyethylene for the bleach and liquid detergent market combined. Polyethylene retained close to the bleach market, and metal cans in the field of detergents. Bleach and detergent bottles must be supplied by bottle manufacturers close to the bleach plant because of the high costs of air shipping. (This factor is now accepted as an inevitable reality in the packaging field.) Stress-cracking problems have been overcome and it is doubtful that any other plastic will replace high-density polyethylene. However, it is expected that since PVC will also make progress in the high-duty detergent field.

104. Blow polyethylene containers might be considered for a developing region such as Israel or Latin America, depending on the size of the consumer demand for these products. If was considering bleach production in Malaysia, a factor which would increase plastics potential in that country. In the liquid detergent area, Colgate sells 14-ounce units of bleach in addition to economy-sized Kiwi Wax Company (Singapore) markets laundry cleaners. These circumstances should motivate an investigation into the possibility of a blow moulding facility to serve all of these producers.

Motor oil

105. The American market consumes 3,000 million cans of motor oil annually. Most of the oil is in the one-quart size and packaged either in tin cans (30 per cent) or fibre-foil packages (70 per cent). Several of the major American

previous firms (Shell, Standard Oil of California, Esso) have accomplished extensive field testing of both high-density and soft, crushable blow containers. Some authority sources conclude that by 1975 (when units will comprise 30 per cent of the total American motor oil market), in order to attain this goal several hurdles must be overcome. Lighter bottles, for example, are more costly than fibre-filled ones, and leakage is still a serious problem. These problems will probably be overcome or counteracted by fully integrated petroleum-container plants. (It should be noted that the lighter containers for motor oil do not use a bottle but rather a lighter cup with metal ends. However, the containers for outboard engine motor oil do use a bottle.)

108. A bewildering variety of sizes of containers and filling lines would confront motor-oil packaging plants which have to build foam and filling containers to their own specs. Polyethylene and polypropylene containers could be by-passed. For example, the Shell Company of Puerto Rico could manufacture a flexible film oil container, holding 30 kg., made from regrind PP, which PP is applied to steel and to many oil containers. Shell Oil uses canning machines and equipment commonly in Philippines, and Shell may also be prepared to market a universal container for a blow moulding process.

Dairy products

109. One of the most exacting packaging tasks in the food-processing business is having sealed aseptic cartons and filling machinery for a couple of the dairy packaging markets. These markets have been slow but steady. Part of the delay stems from having costly investments associated with the change to lighter, less utilitarian dairy packaging as widely emphasized by sleek and fashion-conscious.

110. With the exception of the glass bottles used in retail grocery and the gallons and quarts delivered to the home, the use of these containers has contracted in the liquid milk market.

111. Paper containers are a close call in the dairy industry for several of the dairy products packed under refrigeration. Among the lighter items, the dairy has discouraged paper because fiber, the cut, pre-printed, polyethylene coated pulp forms the container is a real contagion to the milk filling apparatus. Only a dairy which owns the removed dairy volume

can justify this system. Information is obtainable from such firms as American Can Company (New York, New York) or Continental Can Co. (Detroit, Michigan). Smaller-sized dairies buy fully formed paper containers from "performers".

110. Polyethylene manufacturers have been primarily responsible for trying to promote both no-return and returnable high-density polyethylene bottles. These plastic bottles are already making considerable progress in the market formerly held by glass bottles. The plastic gallon bottle is less costly and requires less handling and cleaning since it is non-returnable. Smaller-sized bottles are also penetrating the market, but at a much slower pace since the economic considerations are not as clear cut in the dairy industry as in other industries.

Table 1

Prices for milk containers in markets in the United States of America

Bottle size (fl. oz)	Corresponding metric size (ml)	Price (US dollars/thousand units) Glass	Plastic-coated paper	Plastics	Plastic bottle weight (grams)
Half-pint	237	—	[illegible]		
Pint	473	—	[illegible]		
Quart	946	65	[illegible]		
Half-gallon	1,900	115-130	[illegible]	90-95	60
Gallon	3,800	175-195	[illegible]	85-100	100

111. The optimum cost of the plastic bottle will depend on the cost of resin, the efficiency of the blow moulding operation, the type of equipment used, and the optimum cycle of production. The bottle business is highly competitive. However, new heavy duty-type resin and equipment is getting to the point where moulding procedures is speed to meet the demands of any reasonable market situation, as Hoover, Inc. Kenmore Inc. and Superior Dairy, Pittsburgh. The firm has developed a machine line of blow moulding equipment designed to meet specifications.

112. In many countries, refillable milk bottles are more economical than those made of glass. Thus, a milk industry using glass is slightly limited. Some farmers therefore are producing their own plastic bottles as these

[illegible]. In Israel, [illegible] (Tel Aviv) was considering using the French one-litre plastic bottle which weighs 32 grams instead of the 400-gram half-litre glass bottle. The French system (Perrier) has small (one) is capable of handling 7,500 litre bottles each hour (five to five and one-half million units annually).

111. The type of containers discussed in this section are also appropriate for fruit juices, vinegar, soft drink beverages concentrates and wines.

112. An interesting fabricated container product for liquids, paper or glass bottles for the Japanese is the production of this wrapped spraying cans. The cans is more durable and, over a period of years, more economical than another of metal were appropriate. Young (producer of more than 30 per cent of milk sold in Japan) is going to convert completely to plastic cans. In 1975, all milk cans used in Tokyo were plastic. A technologically satisfying cans can be packed in cans. Information on cans can be sought from Hoechst (Hoechst Film Corporation, Federal Republic of Germany), Phillips Petroleum and [illegible]. It should be recalled that that a straightforward cans or spray can be used as an economical take bag for [illegible].

113. Thermoformed or injection moulded cans shape and weight would add additional oil pressure a disadvantage against the glass industry. There, was planning to introduce small cans injection moulded as a replacement for glass weight bottles. The company was also considering two light thermoformed containers (one is large), the machine was manufactured by Hoechst (Federal Republic of Germany). Other firms is considering such production of plastic containers as an alternative to their existing product line.

114. In Western countries, there are extensive applications for thermoformed polystyrene cans in the cream making. Consumers preferred cans to be partially transparent in order to encourage impulse purchases.

[redacted]
No. 8

[redacted]

[redacted] The establishment of machine fabrication has ceased to serve industrial [redacted] in developing countries to pursue the most challenging problem discussed above for the next decade. Fully industrialized countries utilize plastics for a host of highly complex products such as automobile parts, automotive parts, hardware items, housewares, sports, machine etc. This pattern is not found in developing countries. Engineered products production is to a great extent a reflection of the level of industrialization in a given country. The history of industrialization in developed countries shows, of course, the initial utilization of metals (ferrous and non-ferrous), e.g. steel, lead, zinc and copper. With the advent of synthetic products (leather, fibres), the patterns of growth of new material utilization have shifted markedly in the direction of synthetics. In spite of this shift in growth, users of traditional materials of construction (metals) have been very careful before committing themselves to new, relatively untried products. However, plastics has continued to make considerable progress in replacing metals in a wide spectrum of applications. Evidence of this is the increase of plastics consumption from each automobile produced in the United States from 50 pounds in 1957 to an estimated 200 pounds in 1970. Much of this increase in use has been and will be at the direct expense of metals.

113. It would be unwise to expect any countries to by-pass the use of metals for many industrial parts in favour of plastics. This would be accomplished because of the lack of engineered toughness and conservatism often associated with design engineers trained in the "science of metals utilization". Thus, emerging industrialized nations would normally pursue the utilization of plastics parts for consumer products.

114. There is considerable interesting insight into this possibility. Although it appears as if [redacted] will [redacted] will with industrialization,

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[redacted] "Engineering materials" is a term [redacted] used here in the plastics industry. [redacted] It connotes different things to different people. For the purposes of this discussion, it is [redacted] to those materials requiring highly engineered environments for fabrication into final products.

It should be noted that developing countries are noted for population advances far exceeding their production growth possibilities. Nevertheless, the data in table 4 does point out the potential for growth.

Table 4

Consumption of lead and zinc in the world, 1964

Region	Population (in billions)	Consumption (kg per capita) Refined lead	Slab zinc
Europe	342	3.5	3.8
North America	211	4.8	5.5
Oceania	137	4.7	8.2
Latin America	237	0.6	0.6
Africa (excluding South Africa)	286	0.06	0.02
Asia (excluding Japan)	1,686	0.05	0.08

Source: Data furnished by the Zinc Development Association.

120. The production of the same products and parts is another indication of industrialization. According to the Zinc Development Association, the most notable production is taking place in India and South America. These, of course, are areas where industrialization is progressing.

121. The potential for growth in the industrial segment in developing countries is large as evidenced by the growth that has already taken place. An example of this growth is cited in table 5.

Table 5

Indices of industrial production in Asia and the Far East, 1953-1963
(Index numbers, 1958 = 100)

	1953	1963
ECAFE region a/	59	155
World b/	78	144

Source: United Nations (1965) Industrial Development in Asia and the Far East, New York, pp.27 (Sales No.: 65.II.F.16)

a/ Excludes China (Mainland), Australia, Mongolia, New Zealand, Western Samoa, Japan.

b/ Excludes Albania, China (Mainland), Mongolia, North Korea, North Viet-Nam.

122. The ECAFE region index of production advanced 2.6 times, compared to 1.8 times for the world. During the same decade, Latin America, containing several industrialized countries, increased industrial output by 90 per cent.

123. The remainder of this section will discuss areas of potential opportunity in developing countries for the production of fabricated plastic components for industrial end uses.

Appliances

124. In developed economies, the use of plastics for various appliance applications has reached enormous proportions. Table 6 indicates the consumption of various plastic resins for appliance applications.

Table 6

Consumption of synthetic resins in the appliance industry in the United States of America, 1964

	Consumption (million lb)
Impact styrene	165
Phenolics	60
ABS	40
Polypropylene and polyethylene	25
Urethane	16
Melamine and urea	10
Polycarbonates, delrin, phenoxy	10
Nylon, teflon etc.	6
Reinforced polyester	11
Others (acrylics, PVC, epoxy)	17
Total	360

Source: Compiled from figures from A.W. Karnath, Arthur D. Little, Inc., Cambridge, Mass., USA

125. It can be concluded from table 6 that 70 per cent of the plastics used in appliances are priced under US $0.30 per pound, 2 per cent between US $0.30 and US $0.50 and 10 per cent above US $0.50 per pound. Of the materials considered, American appliance industry plastics experts conclude that the industry pays an average price of US $0.33 per pound for plastics. (This figure refers to 1964. Today this would be slightly lower.)

128. The applications for plastics include refrigerator door and tray liners, housings, fan diameter liners, shelves, compressors, evaporator coolers, ovens, radio and television cabinets. The resins used generally fall into the engineering plastics category. The processing of these resins requires more skill than general-purpose polystyrene or the polyolefins. Nevertheless, assuming that processing equipment is available, the technologies are readily obtainable from the resin suppliers.

127. The utilization of these materials depends on cost performance considerations, and in the final analysis, the industry must rely on enthusiastic design engineers skilled in plastics part design.

128. Developing countries import most of their appliances; however, various reports indicate that even in these countries there is also the steady development of domestic appliance production. In fact, most countries in the ESCAP region are reportedly planning to manufacture various small appliances. This situation would lend itself easily to custom or captive moulding of component parts.

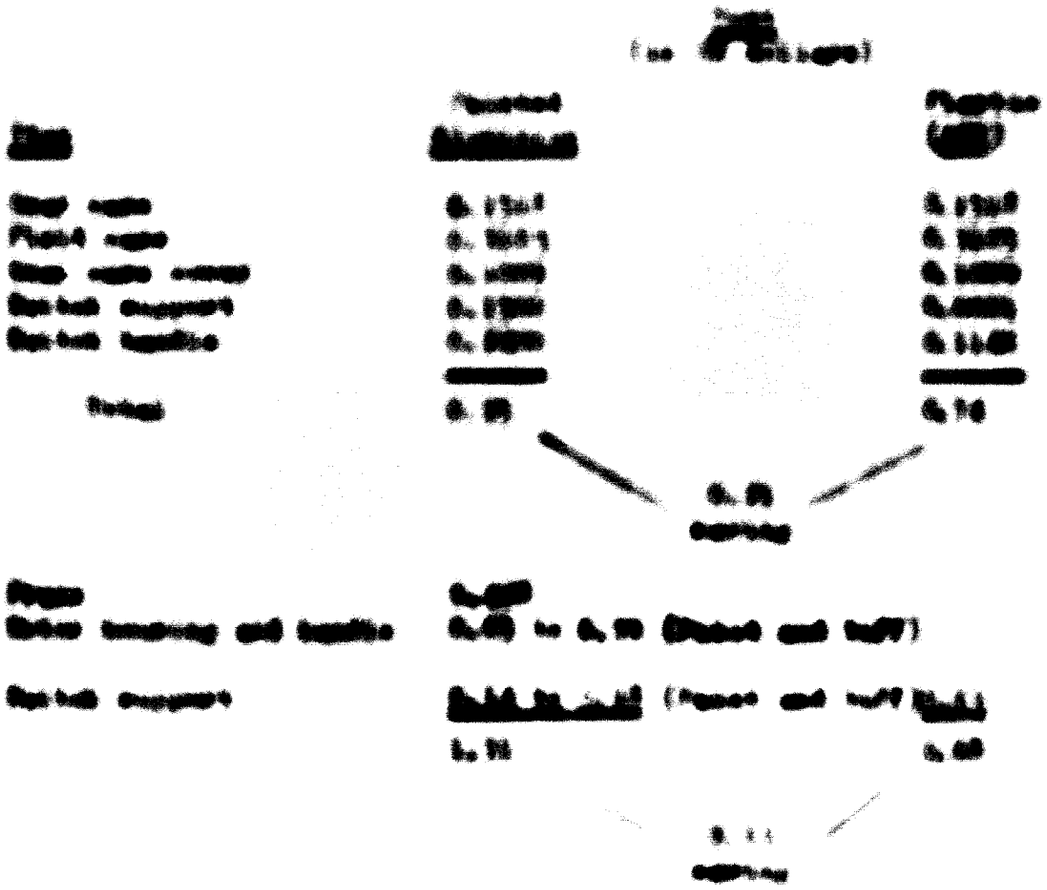
129. Carrier International (Thiago) has produced air conditioners near Manila for [illegible] year. The Philippines has seven refrigerator plants and three freezer [illegible]. The latter plants produce 30,000 units annually. These facts illustrate the point that plastic components manufacturing should be encouraged in all countries.

Tools and Hardware

130. Various tools, tool handles and housings, and assorted hardware items are manufactured from both thermoplastic and thermosetting resins. Electric outlet switch plates, dials, and knobs are typical of parts which can be made either from thermosets or from thermoplastics. A recent interest in the United States has been the development of moulded thermoplastic housings for hand-operated power tools. The American market for the sale of this type of product is $[illegible] million per year. Approximately $[illegible] million of the housings are purchased for these tools. Samples of thermoplastic housings (see table 7), 75 per cent of the housings made for these tools are moulded from thermoplastics

[redacted]

[redacted]



[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[illegible] the American automotive industry has been steadily increasing the application of all types of engineering and structural resins. During the 1980 production model year, [illegible] pounds of plastic per car. These experts agree that this consumption will increase to 400 pounds by 1990.

(1). The number of automotive parts made from plastics is legion. Automotive use thermoset and thermoplastic resins and sheet (rough upholstery). The following list represents some of the major applications for plastics in the automotive industries of the United States and other countries and the materials most commonly used:

- [illegible]
- [illegible]
- [illegible]
- [illegible]
- [illegible]
- [illegible]
- [illegible]
- [illegible]
- [illegible]
- [illegible]
- [illegible]
- [illegible]
- [illegible]
- [illegible]

It should be noted that many of the above parts were once made from steel (e.g. radiator [illegible] and the castings (e.g. fender extension)

(2). The evolution from predominant use of metal parts to selective replacement by various plastics did not occur overnight. In order to reach this point, it has taken the ability of the automotive industry to experiment with the new plastic materials, and the willingness of the resin supplier to spend vast sums on patient, slow and frustrating education, prototype investment, design research, and development of tailor-made resins for the automotive industry. Most of this development has been possible through the co-operation of the world-wide fabrication industry since many of these parts are not captively manufactured. However, without the backing of the financially secure resin producer and

automobile producer, these developments would not have reached such a sophisticated state. It should be clear that this kind of development is beyond the present financial and technical ability of the average custom moulder in the developing world. With the interest and co-operation of firms exporting semi-assembled cars, it is conceivable that some of the parts could be produced from plastic in the developing country. India, for example, produced 73,000 passenger and commercial vehicles in 1965. Some of the parts necessary for the Jeeps and Land Rovers are made within the country, but most are imported. On the other hand, the Yue Loong Motor Company in Taiwan manufactures 55 per cent of the parts necessary for the production of their 4,000 vehicles. Such a firm should be encouraged to investigate the opportunities for the manufacture of plastic parts. Several other developing countries also produce small quantities of vehicles; however, large plastic potential is not foreseen since the small volume of expensive parts does not allow for tool amortization. Calendering operations for vinyl upholstery should be considered and investigated as well as for urethane foam for crash pads and seat stuffing.

CHAPTER VII CONSTRUCTION

135. The consumption of plastics in construction continues to grow in the industrialised nations. It is likely that the developing countries will be able to make use of the vast amount of performance and market data that has been collected by the numerous fabricators and end users who have used plastics in construction. The well-established position of plastics in construction can be appreciated by 1964 data in table 8 which indicate that plastics in construction accounted for 5,400 million of the 23,700 million pounds of plastics produced in the world.

Table 8

Consumption of plastics in construction in the world, 1964

Country	Total production (million lb)	Estimated total consumption (million lb)
United States of America	9,700	2,400
Germany (Fed. Rep. of)	3,700	325
Japan	2,350	460
United Kingdom	2,000	300
Italy	1,500	350
France	1,120	285
USSR	1,200	250
Canada	440	110
Eastern Germany	370	95
Netherlands	350	90
Sweden	220	55
Others (Poland, Czechoslovakia, Belgium, Australia, Argentina)	750	180
India	750	150
Total	23,700	5,400

136. The share of plastics used in construction as a percentage of total world production is expected to increase as building codes in various countries permit the use of plastics in new areas. For example, it has been estimated that the United States could consume 5,000 million to 6,000 million pounds by 1970, which is more than double the usage in 1964.

137. The impressive data on plastics in construction are only meaningful if a developing country can pick out those applications which appear to fit their

current and future situation. It has been suggested that plastics can be used in self-help housing in combination with indigenous materials. This will allow unskilled labourers to erect homes with a minimum of supervision. For example, during 1961 over 50 homes were built in the Caribbean from plastic structural components. While analysts point out that the population rises in developing countries and therefore assures a huge demand for low-cost plastic housing, they fail to see some of the less obvious barriers to the establishment of an industry based on supplying plastics for homes. The variances in labour availability, distribution and marketing systems, roads and banking (credit structure) pose important barriers to plastics as a mass construction material. It seems clear, however, that plastic building components, if they are to be accepted in developing countries, will have to find their start in the cities. Products such as pipe, conduit, wire and cable insulation, and electrical fittings are already established in many developing countries. Second generations of plastic building products such as floor tile, wall coverings, lighting fixtures, and decorative laminates would increase usage of plastics considerably. In particular, PVC polymer production is likely to benefit greatly, since it is used in many of the largest volume applications.

194. Some of the developments in plastics used in construction are outlined below. Since many of these applications may not be feasible for developing countries in the near future, some attention should be paid to improvements in processing, joining and installing of products that are already in use, such as pipe and conduit. This could help increase the penetration of plastics in existing markets as a result of lower cost and ease of installation and handling. The following are the applications for plastics within the construction industry and the specific materials in use for each.

Applications	Materials [2/]
Glazing, skylights	Acr., FRP, PVC
Building panels	PVC
Paints, coatings	Acr., U & M, Ph., PVA, PS, SB, PVC, Alkyl
Plywood, boards	U & M, Ph.
Fire coating	LDPE, HDPE, PVC
Electrical devices	U & M, Ph.
Lighting fixtures	Acr., U & M, PS, PVC
Decorative laminates	U & M, Ph.
Wall tile	PS

Applications	Materials[b/]
Wall coverings	PVC
Plumbing fixtures	ABS, Ph., PVC, PS
Floor covering	PVC
Moisture, insulation barriers	LDPE, PVC, PS
Pipe	PVC, PS, HDPE, LDPE

Below are listed the various fabrication methods for plastic products in construction and the typical products which result.

Process	Typical products
Extrusion	Pipe, panels, wire coating, wall coverings, moisture and insulation barriers, siding
Injection moulding	Pipe fittings, lighting fixtures, wall tile, plumbing fixtures
Blow moulding	Neg.
Laminating	Decorative laminates, plywood
Casting	Acrylic sheet
Calendering	Floor tile, wall coverings, other home decorating products
Compression moulding	Electrical fixtures

Plastic pipe

139. Plastic pipe has become an important replacement of traditional piping materials such as steel, asbestos, cement and copper throughout the world. Light-weight and low-cost qualities, excellent chemical resistance, ease of fabrication and low investment compared to metallic and other pipe producing plants have collectively been responsible for the growing acceptance of plastic pipe. Major applications include irrigation, oil and gas production and distribution chemical lines, drainage, electrical conduit and many related uses.

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b/ Key:

FRP	- Fibre glass reinforced plastics
LDPE	- Low-density polyethylene
HDPE	- High-density polyethylene
PVC	- Polyvinyl chloride
PS	- Polystyrene
ABS	- Acrylonitrile-butadiene-styrene
PH	- Phenolic
U & M	- Urea & Melamine
Acr.	- Acrylic
PVA	- Polyvinylacetate
SB	- Styrene-butadiene

140. In Israel, polyethylene and PVC irrigation pipe has been replacing aluminum. Smaller pipe diameters can be used and the pipe is easily handled and transported from place to place. Southeast Asia has used plastic pipe extensively. Thailand installed nearly one million pounds of pipe (imported and made domestically) in 1966 for electrical conduit and water transportation. Malaysia imported more than 0.2 million pounds of pipe (mainly PVC) for water pipe used in housing developments, tin mines and irrigation of rubber plantations. The Philippines utilized about 2 million pounds of PVC and polyethylene pipe for chemical, water and electrical lines. China (Taiwan) is among the largest specifier of plastic pipe, using 5 to 6 million pounds in 1966 for several applications. Pakistan increased its usage substantially in 1966, largely because of increased demand for water and agricultural piping. An analysis of other developed and developing countries shows the same increasing reliance on plastic pipe.

141. While some countries use several types of thermoplastics (polyethylene PVC, ABS and polypropylene), the newer users of plastic pipe tend to favour PVC and/or polyethylene. Raw materials are readily available for extrusion or the pipe can be imported. Polyethylene pipe is noted for its low-cost, light-weight qualities, good low temperature impact properties, flexibility, and chemical resistance. Its main drawbacks are relatively low strength and structural rigidity, low softening point and low resistance to liquid hydrocarbons. Improved, higher density materials have greatly improved the thermal and mechanical properties of PE pipe. The flexibility of PE pipe, which permits lengths of 100-500 feet or longer, is a major advantage, since few joints are needed. PVC (unplasticized) pipe is rigid and exhibits excellent chemical resistance, good weathering properties and does not support combustion. The latter property is particularly important for use as a construction material. In recent years, several companies have developed mechanical joining systems which have replaced solvent welding techniques that require a longer period of time to set. A very high strength, high molecular weight polyethylene pipe is made in the United States on special equipment. Allied Chemical and Phillips Petroleum supply both resin and equipment. The Plastics Pipe Institute of the Society of the Plastics Industry can provide substantial data on many aspects of the United States pipe business, which in 1966 consumed over 250 million pounds of various plastics for pipe and fittings.

143. [illegible] have been developed in several countries for using auto ploughs to dig and lay up to 75 metres per minute of welded polyethylene pipe (150-300 metres) in a trench which is also prepared. These machines permit above-ground installation.

144. Technology for extruded pipe is readily available from most equipment producers. The production of fittings requires considerably higher investment, outlays of sales and technology. Hence, some countries may produce pipe but still import fittings. Care must be taken since dimensional standards vary from country to country. In areas where scrap or off-grade resin is available, material costs can often be lowered by processing the resins into pipe. Fillers can be added (e.g. cement) to reduce costs even further.

Windows and doors

Windows

144. Methyl methacrylate, polycarbonate and PVC have been used as glazing materials in the United States. In many industrial plants where a high degree of chemical resistance is required, PVC has been chosen. Methacrylate and polycarbonate transparent sheet have been used mainly for replacement of glass, although increased usage is taking place in new construction. Both offer several advantages over glass: light-weight, ease of fabrication and a reduction in breakage.

Doors and window frames

145. Doors and window frames made from rigid PVC are popular in many countries. The window frames are assembled from extruded profiles. In the United States vinyl storm windows (removable windows for winter use) have made important gains against aluminium. The use in structural ("prime") building has been limited because of building codes. Wood-vinyl combinations such as those developed by the Andersen Window Company have also received acceptance. Most of these applications are well developed in several European countries. Some doors are thermoformed over wooden frames (e.g. Bocchi, Milan, Italy); in the United States most of the products are extruded. Tsutsunaka (Osaka, Japan) has made doors by laminating calendered 30-35 plies of vinyl sheet. Combination of different plastics are also being introduced in several countries. For example, one United States firm produced a door based on a 4-pound foamed polystyrene core and several pounds of flexible and rigid vinyl.

Floor tile

146. Floor tile made from PVC homopolymer and copolymers, fillers (asbestos, carbonate, asbestos), plasticisers, stabilisers and pigments are finding gradual acceptance in developing countries. Some acceptance has even been received in Mediterranean countries where marble and cement tiles are readily available.

147. Several EEAFE firms are planning to install calendering equipment with capacities in the range of one to three million square feet per year. Lower cost tile has become increasingly available owing to the incorporation of high filler loadings. Laminates and foamed cores allow placing an appealing surface over a less-cost core made on calenders or double extruders.

148. Technology for establishing a floor tile operation is available from many nations. A number of companies will provide a complete "package" including know-how, plant design and start-up, and will advise on resins and plasticisers. Norsk Spraymat-Industri A/S (Oslo, Norway) has worked with several EEAFE countries interested in producing floor tile.

149. Several firms in Israel make floor tile by different processes. In 1965 five firms produced 150-400 tons of tile, of which 60 percent was calendered, 25 percent coated and 15 percent extruded.

150. In Europe a jute or felt web is spread-coated with vinyl plastisol. These products, however, are not too moisture resistant.

Plumbing and fixtures

Plumbing

151. Plastic pipe and fittings have been used extensively to replace metallic materials for drain, waste and vent plumbing systems. Both PVC and ABS are used. Polyvinyl dichloride has been introduced for high temperature plumbing lines.

152. Many other sanitary facilities from plastic are used around the world. In Europe, toilet tanks and other internal parts are injection moulded from high-impact polystyrene, polypropylene or PVC. Sinks and bathtubs are fabricated from acrylic and polyester resins and find major use in prefabricated homes and trailers as a replacement for cast iron tubs.

Electrical fixtures

151. Compression moulded phenolics have been used for over fifty years in electrical boxes, covers, sockets and switches, industrial switch gear and wiring devices. Technology is readily available for the manufacture of these components.

Lighting fixtures

152. Plastics have been used in lighting fixtures mainly as light controlling devices (refractors, louvers), light modifiers (diffusers, walls, panels) and light transmitters (signs, directional signs). Indoor lighting favours polystyrene, PVC, methylmethacrylate styrene copolymers, and selected thermosets (e.g. polyesters). In outdoor applications, acrylics, cellulosics and polycarbonates have been preferred because of their superior properties.

153. Polystyrene is the largest volume material used in lighting fixtures in the United States since it can be easily injection moulded into a variety of shapes and patterns at low cost. Vinyl copolymers are used for luminous ceilings, while acrylic copolymers are used in many outdoor light systems. The Plastics for Lighting Committee of the Society of the Plastics Industry (SPI) in the United States can provide data and technical information on this market.

154. Fibreglass reinforced polyester ceilings are also found in the United States.

Panels and sandwiches

157. Plastic panels and sandwich construction have been suggested as interior partitions and outer walls for developing countries. In particular, foam plastic panel board may lend itself to concrete or adobe block construction.

156. Sandwich panels have been constructed in various ways from two solid PVC surface sheets with foam or honeycomb interiors or from the foamed core combined with skins of non-plastics. Other variations include polystyrene foam between an asbestos cement panel (e.g. Vitrex, Paris, France), a paper-polystyrene foam-paper combination sold in the United States, and a steel skin sandwich with a polyethylene core marketed by IMPC in Britain.

159. Honeycombs are an important core material. They are a fabricated cellular structure made from aluminium, stainless steel, reinforced plastics and paper. Of this group, kraft paper, either plain or impregnated with phenolic resin, is used extensively. The Hexcel Corporation (Berkley, California) has made finished sandwich constructions from three rolls of this plastic sheet with a honeycomb interior. Considerable work in the United States on polystyrene foam core sandwich panels for construction has been undertaken by the Kopper Company (Pittsburgh, Pennsylvania).

Insulation

160. Plastic foams have become important materials of building insulation. While many types of foam are available, the polystyrene and urethane types are used in largest quantities in most countries.

161. The foams are available as hard, soft, rigid or flexible forms. Their cell structure can be open, closed, interconnecting or non-interconnecting. They may be purchased as extruded boards or as liquids which can be foamed or sprayed in place. In 1967 about four million square feet of polystyrene foam and eight million square feet of polyurethane foam was used in wall insulation in the United States. Other thermal applications include pipe coverings, backer board[1] for metal siding, and thin shell concrete.

162. Various methods are used to make foam insulation. Polystyrene can be extruded into boards of various lengths, widths and thicknesses. Or the polystyrene can be steam-moulded from "beads" into beadboard.[2] In some types of construction, expandible polystyrene can be foamed directly between sandwich facings. Polystyrene foam has also been used as a concrete filler to reduce the weight of the structure (reducing size and cost of other supporting units) and providing better insulation against sound and heat.

163. Polyurethane foams such as polystyrene are easily foamed in place and can be formed into boards. In the United States, polyurethane foams based on toluene diisocyanate are widely used. Data on the use of foams in construction are available from the SPI or the Journal of Cellular Plastics in United States or Fédération française d'Institute Techniques du Petrole (FFITP).

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[1] Backer board is used as a backing for aluminium siding. It is required for dent resistance, longitudinal stiffness, sound deadening, corrosion protection, water resistance and thermal insulation. It also permits the use of thinner aluminium than normally required.

[2] The boards are made from polystyrene beads containing a gaseous hydrocarbon [illegible]

CHAPTER VIII [illegible]

165. Consumer plastic products are usually the first to be produced by fabricators of plastics. International trade shows, literature, and trade associations provide more than enough data on developments in consumer products. A developing country must help create enough demand to be able to sell the myriad of products that can be fabricated. This is easier said than done. However, one approach that has been successful is to continually seek means to replace imported consumer products that have established markets. This obvious strategy has not been easily adopted in some developing countries since the local fabricator is not able to make a product equivalent or lower in cost than the imported product. This again reflects the importance of a low cost materials base.

166. Shoes, tooth brushes, baby holders, and eye glasses are examples of consumer products that have been converted from imported to locally fabricated products by several developing countries during the last five years. Injection moulded furniture components, pails, and other items are presently under consideration by some countries.

Shoes

166. Vinyl shoes and sandals are major consumer products in Asia, South and Central America. Consumption of PVC shoes, collectively, was several million pounds in Thailand, the Philippines and Taiwan (including export). Since investment and technology are relatively minimal, over capacity is common in this industry. Some of the important producers include the Bata Shoe Company (Thailand), Malayan Plastics and Camel Industries (Malaysia), Paramount Vinyl Products Company, Manila Plastics, General Rubber and Plastics, Acme Rubber (Philippines), Pei Hwa Plastics Company (Taiwan), Bata Shoe Company and Karim Rubber Company (Pakistan).

167. In many of the countries, low prices have forced some firms out of production. Most equipment is capable of producing 1.5 2.0 million shoes annually, and a few producers can quickly produce enough to outstrip demand. Shoe heels are injection moulded from high impact polystyrene or ABS, or in special cases, from a thermoformed skin filled with rigid foam. Breathable uppers which look like leather, are mainly PVC, but Corfam (E.I. DuPont) has made rapid gains in the United States. Improved breathable PVC upper materials

have been developed in several countries. Dawa is an expanded breathable PVC as are woven ladies handbag nylon fibre and suede in the United Kingdom. Stockholms (Japan) has made two most breathable shoes. Performing Industries (United States) perforates PVC shoes with tiny holes.

Artificial flowers

168. The artificial flower industry accounted for nearly US$40 million of export value for the Hong Kong economy in 1969. Favourable labour cost and a high degree of creativeness were been responsible for the leading position obtained by Hong Kong. By 1970 it is estimated that over 100 million pounds of polyethylene will be consumed for flowers, fruits and other artificial consumer items. Major moulders of flower petals and stems include Artificial Flowers and Lu and Fung Company [illegible]. Moving labour cost is likely to provide export opportunities for other countries. However, the ability to produce these artificial products at equivalent or lower cost is no guarantee of sales. The market demands styling, colours and quality in many areas.

Toys

169. The toy market is huge in most of the developed countries. In the United States, for example, the wholesale value was US$1,300 million in 1969. There are large fabrication plants with 150 moulding and extrusion machines, as well as small one man operations supplying this business in the United States. Hong Kong is an important exporter of toys. In 1969 over 50 million pounds of plastics were utilized. Polystyrene generally accounts for most of this volume (about 60 per cent) followed by polyethylene (35 per cent) and PVC, particularly for doll heads and inflatables. The doll market is the largest segment of the toy business in the United States and elsewhere. The dolls are generally moulded from PVC plastisol resins. Since many toy makers have their own plastics fabrication operations, the market for countries wishing to export is considerably smaller than gross data would indicate. The cost of moulds can be quite expensive in this market, particularly when changing consumer tastes make a product obsolete.

Tooth brushes

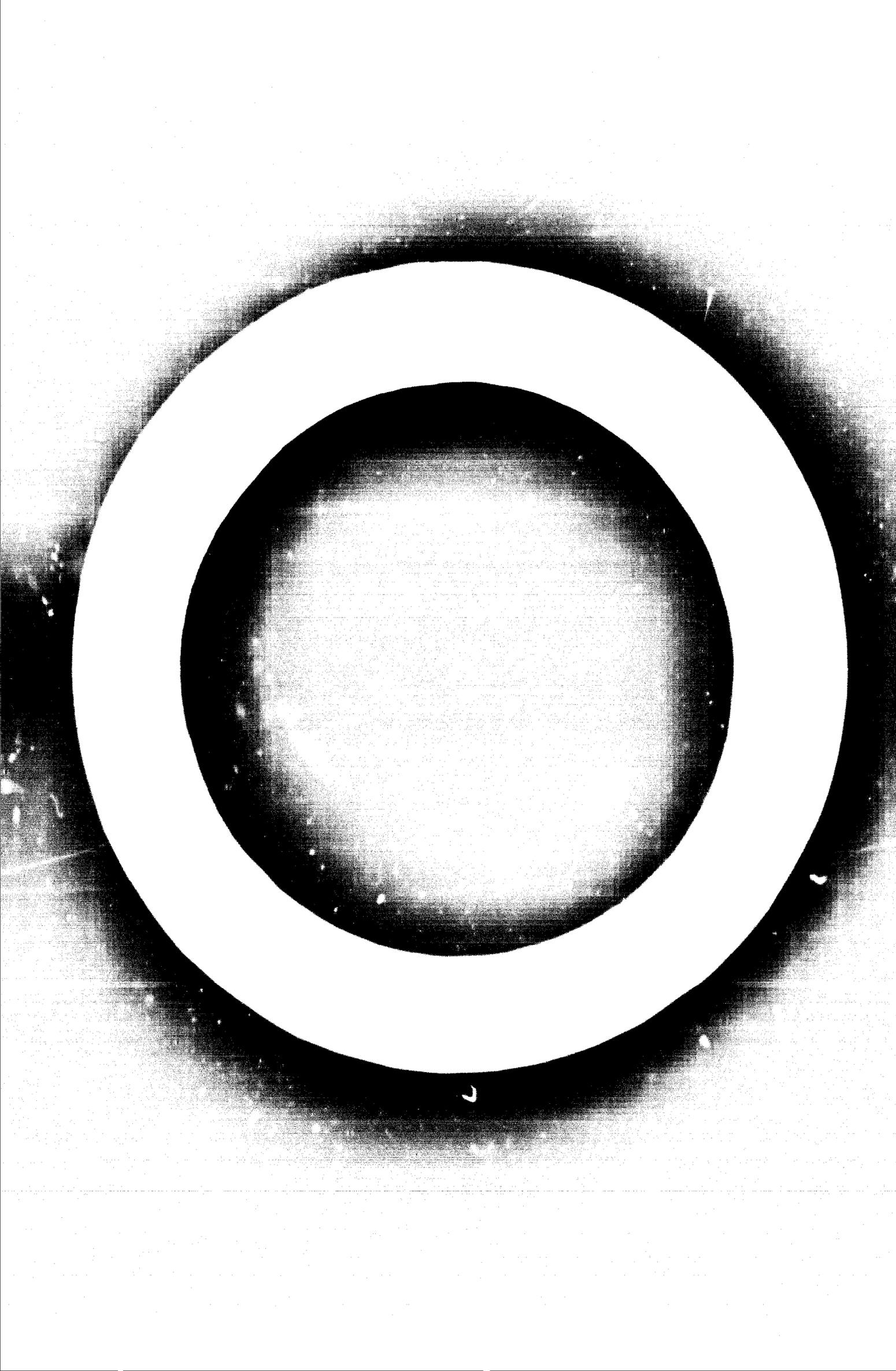
170. Tooth brushes fabricated from high-density polyethylene, cellulose acetate and polystyrene are marketed in countries such as Thailand and Malaysia. Low cost imports have prevented production in a number of areas.

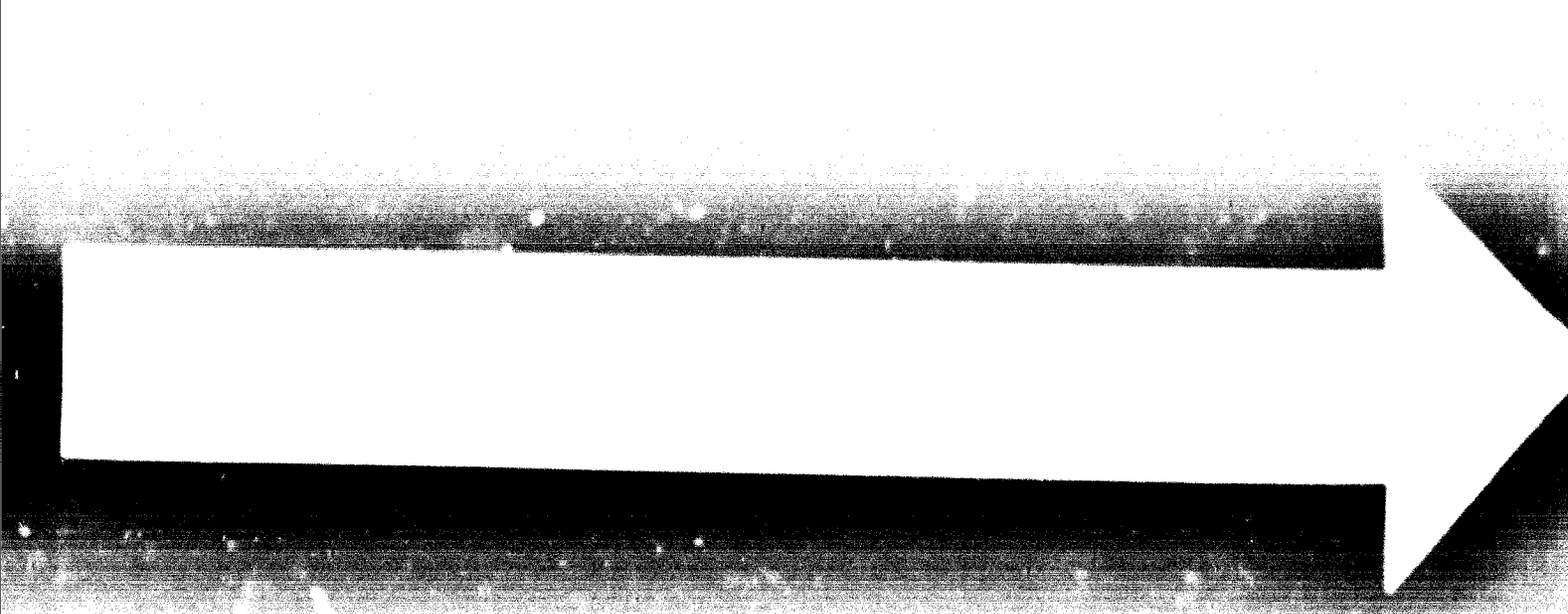
Housewares

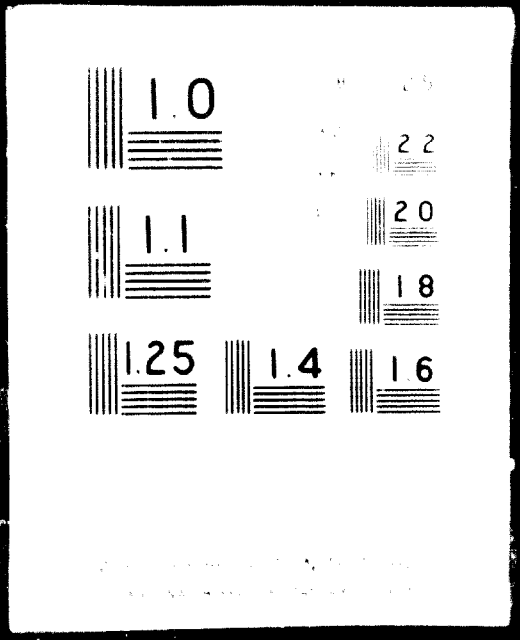
171. Housewares are among the first group of plastic products to be fabricated by a new plastics industry. There are a multitude of items that classify as housewares - trash cans, trays, ice cube trays, drinking cups and so on. As in the toy business, domestic demand is often not large enough to support the number of fabricators entering this business and exports become important. Israel has developed substantial daily business. In contrast to artificial flowers and toys, the housewares market is less influenced by low labour cost. As in other consumer markets, the growth and distribution of consumer income will determine the acceptance of a product. Some fabricators have been successful in introducing new housewares obtained from other countries. A polyethylene baby bathtub was introduced in Argentina as a replacement for styrene in the late 1950s.

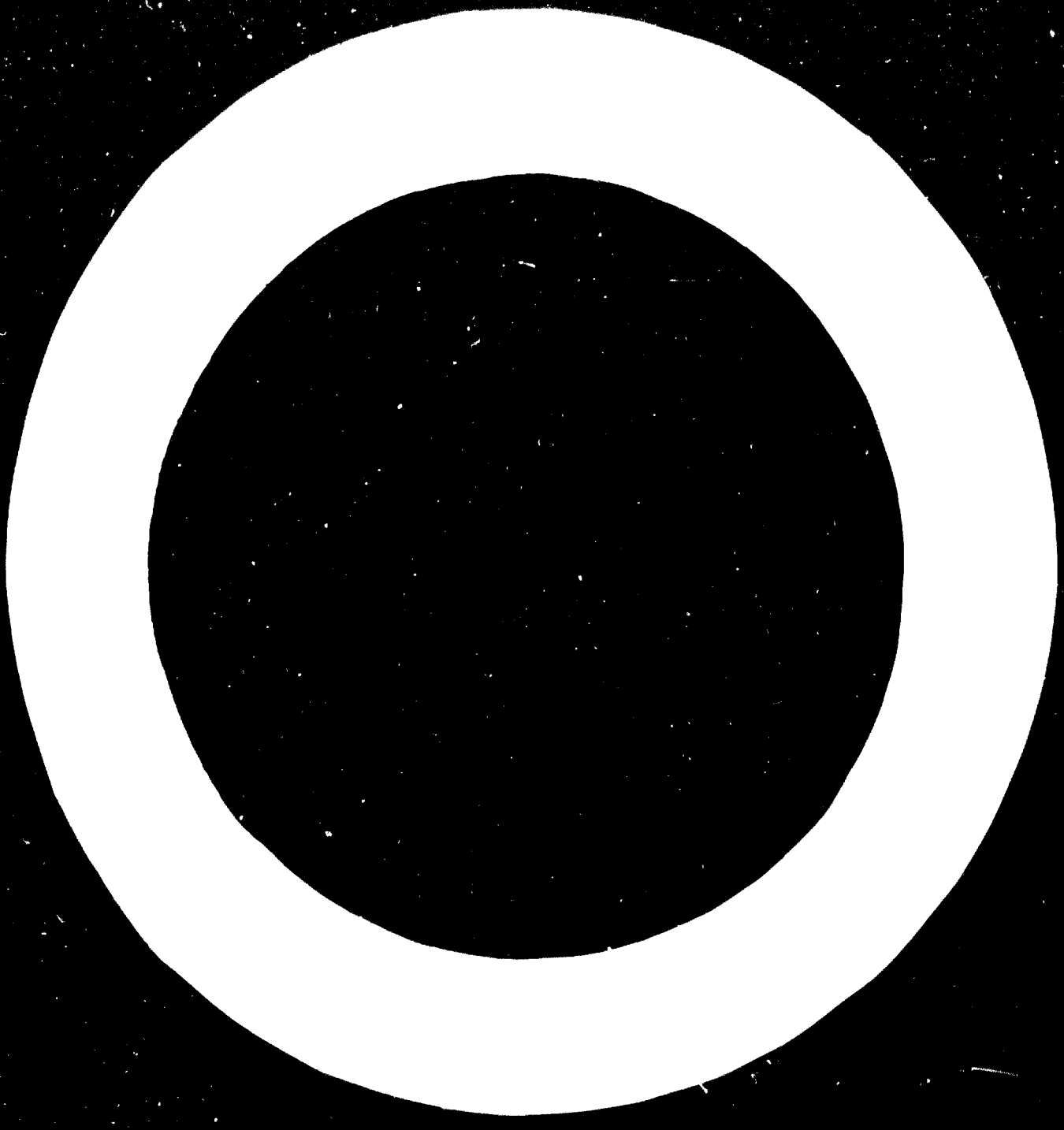
Furniture

172. The availability of wood in many of the developing countries has prevented more than token use of plastic furniture. However, PVC sheet for upholstery has found markets in developing countries. Similarly, imported decorative laminates are in demand for restaurants, hotels and so on, as are injection moulded chairs. In the United States, the institutional seating market is supplied by several plastics - polyethylene, polypropylene, ABS, rigid vinyl and reinforced polyesters. Foam cushioning (mainly urethane) encased in a variety of fabrics is another expanding market. Perhaps the most exciting development in this field is injection moulded furniture components such as chair backs. One United States firm produces seven backs per minute, a figure which is much higher than even skilled labourers can turn out. Injection moulding permits intricate shapes, patterns, carvings etc. to be mass produced instead of being manufactured by the usual machining and sanding procedures. Since skilled woodworking personnel is costly in many countries, the increased productivity of moulding can decrease the cost of furniture for the consumers in lower income brackets. Thermoformed PVC drawers for bureaus and desks is another product area presently emerging. In countries where wood is not available, plastics can play an important role in the furniture market.









Annex 1

Raw materials for plastic - suppliers, processing methods and costs

Resin type	Selected major producers [a] and resin trade names	Processing methods applicable	Typical uses	Cost [b] cents/lb	Cost [b] cents/in^3
Thermoplastics					
Acrylonitrile-butadiene styrene (ABS)	Marbon (USA) Cycolac Uniroyal (USA) Kralastic Bayer (Federal Republic of Germany) Novodur Archon Chemicals (England) Cycolac Wolne Kralastic Montebelli (Italy) Sinoflex Toyo Rayon (Japan) Toyolac	Injection moulding Extrusion Thermoforming	Pipe and fittings Industrial parts Tote boxes Telephone housings	28 - 36	1.07-1.4
Acetal resins	Celanese Corp. (USA) Celcon DuPont (USA) Delrin ICI (England) Kematal Hoechst (Federal Republic of Germany) Hostaform Polyplastics (Japan) Duracon	Injection moulding Blow moulding Extrusion	Industrial parts	65	3.34

[a] See annex for names and locations of resin suppliers listed.

Resin type	Selected major producers[a] and resin trade names	Processing methods applicable	Typical uses	Cost[b] cents/lb	Cost[b] cents/in^3
Thermoplastics (continued)					
Acrylics	DuPont (USA) Lucite Rohm & Haas (USA) Plexiglas Hoechst (Federal Republic of Germany) Resarit ICI (England) Diakon Altuglas (France) Altulite Sumitomo Chemical (Japan) Sumipex - B	Injection Extrusion Castings Thermoforming	Signs Shoe heels TV lenses Displays	45.5	1.96
Cellulosics	Celanese Corp. (USA) Fortisol Tennessee Eastman (USA) Tenite Bayer (Federal Republic of Germany) Cellidor and Triafol Diacel Ltd (Japan) Acetyloid	Injection Extrusion Thermoforming	Pens and pencils Brushes Industrial parts Blister packaging	Cellulose Acetate 40-52 CAB-CP 62	1.83-2.38 3.60
Nylons	Allied Chemical (USA) Plaskon Celanese Corp. (USA) DuPont (USA) Zytel ICI (England) Maranyl BASF (Federal Republic of Germany) Ultramid Toyo Rayon (Japan) Amilan	Injection moulding Blow moulding Extrusion Casting direct from type 6 monomer	Zippers Film Gears Wire insulation Bristles Bobbins	87.5	3.60

Basic type	Selected major producers[a] and Resin trade names	Processing methods applicable	Typical uses	Cost[b] cents/lb	Cost[b] cents/in^3
Thermoplastics (continued)					
Polycarbonates	General Electric (USA) Lexan Mobay Chemical Company (USA) Merlon Bayer (Federal Republic of Germany) Makrolon Mitsubishi Edogawa Chem. (Japan) - Lupilon Teijin Chem Company (Japan) Panlite	Injection moulding Blow moulding Extrusion Thermoforming	Glazing Coil forms Camera parts Gears	80	3.47
Polyethylene-high-density	Allied Chemical (USA) Grex Celanese Corp. (USA) Fortiflex DuPont (USA) Alathon Phillips Petroleum (USA) Marlex Hoechst (Federal Republic of Germany) Hostalen C Shell (England) Carlona Solvay (Italy) Eltex Mitsui Petrochemical (Japan) Hi-Zex	Injection moulding Blow moulding Extrusion Thermoforming Coating	Bottles Automotive parts Seating Toys Tote boxes Pipe	.17	0.6

[a] See annex 2 for names and locations of resin suppliers listed.

[b] 1982 prices

Resin type	Selected major producers[a] and Resin trade names	Processing methods applicable	Typical uses	Cost[b] cents/lb	Cost[b] cents/in^3
Thermoplastics (continued)					
Polyethylene-low-density	DuPont (USA) Alathon Union Carbide (USA) Bakelite U.S.I. Chemicals (USA) Petrothene BASF (Federal Republic of Germany) Lupolen ICI (England) Alkathene Celene (Italy) Sumitomo Chemical (Japan) Sumikathene	Injection moulding Blow moulding Extrusion Thermoforming Coating	Housewares Toys Squeeze bottles Industrial and packaging films Pipe Paper coatings	.15	0.5
Polypropylene	Avisun (USA) Olemer Eastman Chemical Products (USA) Tenite Enjay Chemical (USA) Hercules Inc. (USA) Hi-Fax Hoechst (Federal Republic of Germany) Hostalen PP Montesholl (Italy) Moplen ICI (England) Propathene Mitsui Chemical (Japan) Noblen	Injection moulding Blow moulding Extrusion Thermoforming Coating	Packaging films Mono and multifilament Housewares Toys Industrial parts	.18	0.6
				.18	0.6

Resin type	Selected major producers[a] and Resin trade names	Processing methods applicable	Typical uses	Cost[b] cents/lb	Cost[b] cents/in^3
Thermoplastics (continued)					
Polystyrenes	Dow Chemical (USA) Styron Rexall Chemical (USA) El Rexene Sinclair-Koppers (USA) Dylene Union Carbide (USA) Bakelite BASF (Federal Republic of Germany) Luran, Styropor, Styrofan Dow (Italy) Styron Monsanto-Bussois (France) Lustrex Ashai Dow (Japan) Styron	Injection moulding Blow moulding Extrusion Thermoforming Coating	Containers Toys Housewares Foams Packaging films Industrial parts	17-27	0.64-1.00
Polyurethanes	B.F. Goodrich (USA) Estane Mobay Chemical (USA) Reichhold Chemical (USA) Bayer (Federal Republic of Germany) Vulkollan and Desmopan Takeda Chemical (Japan) Takenate	Injection moulding Extrusion Casting Foaming	Cushioning Insulation Padding	-	-

a/ See annex 2 for names and locations of resin suppliers listed.
b/ US prices

Resin type	Selected major producers[a] and Resin trade names	Processing methods applicable	Typical uses	Cost[b] cents/lb	Cost[b] cents/in^3
Thermoplastics (continued)					
Vinyls	B.F. Goodrich (USA) Geon Borden Chemicals (USA) Diamond Alkali (USA) Diamond Union Carbide (USA) Bakelite BASF (Federal Republic of Germany) Lutofan, Vinoflex Pechiney-Saint-Gobain (France) Lucolene ICI (England) Corvic, Welvic Japan Geon Co. (Japan) Geon	Injection moulding Blow moulding Extrusion Thermoforming	Packaging and industrial films Industrial parts Phonograph records Pipe fittings Tiles Shoes	10-30 depending on type and form	
Thermosets					
Phenolics	General Electric (USA) Hooker Chemicals (USA) Durez Reichhold Chem (USA) Union Carbide (USA) Bakelite La Bakélite (France) Bakelite Plastugil (France) Progilite BASF (Federal Republic of Germany) Kauresin ICI (England) Mouldrite Sumitomo Bakelite (Japan) Sumikon	Compression and transfer moulding Casting	Electrical and electronic components Appliance handles and knobs Ducts and blowers		20-115 (depending on fillers)

a/ See annex 2 for names and locations of resin suppliers listed.
b/ US prices

Annex 2

Selected major producers of raw materials for plastics

Producer	Address
Thermoplastics	
Acetal Resins	
Celanese Corporation	Newark, New Jersey (USA)
E. I. DuPont Corporation	Wilmington, Delaware (USA)
ICI, Ltd	London, England
Farbwerke Hoechst, A.G.	Frankfurt/Main-Hoechst, Federal Republic of Germany
Polyplastics Co., Ltd	Osaka, Japan
ABS	
Marbon Chemical Co.	Washington, West Virginia (USA)
Uniroyal	Naugatuck, Connecticut (USA)
Farbenfabriken Bayer, A.G.	Leverkusen, Federal Republic of Germany
Anchor Chemical	Manchester, England
Ugine	Paris, France
Mazzuchelli Celluloide, S.A.	Castiglione Olona, Italy
Toyo Rayon Co., Ltd	Tokyo, Japan
Acrylics	
E. I. DuPont Corporation	Wilmington, Delaware (USA)
Rohm & Haas Corporation	Philadelphia, Pennsylvania (USA)
ICI, Ltd	London, England
Altalor	Paris, France
Resart	Mainz, Federal Republic of Germany
Sumitomo Chemical	Osaka, Japan
Cellulosics	
Celanese Corporation	Newark, New Jersey (USA)
Tennessee Eastman Co.	Kingsport, Tennessee (USA)
Farbenfabriken Bayer, A.G.	Leverkusen, Federal Republic of Germany
Daicel Ltd	Osaka, Japan
Nylon	
Allied Chemical Corporation	Morristown, New Jersey (USA)
Celanese Corporation	Newark, New Jersey (USA)
I. E. DuPont Corporation	Wilmington, Delaware (USA)
ICI, Ltd	London, England
BASF	Ludwigshafen/Rhein, Federal Republic of Germany
Toyo Rayon Ltd	Tokyo, Japan

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Producer	Address
Polyethylene (High-density)	
Allied Chemical Co.	Morristown, New Jersey (USA)
Celanese Corporation	Newark, New Jersey (USA)
E. I. DuPont Corporation	Wilmington, Delaware (USA)
Phillips Petroleum Co.	Bartlesville, Oklahoma (USA)
Farbwerke Hoechst, A.G.	Frankfurt/Main-Hoechst, Federal Republic of Germany
Shell Chemical Co.	London, England
Solvay & Cie	Milan, Italy
Mitsui Petrochemicals Industries	Tokyo, Japan
Polyethylene (Low-density)	
E. I. DuPont Corporation	Wilmington, Delaware (USA)
Union Carbide Corporation	New York, New York (USA)
U.S.I. Chemical Co.	New York, New York (USA)
ICI, Ltd	London, England
BASF	Ludwigshafen/Rhein, Federal Republic of Germany
Celene, S.A.	Milan, Italy
Sumitomo Chemical	Osaka, Japan
Polypropylene	
Avisun Corporation	Philadelphia, Pennsylvania (USA)
Eastman Chemical Products	Kingsport, Tennessee (USA)
Enjay Chemical Co.	New York, New York (USA)
Hercules, Inc.	Wilmington, Delaware (USA)
Farbwerke Hoechst, A.G.	Frankfurt/Main Hoechst, Federal Republic of Germany
ICI, Ltd	London, England
Monteshell Petrochimica, S.A.	Milan, Italy
Mitsui Chemical Co.	Tokyo, Japan
Polystyrenes	
Dow Chemical Co.	Midland, Michigan (USA)
Rexall Chemical Co.	Paramus, New Jersey (USA)
Sinclair-Koppers Co.	Pittsburgh, Pennsylvania (USA)
Union Carbide Corporation	New York, New York (USA)
BASF	Ludwigshafen/Rhein, Federal Republic of Germany
Dow Chemical, S.A.	Milan, Italy
Monsanto-Bussois	Paris, France
Askai-Dow Ltd	Tokyo, Japan

Producer	Address
Polyurethanes	
B. F. Goodrich Chemical Co.	Cleveland, Ohio (USA)
Mobay Chemical Co.	Pittsburgh, Pennsylvania (USA)
Reichhold Chemical Co.	White Plains, New York, (USA)
Farbenfabriken Bayer, A.G.	Leverkusen, Federal Republic of Germany
Takeda Chemical Industries Ltd	Osaka, Japan
Vinyls	
B. F. Goodrich Chemical Co.	Cleveland, Ohio (USA)
Borden Chemical	New York, New York (USA)
Diamond Alkali Co.	Cleveland, Ohio (USA)
Union Carbide Corporation	New York, New York (USA)
BASF	Ludwigshafen/Rhein, Federal Republic of Germany
ICI, Ltd	London, England
Pechiney-Saint-Gobain	Paris, France
Japan Geon Co.	Tokyo, Japan
Thermosets	
Phenolics	
General Electric Co.	Pittsfield, Massachusetts (USA)
Hooker Chemical Corporation	
Durez Plastics Division	North Tonawanda, New York (USA)
Union Carbide Corporation	New York, New York (USA)
BASF	Ludwigshafen/Rhein, Federal Republic of Germany
La Bakelite, S.A.	Bezons, France
Plastugil	Paris, France
Sumitomo Bakelite	Tokyo, Japan


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