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UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Tel: (+43-1) 26026-0 · www.unido.org · unido@unido.org

PETROCHEMICAL INDUSTRY SERIES

MONOGRAPH No. 3

# STUDIES IN PLASTICS FABRICATION AND APPLICATION

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UNITED NATIONS

# STUDIES
# IN PLASTICS FABRICATION
# AND APPLICATION

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION, VIENNA

PETROCHEMICAL INDUSTRY SERIES

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UNITED NATIONS

New York, 1969

ID/SER.J/3

UNITED NATIONS PUBLICATION

Sales No.: E.69.II.B.32

Price: $U.S. 1.25 (or equivalent in other currencies)

**Printed in Austria**

# FOREWORD

This publication is the third of a series of monographs in the Petrochemical Industry Series to be published by the United Nations Industrial Development Organization. The titles of other studies in this series will be found on the back cover of this publication.

The world petrochemical industry has shown a high rate of growth during the last ten years. The industry supplies intermediate products for a number of other industries and provides substitutes for traditional materials such as steel, lumber, packaging materials, natural fibres, natural rubber and soap. It is considered to be one of the most strategic sectors of industrial development because most of its products go on to other producing sectors.

This series of monographs is designed to assist the developing countries in dealing with technical and economic problems related to the establishment and development of facilities for the manufacture of petrochemicals and consumer products. The present series is concerned with basic and intermediate petrochemicals and end products, such as plastics, synthetic rubbers and synthetic fibres. Nitrogenous fertilizers[1] and textile production based on synthetic fibres are excluded from the series.

Part 1 of this report was prepared by Joseph F. Dash, New York, and Richard M. Kossoff, R. M. Kossoff and Associates, New York; Part 2 was prepared by Richard M. Kossoff; and Part 3 by Irving Skeist, Skeist Laboratories, Inc., Newark, N. J. All were serving as consultants to UNIDO. The views and opinions expressed are those of the consultants and do not necessarily reflect the views of the secretariat of UNIDO.

These studies were prepared in 1967.

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[1] See the Fertilizer Industry Series published by the United Nations Industrial Development Organization (ID/SER. F, Nos. 1, 2, 3, 4 and 5).

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*Part 1*

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## EXPLANATORY NOTES

**Reference** to tons is to metric tons unless otherwise stated.

**Reference** to dollars ($) is to United States dollars unless otherwise **indicated.**

**Reference** to gallons is to US gallons (3.785 litres).

**A** one-year period that is not a calendar year is indicated as follows: **1965/1966.**

.. **period** of two years or more is indicated as follows: 1965 - 1966, 1965 - 1968 **etc.**

*Part 1*

# POTENTIAL PLASTICS APPLICATIONS FOR FABRICATORS IN DEVELOPING COUNTRIES

## 1.1 Methods of processing plastics

Plastics are man-made materials. An accepted definition for a plastic[1] 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".

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

### *Thermoplastic processing*

Injection moulding is an important method for forming objects from thermoplastics. During this process, the resin is fed into a hopper (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 either automatically or by hand.

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 (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 shape 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.

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[1] The Society of the Plastics Industry Inc., New York, N. Y.

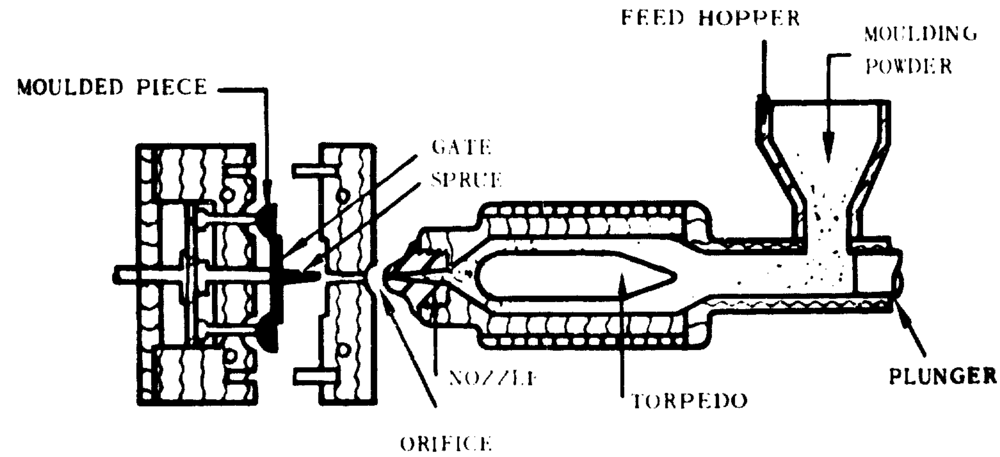
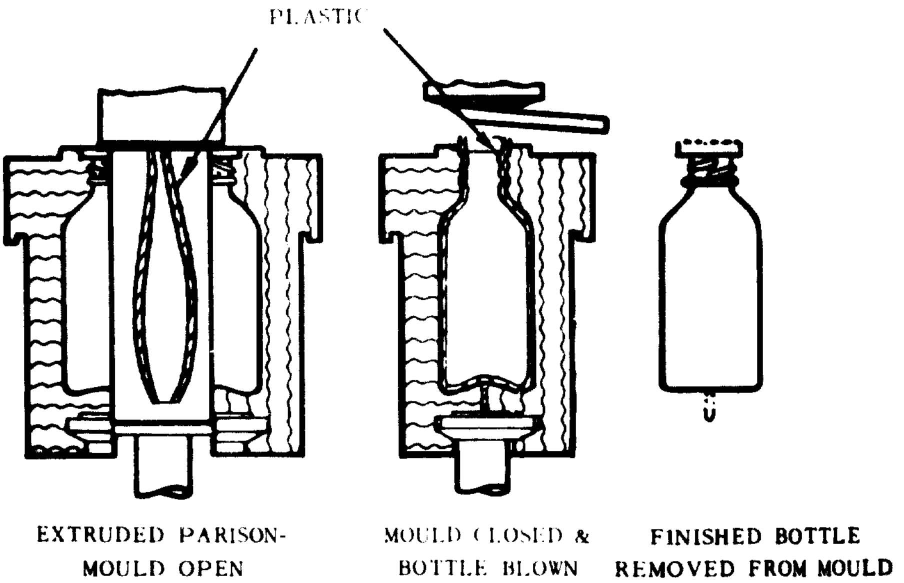



*Figure 1. Injection moulding*

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 that 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 (figure 3).

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.




EXTRUDED PARISON-MOULD OPEN | MOULD CLOSED & BOTTLE BLOWN | FINISHED BOTTLE REMOVED FROM MOULD

***Figure 2. Blow moulding***

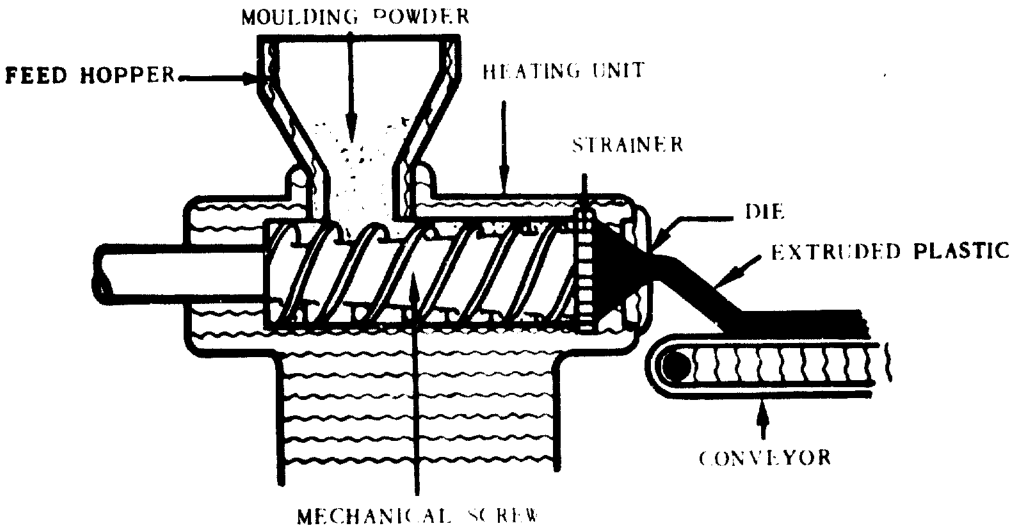



*Figure 3. Extrusion moulding*

### *Thermoset processing*

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 (figure 4). Three critical factors–temperature, pressure and time cause the thermosetting resin to undergo a chemical change in which the resin solidifies into permanent shape.

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 the metal parts without change in the position of the metal.

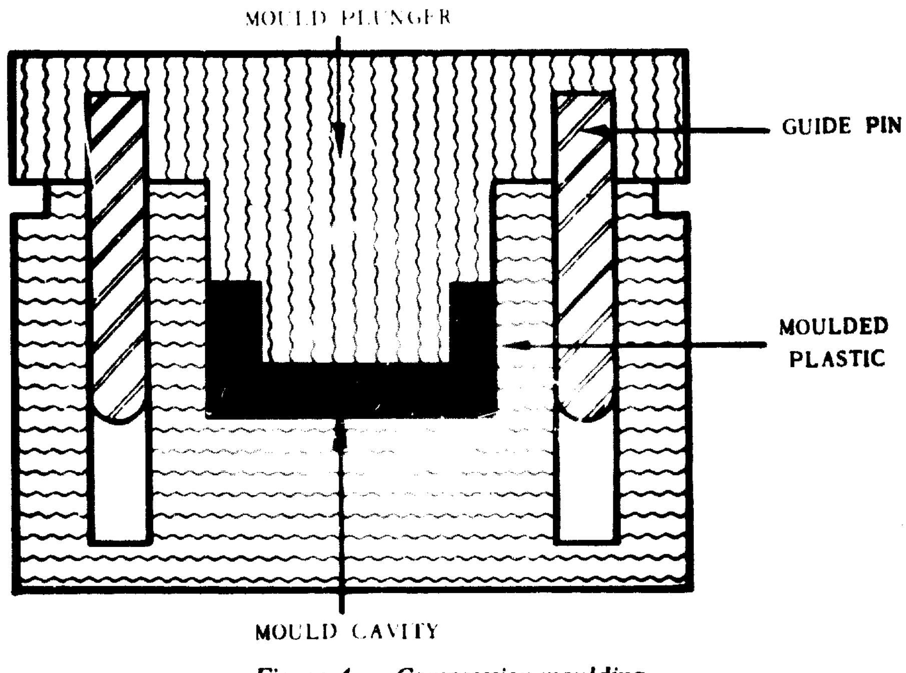



*Figure 4. Compression moulding*

*Other processes*

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

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

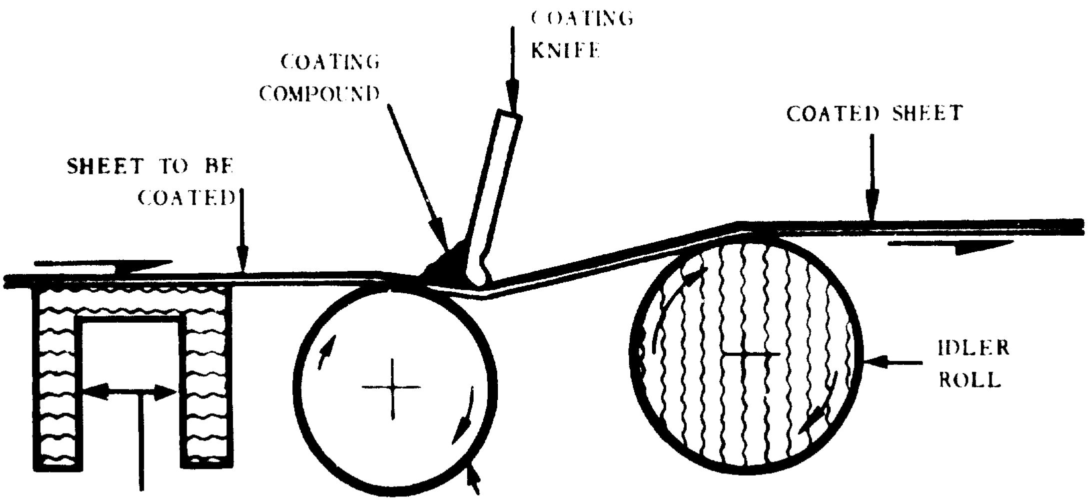



*Figure 5. Spread coating*

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. The film surface can be textured by modifying the roller surface.

The previous section dealt with the most important methods for manufacturing plastic products. The list below indicates the typical fabricated products which can be manufactured by 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, raincoats |

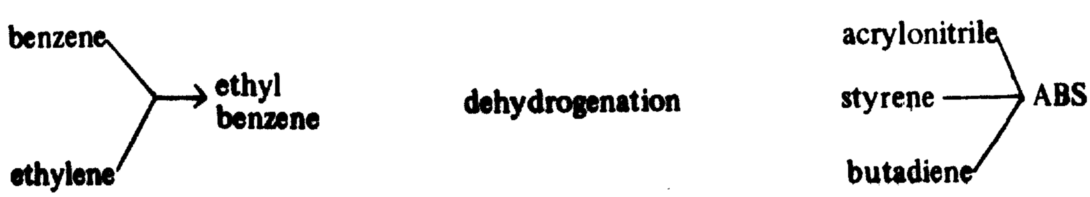
## 1.2 Raw materials for plastics

This chapter discusses briefly the wide range of plastics available, and their key properties, applications, and major world-wide suppliers.

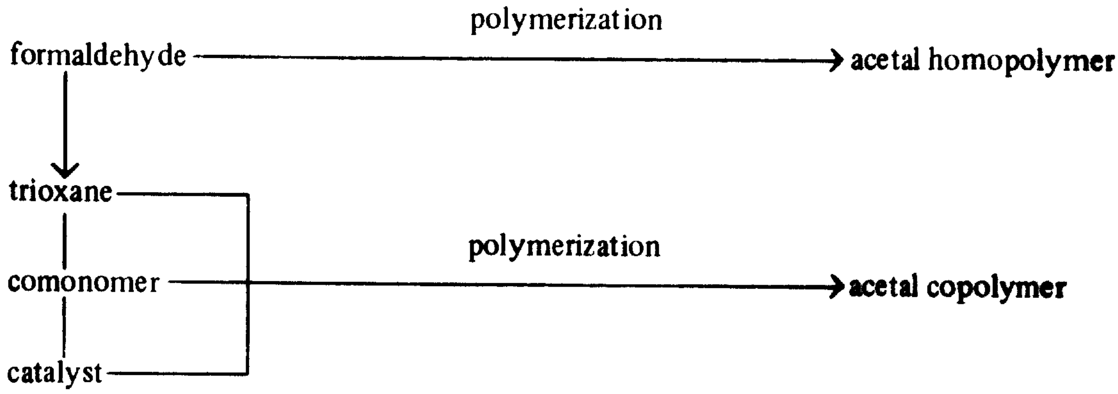
Currently there are almost 40 major plastics in use. Many more are being developed in research laboratories, but are still too exotic for commercial exploration. Because many of the "common core materials" are difficult to process, require special technology, highly skilled and experienced personnel,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

*Thermoplastics*

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 resistance, from 60°F to 175 to 212°F. Typical uses include pipe and pipe fittings, automotive parts, containers, telephone housings, and appliance cases. The chemistry of ABS is indicated below:



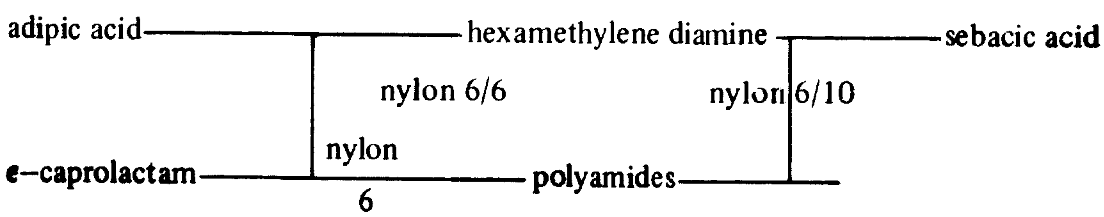
Acetal resins were developed in 1956. They are very rigid but not brittle plastics and they retain their rigidity under a wide variety of conditions. Other outstanding properties include great strength, excellent dimensional stability and resilience. Repeated impact loading usually does not affect them. This balance of properties has caused considerable development of the acetals for replacing metal. Typical uses include plumbing parts, automotive assembly parts, terminal blocks, gears and bushings, and valves. The chemistry of acetals is as follows:




Acrylics were introduced on the United States market in 1936. The outstanding properties are exceptional clarity and light transmission in combination with strength, temperature resistance and resistance to weathering. Typical applications include glazing, sign facings, television lenses, skylights and point-of-sale displays. Acrylic resins are manufactured by polymerizing methyl methacrylate monomer in the presence of a catalyst and heat.

Cellulosics are among the earliest materials developed in the industry, although they are not true "plastics" since they are based on cellulose, a natural material. There are several types of product: cellulose acetate, cellulose acetate butyrate, cellulose propionate and the less commonly used ethyl cellulose. The outstanding properties of cellulosics include great toughness (perhaps the toughest material in the plastics family), durability, transparency, ease of colourability, and good electrical properties. Typical applications include automotive steering wheels, pipe, eye-glass frames, shoe heels, pen and pencil parts, brushes, toys, film and sheet. Cellulosics are custom-blended materials and are literally tailored for the application. The compounds are formed by combining plasticizers, additives and cellulose ester flake.

Nylon, which was commercialized in 1938, is one of the most mature of all the thermoplastics. It is resistant to temperature, wear and chemicals, and has good electrical and lubricating properties. Typical applications include zippers, glass, bushings, bobbins, special wire insulation and, in filament form, fishing line and brush bristles. Nylon types include 6, 6/6 and 6/10, as well as special grades and numerous combined forms. The main types of nylon are produced as follows:



Polycarbonates are a new type of thermoplastics developed in 1957 by Bayer and General Electric. This polymer has high impact strength and working temperature, with heat resistance up to 240°F, excellent electrical properties, chemical and weathering resistance. Typical applications are glazing, streetlight globes, industrial parts, camera parts, and coil forms. Polycarbonate resin is usually made from the reaction of bisphenol A and phosgene.

Polyethylene was developed in 1942 and is one of the most used plastic materials. Its important properties include strength and flexibility, resistance to a wide range of temperatures, colourability, and excellent insulation. It is odourless and tasteless. Typical applications include bottles, packaging films, toys, pipe, housewares and a great variety of industrial products. Polyethylene can be produced in three basic forms: high, medium and low densities via low- and high-pressure polymerization of ethylene.

Polypropylene was first introduced after the Second World War. Although it is, like polyethylene, a polyolefin, polypropylene has high tensile strength, modulus of elasticity, and hardness. Unless the plastic has been impact modified, its impact properties are poorer than those of polyethylene, particularly at low temperatures. Typical uses include containers, packaging films, wire insulation, mono- and multifilament, household ware and a wide range of industrial parts. Polypropylene is produced by polymerizing propylene alone or in the presence of copolymers.

Polystyrene is another thermoplastic sold in large quantity. Its good properties include optical clarity, colourability, rigidity and ease of processing. It can be tailored for a wide variety of impact properties. Typical applications include toys, packaging films, cups, eye-glass frames, appliance housings, household ware, wall tiles, conduit and pipe. Polystyrene is produced from styrene monomer.

Polyurethane is a major material in the field of foamed plastics and is available in rigid and flexible forms. Key properties include toughness and shock 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. polyhydric alcohols.

Vinyls are another large-volume commodity type of thermoplastic first introduced in 1927. They are strong, resist abrasion, and offer 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 copylymer used. Polyvinyl chloride is produced by polymerizing vinyl chloride monomer.

### *Thermosets*

There are five major thermosetting resins used for moulding parts: alkyds, diallyl phthalate, phenolics, melamine and urea. With the exception of melamine, which is popular for moulding household dishes, thermosetting resins are mainly used for electrical and electronic applications. In terms of widest usage, the most important resins are the phenolics discussed below.

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. They are also chemically resistant and are known for their excellent insulation. Typical applications are automobile distributor heads, appliance handles and knobs, tube socket bases and washing machine agitators. Phenolic resins are also custom tailored 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.

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.

## 1.3 Agricultural uses

The use of films in agriculture is a potentially important application for plastics. Moreover, the use of plastics in agriculture helps to improve farm efficiency. Farming is particularly important in developing countries, because *(a)* it is very often the only major industry, *(b)* the major cash export is farm produce, and *(c)* production of food satisfies the needs of the population.

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

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 agriculture. Of this amount 75 million were for packaging (see 1.4) and 35 million for agricultural covering materials. Since many agricultural problems of developed countries exist in developing countries, we will examine the successful applications in the former in order to gain insight into possible applications for developing countries.

The main agricultural objective is to maximize yields at the lowest possible cost. In order to accomplish this goal, the plant environment must be appropriately balanced. This means that the environmental factors of soil, water, light, temperature, nutrients and carbon dioxide must be in balance. Plastics can help to improve this balance.

### *Reservoirs and liners*

The use of plastic liners for reservoirs has been successful in Israel and the United States. 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 0.01 to 0.02 in thick. The United States has used approximately 4 million pounds of these films for this application. Another use has been for water "traps" in arid areas. (Enjay has been promoting butyl rubber for this purpose.) The polyethylene used is, of course, cheaper than PVC, and has sometimes been found unsatisfactory. The polyethylene formulation requires a carbon black content.

For large areas, such as ponds, any sheet widths are too narrow; the desired size must, therefore, be built up from sections sealed together. This requires a certain amount of skilled labour.

Despite the various problems, 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 to neighbouring lands, e.g. Africa.

*Soil modifiers*

Polyethylene sheet, 0.00075 in thick, 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 could siphon away the "off-grade" film manufactured for more demanding applications.

*Animal shelters*

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

*Tunnels and greenhouses*

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

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 worked out a system ("tunnel Nantais") in which a continuous sheet is extended over wire wickets. This system has been also successfully implemented in Israel. For example, at Bet Dagon, tomatoes and strawberries have yielded earlier and better crops. The Israel Ministry of Agriculture has recommended the full-scale usage of tunnel row coverings. A major drawback is the reduction of usable soil when these tunnels are installed (as a result of the space between tunnels). Japan is the largest advocate of these tunnels, employing primarily PVC; the use of polyethylene predominates in France, Italy and the United States.

Greenhouses are used in high latitudes. The development of plastic greenhouses is possible in latitudes below 48°. At latitudes higher than 48°, glass is used because of the low intensity of light. At latitudes below 35°, crops can be grown without shelters.

In Italy and the United States, greenhouse frames are built by the growers. Californian greenhouses serve their purpose as plastic-covered shelters against winds and heavy rain. In other areas, plastic greenhouses are renewed each year and equipped with heating, ventilation and irrigation. In southern Italy they cost $0.20

to 1.40 per square metre. At this cost, glass cannot compete, since heated and ventilated glass greenhouses cost $15 to 25 per square metre depending on the design.

When polyethylene is used in greenhouses, double layers are common. Polyvinyl chloride reinforced with nylon net coating has lasted up to three years. Such films are available from Sfat and Griltex. Péchiney Progil produces a PVC film called "wave lock" which is also suitable for this purpose. Table 1 summarizes the types of film used in developed countries.

TABLE 1. DISTRIBUTION OF FILM BY TYPE FOR PLASTIC GREENHOUSES IN FOUR COUNTRIES

*(Per cent)*

| *Type of film* | *France* | *Italy* | *USA* | *USSR* |
|---|---|---|---|---|
| Polyethylene | 45 | 86 | 90 | 100 |
| Polyester } Rigid PVC } | 10 | 7 | 10 | |
| Reinforced PVC | 45 | | | |
| Plasticized PVC | | 7 | | |
| Nylon | | | | Some |

*Source:* Buclon, F.(1966), Proceedings of the Seventh National Agricultural Plastics Conference, University of Kentucky, USA.

Recently a new type of greenhouse has been developed by Austrian engineers, a high-rise structure of steel, glass and polyester film. A continuous escalator carries the seedlings through a routine of sprays and nutrients in a controlled climate. For the last four years, Austria, Canada, the Federal Republic of Germany, Norway, Sweden and Switzerland, have experimented with this system. The firm responsible for the development is the Ruthner Company, Vienna, Austria.

### *Mulch*

Mulch reduces moisture evaporation from the soil, increases soil temperature, controls weeds, accelerates plant maturity and reduces nutrient leaching. Straw is still used for this purpose, but experience in the United States has shown that black polyethylene film mulch has reduced disease and promoted growth.

Most of the cost of laying plastic film mulch is in the raw material rather than the labour. Labour costs are small because of the reduction in weeding and hoeing. Special tractor attachments for laying down the mulch have been developed by both Union Carbide and Gulf Oil (formerly Spencer Chemical). Bakelite Ltd will demonstrate to farmers the necessary techniques involved. Plastic mulch is being used successfully in Israel. F. Buclon estimates that the cost of the mulch ranges from $80 to $120 per acre (1 acre = 0.405 hectare), but this seemingly high cost is compensated by greater yields and higher profits for the farmer. The most common material is grey or black polyethylene film, 0.03–0.05 mm thick. The quality required of the film is not high, and, therefore, it is an ideal product for a developing country oriented towards agriculture.

### *Silage covers*

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, reducing the possibility of fermentation spoilage. Silage bags are also used on smaller farms.

### *Miscellaneous applications*

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

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

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

### *Sources of additional information*

Because plastics help reduce labour costs or increase crop yields, the use of plastics in agriculture has been developing rapidly. 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 Pinel
Paris 13e, France

Dr. Enrico
Soc. Montecatini
Milan, Italy

Péchiney-Saint-Gobain
Verrières-le-Buisson, France

Instituto Nazionale Studi Industrializzazione Agricultura
Milan, Italy

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

Israel Ministry of Agriculture
Tel Aviv, Israel

## 1.4 Packaging materials

Packaging is considered to be one of the largest markets for 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 packaging industry in the United States in 1965. This figure 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 because rigid plastic containers will be increasingly used.

TABLE 2. DISTRIBUTION OF PLASTICS ON THE PACKAGING MARKET IN THE UNITED STATES OF AMERICA, 1967 AND 1975

*(Per cent of total sales)*

| *Type of plastics* | *1967* | *1975 (estimated)* |
|---|---|---|
| Containers | 30 | 35 |
| Films | 45 | 40 |
| Closures | 6 | 5 |
| Coatings | 17 | 16 |
| Foams | 2 | 4 |

The plastic raw materials that predominate in the fabricated products area are polyethylene, polypropylene, polystyrene, polyvinyl chloride, cellophane and Saran. Combined, these materials 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 special engineering materials will be of importance in this field. (Cellophane is based on a natural product from cellulose, and is in the strictest sense of the word not a plastic; nevertheless, most discussions on this subject include cellophane as a plastic.)

### *Technical and marketing trends*

In the more developed countries 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 occur both in techniques and in marketing.

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.

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.

The marketing trend of mass merchandising, e.g. supermarkets, until recently limited to North America, is taking hold in many other cultures. Promotion through various media, such as television, is having a marked effect on the use of all types of packaging materials. Automatic vending is already important and its popularity continues to grow as a means of selling.

The following sections discuss various major packaging applications and assess the likelihood of establishing profitable fabrication enterprises with respect to these markets in developing countries.

## *Films for food packaging*

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

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

An examination of this 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 local production of the particular product. Each of the above product-packaging opportunities will be discussed in turn, with emphasis on those considered feasible in developing countries.

### *Confectionery*

In 1965 the market for confectionery in the United States was approximately $2,000 million, representing 4,000 million pounds of various products. The wrapping materials are generally custom-made 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 sweets. When films are used for wrapping sweets, many types of equipment and packaging methods are employed, for example, overwrap, direct wrap, form-fill-seal pouches, strip packaging and vacuum packaging.

The properties of polyethylene and polypropylene films are suitable for film overwraps. The trend has been towards the use of stiffer films (0.928–0.935 density) in order to achieve cellophane-like handling on packaging equipment. The major films used for all types of confectionery, 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 (Horsham, Pennsylvania and Green Bay, Wisconsin).

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

*Baked goods*

Baked goods are packaged in order to prolong the freshness of the product and to keep it clean. 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. United States Industrial Chemicals (USIC) and Mobil Chemical (Kordite) have also been successful in promoting the stronger and clearer polypropylene films for bread wrapping. The non-plastic packaging material suffering the most from this transition has been waxed paper.

Bags are convenient for housewives because they can be opened and re-closed, they prolong the freshness of the product and they can be re-used. Machinery capable of automatically forming the bag, loading it and twist-clip closing it is now available.

As the plastic bread-wrap market was geared to cellophane, the polyolefin film suppliers went to great expense in persuading bakeries to use the limper polyolefins. In order to use polyolefins, cellophane equipment had to be modified at additional expense. A new bakery beginning today to wrap its product in plastic would not encounter this problem. The bakery can purchase the proper equipment from Hayssen and Adams Powel Equipment (Gateshead, England).

The least expensive packaging method for a bakery would be the use of plain or printed polyolefin bags. It is most important in all countries to create or continue the tradition of purchasing baked goods under sanitary conditions. This requires government co-operation and encouragement through mass media advertising.

*Fresh produce*

Low-density polyethylene film is widely and increasingly used for prepackaging fresh produce in the United States. Approximately 65 per cent of the produce is prepackaged by the distributors. This figure should increase to 75 per cent by 1975. Of all the products so packaged, carrots are the most popular prepackaged items (95 per cent by weight of all carrots). Tomatoes are also prepackaged (75 per cent using to a great extent film and tray combinations). Apples, onions, citrus fruits, lettuce and potatoes are also prepackaged. Bags made of film 0.02 to 0.05 mm thick are most often used.

The key to success in this market depends on the type of distribution methods used for the produce. Central terminals or grower-packaging operations easily lend themselves to prepackaging. Primitive marketing conditions do not. Consumer acceptance also determines the choice of packaging method. A plain or printed bag would often suffice. Relatively low investments in machinery are required once an adequate internal or external film supply is established.

*Meat, poultry and fish*

Both bags and overwrap 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 board (paper, foamed polystyrene or transparent polystyrene) and overwrapped, or the meat is simply overwrapped with a film. In order to ensure that the meat is properly wrapped, the film must be:

*(a)* Tear- and puncture-resistant
*(b)* Balanced in moisture- and oxygen-transmission
*(c)* Economical
*(d)* Heat-sealable
*(e)* Transparent, glossy and appetizing in appearance

Cellophane is the dominant film for wrapping fresh meat, because it has the best balance of these critical properties. Improvements in cellophane have been made by coating it with either nitrocellulose or low-density polyethylene. Cellophane films are now available that have been custom-designed for particular meat packaging problems.

The packaging market has recently experienced a heavy demand for PVC because of its fine balance of properties. Polyvinyl chloride is more flexible than cellophane, costs less, and has important shrink characteristics. It is predicted that by 1975, PVC film will predominate in the meat packaging industry, followed by cellophane and low-density polyethylene film. In addition, polystyrene trays will be extremely important when used in combination with films. This advance in the demand for PVC film will be at the expense of paper and board trays.

Processed meats, e.g. bacon, salami, frankfurters, and bologna sausage, require a different set of film properties:

*(a)* Low moisture transmission
*(b)* Low oxygen transmission
*(c)* Heat sealability
*(d)* Gloss and transparency
*(e)* Abrasion resistance
*(f)* Thermoformability
*(g)* Grease-proofness
*(h)* Flexibility at low temperatures
*(i)* Machinability

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 $1,000 for manual types or $35,000 to $45,000 for high-volume fully automatic designs.

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 cellophane overwrap.

Cryovac L, developed by W. R. Grace (Cryovac Division), is an irradiated polyethylene film with shrink properties. This film in bag form is used for frozen poultry processing. The bird is stuffed into 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.

The 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 main films used.

As food packaging and marketing usually require a rather advanced stage of development and a general 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 a country with relatively large meat packaging plants, e.g. Argentina, the possibilities for using plastics should be investigated.

*Dry foods*

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.

In the United States, where climate conditions are more varied and less severe than in many of the developing countries, dry foods require packaging materials which protect from dirt and moisture. Two thousand million units a year of several different types of sugar (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 are to protect the contents, to carry an advertising message and establish brand identity.

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 9 million pounds of polyethylene film were manufactured, most of it for bags. The bags were used for packaging a wide assortment of bazaar items. Paper had been previously used, but the Government decided to discourage this practice for health reasons. In addition, polyethylene bags are less expensive than paper bags.

*Frozen foods*

The number and types of foods that can be frozen while still fresh 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, offer an accepted mode of packaging, although the major packaging material, current and future, is the plastic-coated or wax-coated box.

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 because of the many problems involved–cost, sealing, and the need for specialized equipment for filling and sealing.

Polyester pouches are used to package the premium-priced boil-in-bag foods. The United States frozen food market consumes only 10 million pounds of polyester film for this use.

The area of frozen foods is a difficult field to recommend for plastics fabrication. Where a market exists for frozen foods (i.e. where refrigerators with deep-freeze compartments are available), polyethylene bags could be justified because of the low fabrication investment cost. This factor would have to be weighed against the total output of frozen foods. It is unlikely that any sizable immediate demand for frozen food packaging will develop in Asia or Africa.

*Films for non-food packaging*

The following discussion highlights 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*

In 1960 the all-plastic heavy-duty sack was introduced on the American market. The producers of these bags (e.g. Bemis, Union Carbide, Gulf Oil) have since 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 moisture protection afforded by polyethylene film or coating or asphalt laminate. The 50-pound plastic bag is available in thicknesses of 0.005 to 0.008 inch. From the very beginning, plastic sacks presented problems. In addition to high cost, there were also difficulties in filling the sacks and avoiding tears. Most problems 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 such equipment are Doughboy Industries (New Richmond, Wisconsin), Wiedmann (Stuttgart, Federal Republic of Germany) and Windmoller and Holscher (Westphalia, Federal Republic of Germany).

Low-density polyethylene is used for making the bags, although recently blends of high and low-density resins are becoming more popular. Polyethylene appears to offer a better balance of properties than plasticized PVC.

Jute or burlap bags are used for many agricultural or chemical products, in particular peat moss. Carbon black, produced in the countries of the Latin American Free Trade Association (LAFTA), pigments, cements, explosives, and super-phosphates can all be packed in plastic sacks. The major obstacle may well be the cost of replacing or modifying the existing filling equipment. Nevertheless, the possibility merits consideration and evaluation. Those interested in information concerning the applications for plastic sacks are urged to contact Fisons Fertilizer Ltd (London, England). This company packages most of its fertilizer in sacks produced by British Visqueen. Imperial Chemical Industries (ICI) recommends that these bags be opened by slitting, for use later around the farm.

Several examples of potential uses for fertilizer bags should be cited with special reference to the countries of the Economic Commission for Asia and the Far East (ECAFE). According to a recent report on the ECAFE countries, "More emphasis has been laid on the production of fertilizers to increase the output of food and industrial crops for domestic requirements as well as for export purposes".[2] Five

[2] United Nations (1965), ***Industrial Development in Asia and the Far East***, New York, p.24. (Sales No.: 65.II.F.16)

countries in the region produce fertilizers China (Taiwan), India, the Republic of Korea, Pakistan and the Philippines. The production in 1965/1966 from these five countries totalled 357,000 metric tons. The volume of fertilizer domestically produced and the number of countries producing in the ECAFE region should increase. South America (in particular Chile) produced 340,000 tons and Africa (the United Arab Republic in particular) 185,000 tons in the same period. It can be concluded, therefore, that there are substantial opportunities for the use of plastic fertilizer bags. Bags for this purpose are already being produced in China (Taiwan). The other ECAFE countries are using polyethylene-lined jute bags. Imperial Chemical Industries had plans to manufacture fertilizer in Malaysia, a country with opportunity for local extrusion and bag fabrication.

*Textiles*

The term "textiles" usually refers to soft goods, e.g. shirts, undergarments and linens. Bags and overwrap films are used to package textiles. Clarity and gloss are extremely important film requirements. The United States market favours low-density polyethylene film and more recently cast polypropylene. A new trend, particularly evident in the packaging of sheets and towels, is towards the use of shrink films. This form of packaging is popular because of the resulting tight seal and clarity.

As the investment needed for the extrusion of polyethylene film is relatively low, the investors in countries that manufacture and market textiles might be induced to survey these packaging possibilities.

*Strapping*

Plastic strapping is a growing business in the American plastics market. The sale of non-metallic strapping in the United States is currently $3.5 million out of a total strapping market of $190 million. It is estimated that by 1972, the sale of non-metallics will grow to $33 million. Du Pont manufactures nylon strapping for distribution; however, the material which will predominate in future markets will be polypropylene because of its lower cost. Food Machinery and Chemicals (FMC) is a principle producer and distributor of types of polypropylene. The major United States steel strapping producers recognize the marketing opportunity for polypropylene, and most have begun producing it. The cost of resin is $0.22 per pound. Currently American polypropylene strapping sells for $1.05 per pound, which should decline to $0.85 0.90 per pound by 1972. There is good value-added opportunity in fabricating this product and many end-use situations can be hypothesized. For example, plastic strapping could be used by cotton producers in any developing country that produces and exports textile products, or it could be used for the packing and shipping of lumber. The key to success is the ability to offer users a complete system. Strapping, whether it is metallic or non-metallic, requires a device for sealing the ends together. Strapping suppliers generally design and offer such sealing devices; it seems likely that a fabricator or distributor of non-metallic strapping in a developing country would have to do the same. The Japanese are involved to a great extent in manufacturing and distributing polypropylene strapping throughout the world.

## 1.5 Containers

The use of blow-moulding technology with low-cost raw materials (polyethylenes, polystyrene, PVC and polypropylene) has resulted in a yearly demand for over 3,000 million plastic containers in the United States. In spite of this impressive growth over a short period of time, only a fraction of the potential market, still dominated by glass, has been penetrated.

Two important trends are taking place in this market and both are evident in the United States and Europe:

*(a)* Development of high-speed highly automated blow-moulding machines for consumer goods;

*(b)* Tailor-made design and installation of machines geared for in-plant captive blow moulding by the packager.

On the American market, the production of plastic bottles is dominated by the packaging manufacturers who have moved into plastics (Owens-Illinois, American Can, Continental Can); by resin suppliers who have moved into containers (Union Carbide, Monsanto, Rexall); and by smaller regional suppliers of custom-built containers. The major suppliers of containers exist on extensive contracts with large suppliers of household products, such as bleach, detergents, liquid starch etc. A reversed trend towards the use of blow moulding by the household product manufacturer has not yet taken place. (There are notable exceptions, for example, Purex, 8 per cent of which is owned by Phillips Petroleum.) The reluctance to take this important step is motivated by sharp competition among the blow moulders, a fact that results in severe price concessions to major detergent producers. In order to avoid undue pressure, the bottle manufacturer must therefore be assured of competitive resin supplies. As blow moulding 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 the market as possible. It becomes apparent that in order to be successful at blow moulding for packaging applications, a firm must either be able to obtain resin at minimum cost or possess a secure outlet for his bottles. Firms such as Owens-Illinois are often able to do both. (Owens-Illinois and U.S. Industrial Chemicals have a joint polyethylene venture. Owens-Illinois is one of the largest US suppliers of glass containers.)

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

Special problems will always exist. For example, in Israel, the cash deposits on bottles 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.

*Raw materials for blow moulding*

Polyvinyl chloride has been developed to a large degree in Europe, whereas high-density polyethylene is the preferred material for blow moulding in the United States. In France, Lesieur & Fils (Paris and Le Havre) have developed PVC bottles for salad oil using single parison, six-station equipment. The Marrick 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 Marrick multiple-station machine. Kautex Werke (Hargelar-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 from overheating.

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

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

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

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

*Household chemicals*

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 US market consumed close to 200 million pounds of high-density polyethylene for the bleach and liquid detergent market combined. Polyethylene repiaced glass as a container for bleach, and replaced metal cans for containing 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 inevitable in packaging.) Stress-cracking problems have been overcome and it is doubtful whether any other plastic will replace high-density polyethylene. However, it is expected that clear PVC will also make progress in the high-duty detergent field.

Blown 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. Imperial Chemical Industries 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 scouring powder. Kiwi Wax Company (Singapore) markets lavatory cleaners. These applications should motivate an investigation into the possibility of a blow-moulding facility to serve all of these producers.

*Motor oil*

The US market consumes 2,000 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 US petroleum firms (Shell, Standard Oil of California, Esso) have accomplished extensive field testing of both polypropylene and high-density polyethylene blown containers. Some packaging experts conclude that by 1975 plastic units will comprise 30 per cent of the total US motor oil market. In order to attain this goal, several obstacles must be overcome. Plastic bottles, for example, are more costly than fibre-foil cans, and leakage is still a vexing problem. These problems will probably be overcome or overlooked by fully integrated petroleum-plastics producers. (It should be noted that the plastic container for motor oil is not a bottle but rather a plastic can with metal ends. The container for outboard engine motor oil however is a bottle.)

A developing country without oil refineries and filling lines could consider importing its motor oil in bulk, so as to fill the containers locally. Polyethylene and polypropylene containers could be by-passed. For example, Paz Oil Company Ltd (Haifa, Israel) considered a flexible film oil container, tubular or bag, made from rigid PVC, since PVC is easier to print and is more oil resistant. Shell Oil uses several million oil cans annually in Malaysia, and Mobil may also represent a potential customer for a blow-moulding process.

*Dairy products*

One of the most exciting crusades taking place in the US plastics market is being waged against paper and glass containers for a share of the milk packaging market. Developments have been slow but steady. Part of the delay stems from higher costs sometimes associated with the change to plastics. In addition, milk marketing is highly regulated by state and federal authorities.

With the exception of the glass gallon bottles sold in retail stores and the gallons and quarts delivered to the home, the use of paper containers has increased in the liquid milk market.

Paper containers are either sold to the dairy completely fabricated or the dairy installs rented paper-forming equipment within the plant. Using the latter option, the dairy buys plastic-coated paper blanks (flat, die cut, preprinted, polyethylene-coated) and forms the container in a line next to the milk filling apparatus. Only a dairy with the required daily output can justify this system. Information is obtainable from such firms as American Can Company (New York, New York) or Ex-Cell-O Corporation (Detroit, Michigan). Smaller dairies buy fully formed paper containers from "preformers".

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 bottles are also penetrating the market, but much more slowly because the economic considerations are not as clear cut in the dairy industry as in other industries.

The actual cost of the plastic bottle depends on the cost of resin, the efficiency of the blow-moulding, the type of equipment used, and the annual rate of production. The entire subject is highly complicated. However, a dairy desiring expert information on setting up in-plant blow-moulding processes is urged to seek the advice of any reputable resin supplier, or Uniloy Division, Hoover Ball and Bearing (Saline, Michigan). The firm has developed a custom line of blow-moulding equipment geared to in-plant production.

TABLE 3. COST AND WEIGHT OF MILK CONTAINERS IN THE UNITED STATES OF AMERICA

| *Bottle size in USA* | *Corresponding metric size ($cm^3$)* | *Cost (US dollars/thousand units)* Glass | Plastic-coated paper | Plastic | *Plastic bottle weight (grams)* |
|---|---|---|---|---|---|
| Half-pint | 227 | – | 8.60 | | |
| Pint | 455 | – | 10.80 | | |
| Quart | 910 | 45 | 15.19 | | |
| Half-gallon | 1,820 | 113–150 | 24.40–26.90 | 50–70 | 60 |
| Gallon | 3,640 | 173–226 | 48.08–51.66 | 85–105 | 100 |

In many countries, paper containers are more expensive than those made of glass. Thus, a shift directly from glass to plastics could be accomplished. Some French dairies are producing plastic no-return bottles in their plants. In Israel, T'nuva Dairies (Tel Aviv) was considering using the French one-litre plastic bottle which weighs 22 grams instead of the half-litre glass bottle weighing 400 grams. The French system (form-fill heat-seal line) is capable of handling 2,500 bottles of one litre per hour (5 to 5.5 million units annually).

Containers of the type discussed in this section are also appropriate for fruit juices, vinegar, soft drink concentrates and wine.

An interesting fabricated companion product for plastic, paper or glass bottles for the dairy is the injection or blow-moulded carrying case. The case is more durable and, over a period of years, more economical than wooden or metal wire equivalents. T'nuva (producer of more than 80 per cent of milk sold in Israel) expects to convert completely to plastic cases. In Haifa in 1965, all the milk cases were plastic. A high-density polyethylene case is expected to last ten years. Information on cases can be sought from Mauser Plastik KG (Bammental, Federal Republic of Germany), Phillips Petroleum, or Union Carbide. It should also be pointed out that a single-celled case (no partitions) can be used as a container for carrying farm produce during the harvest.

Thermoformed or injection-moulded ice cream and yogurt cups are additional practical applications within the dairy industry. T'nuva was planning to injection-mould clear polystyrene cups as a replacement for glass yogurt bottles. The company was also considering in-plant thermoforming operations. Also in Israel, the container manufacturer, Palestine Can Company (B'nei B'rak), is entering into the production of plastic containers in addition to their existing product.

In ECAFE countries, there are potential applications for thermoformed polystyrene cups in ice cream vending. Government promotional support is probably necessary in order to encourage sanitary conditions.

## 1.6 Industrial products

The establishment of plastics fabrication businesses to serve industrial markets in developing countries is perhaps the most challenging problem discussed thus far in this paper. ("Industrial markets" is a broadly used term in the plastics industry, which can mean different things to different people. For this discussion, it is defined as those markets requiring highly engineered components for fabrication into final products.)

Fully industrialized countries use plastics for a host of highly complex products, such as appliance parts, automotive parts, hardware items, housings, gears, bushings etc. This pattern is not found in developing countries. The engineering production in a country is to a great extent a reflection of its level of industrialization. The history of industrialization in developed countries shows, of course, the initial utilization of natural (extracted) raw materials, e.g. steel, lead, zinc and copper. With the advent of synthetic products (plastics, fibres), the patterns of growth of raw material utilization have shifted markedly towards 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 unproven products. However, plastics have continued to make enormous strides in replacing metals in a wide spectrum of applications. Evidence of this is the increase of plastics consumption for each automobile produced in the United States from 35 pounds in 1965 to an estimated 100 pounds in 1970. Much of this expansion has been and will be at the direct expense of metals.

It would be possible in developing countries to by-pass the use of metals in favour of plastics for many industrial parts. This is possible because of the absence of the frequently ingrained conservatism of design engineers raised in the "school of metals utilization". Thus, emerging industrialization could actually favour the utilization of plastics parts for demanding applications.

Table 4 provides an interesting insight into this possibility. Although it appears as if *per capita* consumption correlates well with industrialization, it should be noted

TABLE 4. WORLD CONSUMPTION OF LEAD AND ZINC, 1964

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

*Source:* Zinc Development Association, London, England.

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

The production of castings 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.

The potential industrial growth in developing countries is great, as shown 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 THE ECAFE REGION AND THE WORLD, 1953 AND 1963

*(Index numbers, 1958 = 100)*

| | *1953* | *1963* |
|---|---|---|
| ECAFE region excluding Australia, China (mainland), Japan, Mongolia, New Zealand, Western Samoa | 59 | 155 |
| World excluding Albania, China (mainland), Mongolia, North Korea, North Viet-Nam | 78 | 144 |

*Source:* United Nations (1965) E/CN.11/710, *Industrial Development in Asia and the Far East*, New York, p.2. (Sales No.: 65.II.F.16)

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 its industrial output by 80 per cent.

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

### *Appliances*

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

TABLE 6. CONSUMPTION OF SYNTHETIC RESINS IN THE APPLIANCE INDUSTRY IN THE UNITED STATES OF AMERICA, 1964

*(In millions of pounds)*

| | |
|---|---|
| Impact styrene | 165 |
| Phenolics | 60 |
| Acrylonitrile-butadiene-styrene (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 by A. W. Karnath, Arthur D. Little, Inc., Cambridge, Massachusetts, United States.

It can be concluded from table 6 that 70 per cent of the plastics used in appliances cost less than $0.30 per pound, 2 per cent between $0.30 and $0.50 and 10 per cent above $0.50 per pound. For those materials US appliance industry plastics experts concluded that in 1964 the industry paid an average price of $0.33 per pound for plastics. (The current figure 1968 would be slightly lower.)

The applications for plastics include refrigerator door and box liners, housings for electric knives, clocks, sharpeners, transistor radios, mixers, radio and television consoles. The resins used generally fall into the category of engineering plastics. The processing of these resins requires more skill than general-purpose polystyrene or the polyolefins. Nevertheless, assuming that processing equipment is suitable, the techniques are obtainable from the resin suppliers.

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

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

Carrier International (Malaya) has produced air conditioners near Kuala Lumpur. China (Taiwan) has four refrigerator plants and the Philippines seven. The Chinese plants produce 50,000 units annually. These facts illustrate the point that manufacture of plastic components should be investigated in all countries.

*Tools and hardware*

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 the parts that can be made either from thermosets or from thermoplastics. Of recent interest in the United States has been the development of moulded thermoplastic housings for hand-operated power tools. The US market for the sale of this type of product is $280 million per year. Approximately $10 million of die castings are purchased for these tools. Because of favourable economics (see table 7 below), 75 per cent of the housings made for these tools are moulded from thermoplastics.

TABLE 7. COMPARISON OF COST OF DRILL HOUSINGS IN THE UNITED STATES OF AMERICA

*(In US dollars)*

| *Item* | *Painted aluminium* | | *Plastic (ABS)* |
|---|---|---|---|
| Gear case | 0.1518 | | 0.1518 |
| Field case | 0.3105 | | 0.3105 |
| Gear case cover | 0.1009 | | 0.1009 |
| Switch support | 0.1500 | | 0.0601 |
| Switch handle | 0.2400 | | 0.1146 |
| Total | 0.95 | saving of 0.21 | 0.74 |
| Frame | 0.428 | | |
| Motor housing and handle | 0.65 to 0.70 | (paint and buff) | |
| Switch support | 0.14 to 0.18 | (paint and buff) | 0.63 |
| | 1.31 | saving of 0.63 | 0.68 |

*Source:* Compiled from figures by G. W. McCarty, Vice-President of Research, Black and Decker Manufacturing Company, Towson, Maryland, USA.

Another motivation for the employment of moulded plastic housings is the greater safety of the insulation offered by plastics. These tools and other items, such as flashlight cases, electric torch cases, battery cases, are possible products for a developing country or region. In 1962, Hong Kong exported $17.5 million worth of such products, many of which are candidates for plastic housings.

### *Automotive parts*

No other end-use market for plastics has generated the excitement and growth that the automotive uses for plastics have created. The fact that the US automotive industry has been steadily increasing its consumption of all types of materials was mentioned earlier. During the 1966 automotive model year, Detroit, the automotive centre of the USA, used some 35 pounds of plastics per car. Most experts agree that this consumption will increase to 100 pounds by 1970.

The number of automotive parts made from plastics is legion. Automobiles use thermoset and thermoplastic resins and sheet (vinyl upholstery). The list below indicates some of the major applications for plastic in the automotive industries of the United States and other countries and the materials most commonly used.

Calendered upholstery (PVC)
Radiator fan (nylon)
Mudguard extensions (acetal)
Fuel tank (polyethylene)
Turn signal housing (acetal)
Consoles (ABS)
Arm rests (ABS)
Kick panels (polyethylene)
Wheel covers (ABS)
Back-up light lenses (acrylic)
Crash padding (urethane foam)
Front grill (ABS)
Steering wheels (cellulose propionate and acetate)
Wire insulation (nylon, PVC)
Distributor head (phenolic)
Connectors (diallyl phthalate)

It should be noted that many of the above parts were once made from steel (radiator fan) or zinc die castings (mudguard extension).

The evolution from predominant use of metal parts to selective replacement by various plastics did not occur overnight. In order to reach this point, the automotive industry has had to experiment with the new plastic materials, and the resin suppliers have spent 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. This kind of development is therefore beyond the present financial and technical ability of the average custom moulder in developing countries. 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 manufacturing plastic parts. Several other developing countries also produce small quantities of vehicles; however, large plastic potential is not foreseen because the small volume of expensive parts does not allow the tool to be amortized. Calendering operations should be investigated for vinyl upholstery as well as for urethane foam for crash pads and seat stuffing.

## 1.7 Construction

The consumption of plastics for construction continues to grow in the industrialized countries. It is likely that the developing countries will be able to make use of the vast amount of performance and market data that have been collected by the numerous fabricators and users who have used plastics in construction. The

TABLE 8. WORLD PRODUCTION AND CONSTRUCTION OF PLASTICS IN CONSTRUCTION, 1964

*(Million pounds)*

| *Country* | *Total production* | *Consumption in construction* |
|---|---|---|
| USA | 9,700 | 2,400 |
| Germany (Fed. Rep. of) | 3,700 | 825 |
| 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 (Argentina, Australia, Belgium, Czechoslovakia, India, Poland) | 750 | 180 |
| Total | 23,700 | 5,400 |

well-established position of plastics in construction can be appreciated from the data in table 8 which indicate that plastics in construction accounted in 1964 for 5,400 million of the 23,700 million pounds of plastics produced in the world.

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 of plastics by 1970, which is more than double the usage in 1964.

The impressive data on plastics in construction are only meaningful if a developing country can pick out those applications which appear to fit its current and future situation. It has been suggested that plastics can be used in self-help housing in combination with indigenous materials. This would allow unskilled labourers to erect homes with a minimum of supervision. For example, during 1963 over 50 homes were built in the Caribbean from plastic structural components. While analysts point out that the population grows in developing countries, therefore assuring 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 variations 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, could increase the usage of plastics considerably. In particular, PVC polymer production is likely to benefit greatly, since it is used in many applications consuming large volumes of plastics.

Some of the developments of 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 into 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 |
|---|---|
| Glazing, skylights | Acr., FRP, PVC |
| Building panels, wall or floor coverings | PVC |
| Paints, coatings | Acr., U & M, Ph., PVA, PS, SB, PVC, Alkyl |
| Plywood, boards | U & M, Ph. |
| Wire coating | LDPE, HDPE, PVC |
| Electrical devices | U & M, Ph. |
| Lighting fixtures | Acr., U & M, PS, PVC |
| Decorative laminates | U & M, Ph. |
| Wall tile | PS |
| Plumbing fixtures | ABS, Ph., PVC, PS |
| Moisture, insulation barriers | LDPE, PVC, PS |
| Pipe | PVC, PS, HDPE, LDPE |

**Key:**

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

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

| Process | Typical products |
|---|---|
| Blow moulding | Negligible (bottle shapes) |
| Calendering | Floor tile, wall coverings, other home decorating products |
| Casting | Acrylic sheet |
| Compression moulding | Electrical fixtures |

| | |
|---|---|
| Extrusion | Pipe, panels, wire coating, wall coverings, moisture and insulation barriers, siding |
| Injection moulding | Pipe fittings, lighting fixtures, wall tile, plumbing fixtures |
| Laminating | Decorative laminates, plywood |

*Plastic pipe*

Plastic pipe has become an important replacement of traditional piping materials such as steel, asbestos, cement and copper throughout the world. Light weight, low cost, excellent chemical resistance, ease of fabrication and low investment compared with 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.

In Israel, irrigation pipes of polyethylene and PVC have been replacing aluminium. Smaller pipe diameters can be used and the pipe is easily handled and transported from place to place. South-East Asia has used plastic pipe extensively. Thailand installed nearly 1 million pounds of pipes (imported and domestic) in 1966 for electrical conduit and water transportation. Malaysia imported more than 0.2 million pounds of pipe (mainly PVC) for water pipe 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 user of plastic pipe, using 5 to 6 million pounds in 1965 for several applications. Pakistan increased its usage substantially in 1966, largely because of an increased demand for water and agricultural piping. An analysis of other developed and developing countries shows the same increasing reliance on plastic pipe.

While some countries use several types of thermoplastics (polyethylene, PVC, ABS and polypropylene), the more recent users of plastic pipe tend to favour PVC or polyethylene. Raw materials are either readily available for extrusion or the pipe can be imported. Polyethylene pipe is noted for its low cost, light weight, good low-temperature impact strength, flexibility, and chemical resistance. Its main drawbacks are relatively low strength and structural rigidity, low softening point and low resistance to liquid hydrocarbons. Improved, denser materials have greatly improved the thermal and mechanical properties of polyethylene pipe. The flexibility of polyethylene pipe, which permits lengths of 100–500 feet or longer, is a major advantage because few joints are needed.

Polyvinyl chloride (unplasticized) pipe is rigid, but with excellent chemical resistance and good weathering properties, and does not support combustion. The latter property is particularly important for use in construction. 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-colecular weight polyethylene pipe is made in the United States on special equipment from Allied Chemical and Phillips Petroleum who supply also the resin. The Plastics Pipe Institute of the Society of the Plastics Industry (SPI) 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.

Techniques have been developed in several countries for using mole ploughs to dig and lay up to 75 metres per minute of coiled polyethylene pipe (coils of 150 to 200 metres) in a trench which is also covered. Other countries favour above-ground installation.

Techniques for extruding pipe are readily available from most equipment producers. The production of fittings requires considerably higher investment, volume of sales and technology. Hence, some countries may produce pipe but import fittings. Care must be taken because 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. for conduit) to reduce costs even more.

## *Windows and doors*

### *Windows*

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 sheets have been used mainly as replacements for glass, although increased usage is taking place in new construction. Both materials offer several advantages over glass: light weight, ease of fabrication and less breakage.

### *Doors and window frames*

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) have made important gains against aluminium. The use in structural ("prime") building has been limited because of building by-laws (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 30–35 plies of calendered vinyl sheet. Combinations of different plastics are also being introduced in several countries. For example, one United States firm produced a door based on a 3-pound foamed polystyrene core and several pounds of flexible and rigid vinyl.

## *Floor tile*

Floor tiles made from PVC homopolymer and copolymer, fillers (calcium carbonate, asbestos), plasticizers, stabilizers and pigments are finding gradual acceptance in developing countries. Some acceptance has even been received in Mediterranean countries where marble or concrete tiles are readily available.

Several ECAFE firms are planning to install calendering equipment with capacities in the range of 1 to 3 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 an appealing surface to be fixed over low-cost bases that are made on calenders or double extruders.

Techniques for making floor tiles are available from many countries. A number of companies will provide a complete "package", including plant design, start-up and information, and will advise on resins and plasticizers. Norsk Spraenstofindustri A/S (Oslo, Norway) has worked with several ECAFE countries interested in producing floor tile.

Several firms in Israel make floor tile by different processes. In 1965 five firms produced 350 to 400 tons of tile, of which 60 per cent was calendered, 25 per cent coated and 15 per cent extruded.

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*

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.

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 units.

### *Electrical fixtures*

Compression-moulded phenolics have been used for over fifty years in electrical boxes, covers, sockets and switches, industrial switchgear and wiring devices. Techniques are readily available for making these components.

### *Lighting fixtures*

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, methyl methacrylate styrene copolymers, and selected thermosets (e.g. polyesters). In outdoor applications, acrylics, cellulosics and polycarbonates have been preferred because of their superior properties.

Of all the materials in lighting fixtures in the United States polystyrene is the most used because 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 SPI in the United States can provide data and technical information on this market.

Fibre-glass reinforced polyester ceilings are also found in the United States.

## *Panels and sandwiches*

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

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) and a paper-polystyrene foam-paper combination sold in the United States.

Honeycombs are an important core material. They are a fabricated cellular structure made from aluminium, stainless steel, reinforced plastics and paper. In this group, kraft paper, either plain or impregnated with phenolic resin, is used extensively. The Hexcel Corporation (Berkeley, California) has made finished sandwich constructions from three rolls of thin 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 Koppers Company (Pittsburgh, Pennsylvania).

*Insulation*

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

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 that can be foamed or sprayed in place. In 1967 about 4 million square feet of polystyrene foam and 8 million square feet of polyurethane foam were used in wall insulation in the United States. Other thermal applications include pipe coverings, backer board[3] for metal siding, and thin shell concrete.

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. In some types of construction, expandable polystyrene can be foamed directly between sandwich facings. Polystyrene foam has also been used as a filler in concrete to reduce the weight of the structure (reducing size and cost of other supporting units) and to provide insulation against sound and heat.

Polyurethane like polystyrene, is 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 the United States or the Fédération française d'instituts techniques du pétrole (FFITP).

## 1.8 Consumer products

Consumer plastic products are usually the first to be produced by fabricators of plastics. International trade exhibitions, 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 products that

[3] 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. Beadboard is made from polystyrene beads containing a gaseous hydrocarbon blowing agent (e.g. pentane).

can be fabricated. This is easier said than done. However, one successful approach has been 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 because 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.

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*

Vinyl shoes and sandals are major consumer products in Asia, Central and South America. The annual consumption of PVC shoes totalled several million pounds in China (Taiwan), the Philippines and Thailand (including export). As investment and technology are relatively minimal, overcapacity 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 (the Philippines), Pei Hwa Plastics Company (Taiwan), Bata Shoe Company and Karim Rubber Company (Pakistan).

In many of the countries, low prices have forced some firms out of production. Most equipment is capable of producing 1.5 to 2.0 million shoes annually; thus a few producers can quickly produce enough to meet the demand. Shoe heels are injection moulded from high-impact polystyrene or ABS, or in special cases, from a thermoformed skin filled with rigid foam. "Breathing" uppers that look like leather are mainly PVC, but Corfam (Du Pont) has made rapid gains in the United States. Improved "breathing" PVC upper materials have been developed in several countries. "Quox" is an expanded breathing type of PVC on non-woven latex-bonded nylon fibre mat made in the United Kingdom. Mitsubishi (Japan) has also made low-cost breathing shoes and Perforating Industries (United States) perforated PVC sheet with tiny holes.

### *Artificial flowers*

The artificial flower industry accounted for nearly $40 million of goods exported from Hong Kong in 1965. Favourable labour cost and a high degree of creativity have been responsible for the leading position attained by Hong Kong. It is estimated that by 1970 over 100 million pounds of polyethylene will be used for flowers, fruits and other artificial consumer items. Major moulders of flower petals and stems include Artificial Flowers and Li and Fung Company, Ltd. The rising cost of labour is likely to release 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 in many areas demands styling, colours and quality.

### *Toys*

The toy market in most of the developed countries is huge. In the United States, for example, the wholesale value for toys was $1,300 million in 1965. There are large fabrication plants in the USA with 150 machines for moulding and extrusion, as well as small one-man operations. Hong Kong is an important exporter of toys, and in 1965, used over 50 million pounds of plastics. Polystyrene generally accounts for most of this volume (about 60 per cent) followed by polyethylene (35 per cent) and PVC. The latter is particularly good 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*

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

### *Household ware*

Household ware is among the first group of plastic products to be fabricated by a new plastics industry. There are a multitude of items in this class, rubbish buckets, 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 take on a new importance. Israel has developed a substantial doily business. In contrast to artificial flowers and toys, the household ware 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 household ware from other countries. A polyethylene baby bathtub was introduced in Argentina in the late 1950s as a replacement for styrene.

### *Furniture*

The availability of wood in many 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 USA, 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 workers 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. Skilled woodworkers are costly in many countries, but 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 are another recent product. In countries where wood is not available, plastics can play an important role in the furniture market.

*Part 2*

# PLASTICS FABRICATION AND RAW MATERIALS INTEGRATION IN DEVELOPING COUNTRIES

The diversity among the developing countries in size, physical resources and socio-economic functions makes it possible to formulate a set of approaches that will uniformly spark the growth of an integrated plastics industry. It is clear, however, that a number of related factors determine why some countries have been able to expand their plastics integration programme faster than others. Often some of these variables cannot be altered. The availability of raw materials, land, and size of population must be taken as they are. However, many other factors that affect the success of an integrated plastics industry do fall under the control of interested groups. Government import policies, acquisition of technology, local technical education, realistic planning and other factors can mean the difference between success or failure in the establishment and expansion of a plastics industry.

Even a cursory examination of the pace at which some developing countries have been able to start a fabrication industry and eventually make monomers and basic feedstocks shows several factors for success. Increased income *per capita*, growing concentration of the population in high income urban areas, new and better roads to rural areas allowing improved income distribution, installation of power complexes, realistic government policies which protect plastic fabricators and allow needed raw materials to enter, and monetary stability are some of the factors that have contributed to the healthy growth of the plastics industry in developing countries around the world.

There is often a tendency to study the needs of a country interested in plastics development without respect to the multitude of social, economic and political trends that influence what is best for the country. However, for many countries with the resources necessary for progressing from the stage of petroleum, coal or gas "in the ground" to the production of a wide spectrum of consumer and industrial products, the plastics industry is a key factor in the success of an integrated programme. The wide variety of products that can be made from an integrated petrochemical operation lends itself to substantial import substitution, important for countries lacking in capital resources and foreign exchange. Furthermore, the value of available raw materials is multiplied substantially when the materials are converted into finished or semifinished goods. The expansion of exports similarly strengthens the balance of payments position. The reasons for plastics-petrochemical integration have often been discussed. Careful understanding of the mistakes and successes of developing and developed countries in relating the importance of plastics to petrochemical development can provide a valuable guide to those in various stages of long-range planning.

## 2.1 Plastic industry in developing countries

*Economic importance of a plastics industry*

The contributions that plastics have made to the economies of developing countries around the world are well documented. While the magnitude of these contributions vary, the ends they achieve are basically the same. Products can be fabricated with processing equipment that is substantially less expensive to buy than the investments required to make the same products from traditional materials. For example, the investment, technology and labour requirements for producing plastic pipes or blow-moulded containers are far below the huge investments required to make these products either from steel or glass. Consumer and industrial plastic products that have been imported can usually be made internally and a portion of the finished products can often be exported. As the consumption of polymers for these finished goods increases, the gradual manufacture of intermediates can be planned. In short, the development of a fabricating industry is a key step towards eventual backward integration of basic feedstocks from coal, oil or gas. The successful establishment of an integrated plastics industry affects a large group of other industries over a period of time, because the feedstocks can be upgraded into fibres, fertilizers, detergents, coatings, adhesives, carbon black and so on. The continued substitution of imports in all areas helps countries lacking capital resources and foreign exchange. Expanded exports similarly strengthen the balance of trade.

During the last decade, more and more developing countries have executed long-range programmes designed to convert basic raw materials into finished plastic products. Differences in product demand, income distribution, resources, availability of labour and capital account for the variety in strategies and successes of these programmes. In almost all countries, however, a thriving plastics fabrication industry has been the catalyst for further backward integration.

As it would be difficult to analyse and evaluate the approaches taken by all developing countries, groups of selected countries from the LAFTA (Latin American Free Trade Association) and ECAFE (Economic Commission for Asia and the Far East) regions have been chosen as representative examples. The LAFTA countries chosen were: Argentina, Brazil, Chile, Colombia, Mexico, Peru, Uruguay and Venezuela, and the ECAFE countries were: China (Taiwan), Malaysia, Pakistan, the Philippines and Thailand. While statistics from several sources documenting the nature and growth of plastics industries in these countries vary considerably, the basic thinking and action that led these countries to reach their current level of production can be analysed. Their experiences may serve as an important guide for countries faced in the future with decisions concerning the development of an integrated plastics industry.

*Problems in developing a plastics industry*

Several related obstacles have retarded the growth of plastics fabrication, polymer and monomer production in various countries. Some of the most important are:

*(a)* Inadequate demand for the end-product;
*(b)* Shortage of imported or locally available raw materials;
*(c)* Government restrictions (including high duties) on imports of critical materials;
*(d)* Poor promotion of fabricated plastics.

Government restrictions have been a major problem in many countries attempting to start or to expand a plastics industry. Import restrictions and high duties have prevented moulders from acquiring the needed materials. In one country, for example, a polyethylene plant was operated only partially because of a shortage of alcohol. A vinyl film and sheet plant in another country was forced to run at low capacity because the government would not allocate foreign exchange for importing resin.

A government undoubtedly must weigh the implications of its actions on all industries with respect to the contributions of each industry to the country. Plastics cannot be evaluated without comparing them to other business segments. Many governments have realized, however, that the success of a plastics industry has a great effect on the future development of a basic chemical raw materials industry.

Many governments have helped the plastics industry to grow by linking it with the start of the petrochemicals industry. Carefully planned import programmes are often the first step. Such programmes take into account the eventual export of finished products. For example, some countries will repay part or all of the import duties on imported plastic materials that are fabricated into finished goods intended for export.

*Fabrication industry*

The plastics fabrication industries of developing countries often share several characteristics. Production tends to be dominated by a few firms located in or near the major cities. Film extruders comprise the largest portion of the industry. They print and convert film to bags to be sold to various end users. Injection moulders rely on proprietary products, usually household wares, toys and other consumer products. Custom-moulded components (e.g. appliance housings) are limited in most countries. Smaller fabrication units operate in areas outside the cities. In some countries three or four fabricators account for 80 to 90 per cent of a specific market. Many are owned in part by resin producers, or vice versa.

Extrusion, injection moulding and compression moulding represent more than 50 per cent of resin usage. Blow moulding and foam moulding are generally introduced during the later stages of growth of the industry.

A lack of good moulds, credit problems, machine overcapacity and raw material shortages are some of the problems most fabricators face at one time or another. The production of suitable moulds is expensive and technically demanding. Imports from foreign sources is one alternative. Credit squeezes are almost universal. The fabricator may be forced to wait 120 days or more to receive payment from customers, yet be required to pay resin suppliers in 90 days or less. Suitable agreements with both parties must be clearly balanced before the start of plant operations in order to prevent a cash squeeze. Overcapacity is prevalent in plastics fabrication industries throughout the world, particularly where the investment is relatively low, the product easy to make, and the market apparently large. Although there is no formula that insulates a fabricator against the intense price competition that typifies this situation, some moulders have been able to attain greater success than others by careful resin purchases, compounding of off-grade materials, and investment in somewhat more sophisticated equipment or moulds. The combination of low-cost materials and uniqueness of product has helped the growth of many fabricators operating under extremely competitive conditions. Government restrictions on imports of plastic raw materials have been alleviated in many countries by documented presentations of the benefits of a healthy plastics industry to the economy.

### *Moulds*

The shortage of skilled mould makers and designers has been a major problem for developing plastics fabrication industries. Local fabricators tend to use poor moulds, and extended delivery time often prevents competition in export markets. Poor quality and the delivery problem also decrease the chances that plastics will replace other materials in the country. As a result, firms must often import moulds from abroad. However, mould exchange firms are often difficult to deal with and the fabricator may not get what he thinks he is paying for. One LAFTA moulding operation had to wait four months for imported moulds before moulding could start.

Establishing mould-making facilities is important for the growth of a plastics fabrication industry. This is primarily an educational problem, mould makers must be carefully trained. Several developing countries have employed foreign specialists to prepare and execute such a programme. Organizations such as the BPF (British Plastics Federation) in the United Kingdom, GKV (Gesamtverband Kunststoffverarbeitende Industrie) in the Federal Republic of Germany, and SPI (Society of the Plastics Industry) in the United States of America can help locate suitable personnel. As it takes time for the first trainees to successfully complete such a programme and begin working, it may be advisable in the meantime to obtain assistance on specific products from experienced mould makers in other countries.

The combination of trained mould makers and a well-equipped mould-making shop is an important contribution to the growth of the industry. One country was able to establish mould-making facilities by inviting a foreign moulder to invest in a shop, provide information for the developing country, and manufacture moulds for his own firm.

### *Exporting to surrounding areas*

The export of fabricated plastics can often be negotiated in nearby areas, depending on trade relationships and geography. Many developing countries have found that products that cannot be sold at home can be exported to a country where differences in purchasing power or product demand provide a ready market. By taking advantage of these opportunities, economies of production can often be achieved to allow the eventual penetration of local markets.

Dodhia Plastic International Ltd, jointly owned by Good Shoes Ltd and the Phillips Petroleum Company, is an example. Good Shoes Ltd has a plastic shoe factory at Arusha, the United Republic of Tanzania, and an injection-moulding plant at Mombasa, Kenya, which turns out chairs, petrol jerrycans, refuse bins, beer and soft-drink crates. Another factory at Mombasa manufactures pipe, consumer items, printed polyethylene bags, barrels and electrical accessories.

Shoes sell well in the United Republic of Tanzania, but chairs are marketed mainly in Kenya and Zambia where restaurants and hotels can afford the high prices (approximately $6.50). On the other hand, crates for soft drinks and beer find minor acceptance in Kenya, but a satisfactory export market in Ethiopia, the Sudan and several Middle East Countries. Other products are sold in Malawi and Zambia.

Many new plastics fabricators have missed the obvious markets close to their production facilities because of their concentration on markets in major industrialized countries or because of the lack of local demand.

### *Exporting component plastic parts for packaging*

Market studies usually can determine the products that lend themselves to export. However, a hidden market for developing countries is often that of plastic components that can be used in conjunction with non-plastic exports. Packaging is a primary example. Countries exporting fruit can supply foamed polystyrene packing for fragile fruits, while formed polystyrene trays can be used for harder fruits. Foamed polystyrene can also be used for protecting sensitive instruments, appliances and other products which must be shipped long distances. Drum liners can mean important savings for products such as detergents. These opportunities are especially attractive because the fabricator does not have the expenditures of time and money in developing overseas markets. Usually the major problem is convincing the exporter that plastics can mean real savings in comparison to existing methods. Often actual testing and approval by the purchaser (importer) alone can prove the utility of plastics.

### *Research and development*

Some developing countries contend that research and development are too costly. During the early period of growth this may be true. Most fabrication operations are owned by one or several individuals who cannot justify expenditures on new product development, quality control, or process improvement. The nature of demand at the beginning may not require sophistication in any of these areas. However, as fabricators increase exports into new markets, they begin to compete with countries which have spent time and money to make their products meet market requirements. A dependence on suppliers of raw material to accomplish this work has not been an effective answer for most firms.

Where individual firms cannot meet the financial and technical requirements of a research and development programme, the government often can. A technical centre with appropriate testing equipment, laboratory facilities, pilot processing equipment, and polymer research resources (particularly in compounding) could make an important low-cost contribution to the government or participating firms. Trade associations have been successful in accomplishing these aims while still permitting the individual processor to maintain his proprietary freedom. The Plastics Pipe Institute of the SPI in the United States has made remarkable strides by pooling the individual talent of fabricators for the good of the industry.

*Education*

The education of workers, technical people and management is an integral part of maintaining competition in plastics. While the popularity of "packaged" plants reduces the initial need for intensive exposure to changes in materials, equipment, and products, it soon becomes apparent that further training is needed to keep the progressive trend from reversing in the future. Various approaches to this problem have been sought by developing countries. Assistance from the suppliers of raw material, governmental and world organizations (e.g. UNIDO), and enrolment in plastics training courses offered by several countries are some of the obvious answers. One important help is the current literature and publications on plastics. Further data on new products, materials or equipment can usually be obtained at little or no cost from the respective sources. Some of the recommended publications are:

*British Plastics* or *Plastics*, London
*International Plastics Engineering*, United Kingdom, equipment
*Japan Plastics Age*, Tokyo
*Journal of Cellular Plastics*, Stamford, Connecticut, foams
*Kunststoffe*, Munich
*Modern Packaging*, New York, packaging
*Modern Plastics*, New York
*Package Engineering*, Chicago, packaging machinery and design
*Plastics World*, Boston, largely oriented to applications
*Plastiques Bâtiment*, Paris, building
*Plastikverarbeiter*, Speyer, Germany (F.R.)
*Poliplasti* or *Materie Plastiche*, Milan
*Reinforced Plastics*, London
*SPE Journal*, Stamford, Connecticut, technical, resins, processing, other topics

Contact should be made with any of the institutions that have plastics training programmes. One organization is the Plastics Institute, which has a curriculum formulated to prepare individuals for processing and maintenance jobs in the United Kingdom. The SPE (Society of Plastic Engineers) and the SPI in the United States also have vast educational resources.

## 2.2 Plastics processing equipment

Any group organized to produce fabricated plastic products must of necessity become expert in the types, capabilities and relative economics of plastics processing equipment. Although this review is not designed to discuss in depth the mechanical side of the plastics industry, this section will briefly discuss:

*(a)* Major trends in plastics processing machinery;
*(b)* Key and reliable sources of machinery and expert advice;
*(c)* Comparative costs of various types of machines and auxiliary equipment.

The selection of machinery usually begins by deciding the type of fabricating operation desired. In the United States and throughout most other industrialized countries, plastic product fabricators often specialize in one area of fabrication, e.g.

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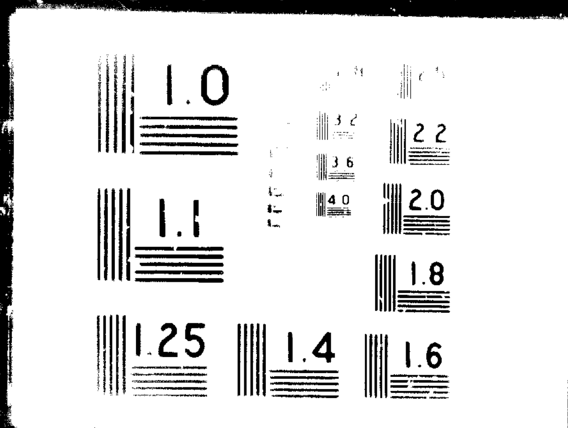

moulding or extrusion. This specialization continues with respect to thermoplastic versus thermoset plastic moulding. On the other hand, there are scores of businesses where many types of operations coexist within the same plant. For example, moulders often have thermoplastic and thermoset-moulding equipment or moulding and extrusion operations in the same factory.

Once a decision has been reached, it is usually quite easy to secure expert and reliable advice on starting work from the major resin suppliers. The advice sought can include help in choosing the correct equipment for the business sought or expected and the choice of equipment supplier. If the financial situation is viable, credit is often extended by the resin supplier on initial purchase of raw materials. The resin supplier also analyses recent equipment trends as the paragraphs below indicate.

### *Injection-moulding and extrusion machinery*

The reciprocating screw injection-moulding equipment has displaced the plunger machines. The older plunger machines meter the resin to the plasticizing cylinder by measuring a fixed volume in a special volumetric feeder. The reciprocating screw machine plasticizes the resin by the action of the screw while the screw moves backward in the cylinder. The screw then rams the material through the nozzle by moving forward. Most plunger types are now ordered in small sizes, making them impracticable for screw machines. Another trend is the increased use of larger machines. This is a result of the evolution from small plastic fabricated items to products weighing several pounds. Very often the large applications result from custom moulding of appliance, automotive and household parts.

In the extruder field, the most recent technical changes have also come about in the area of screw design, e.g. the development and use of multistage screws. An important consideration to remember in discussing extruders is the fact that optimization of product quality usually requires that the screw be custom-tailored to the kind of resin used.

### *Thermoforming equipment*

Few technical changes have recently taken place in thermoforming equipment. Most of the break-throughs in thermoforming have resulted from new kinds of mould designs.

### *Blow-moulding equipment*

Notable in the field of blow-moulding equipment is the emphasis on equipment geared to specific applications. For example, the Uniloy Division of Hoover Ball and Bearing Company has developed a successful machine for in-dairy moulding of milk bottles. The best machines on the market offer reciprocating screw parison extrusion or continuous parison extrusion operated in connection with a multiple-mould system.

### *Thermoset-moulding equipment*

The most exciting development to take place in this segment of the industry is the advance of the reciprocating screw injection machine. In plants with the necessary volume to justify the increased expense, this equipment will eventually eliminate the need for the slower compression and transfer moulding machines. In terms of price, automatic compressions machinery costs the least, reciprocating screw is medium-priced, and screw transfer is the most expensive.

*General trends*

Machinery suppliers are catering to the demand for "package" plants. This refers to the sale of an entire plant system, much the same as buying a "turn-key" resin plant from a design and engineering company. Machinery suppliers are extending their activities and services to mould procurement and the training of moulding plant operators. This evolution is a desirable opportunity for a developing country interested in setting up an operation quickly. It is also an expeditious plan because the buyer can obtain his entire plant system from one supplier.

*Major suppliers of processing equipment*

The annexes give lists of selected machinery suppliers. Prices, however, do vary greatly with time. It is also conceivable that special price concessions might be available depending on the size of the order, customer, ordering country, credit risks and so on. One of the most complete catalogues of available equipment is published by the magazine *Plastics Technology*, New York.

Annex 8 is a price list for a typical reciprocating screw injection machine manufactured by Van Dorn Plastic Machinery Company, Cleveland, Ohio, a major machinery systems supplier. The point of this inclusion is to illustrate that merely purchasing the $50,750 moulding machine does not put one in the plastics fabricating business. Considerable cost must be incurred for "optional" equipment which is very often essential.

## 2.3 End-products

***Categories***

Table 9 lists typical products made by **plastics fabricators in developing** countries categorized by end-products sector.

*Consumer products*

Housewares, toys, combs, tooth-brushes, soap dishes and a multitude of other home and personal products made from polystyrene and polyethylene make up this group. As most countries import these products, there is usually an established market that eventually reaches enough volume to justify local production.

*Packaging*

Film and bags for a wide range of products including food, textiles, fertilizers and protective wrapping are sold to meet the specific product needs of the country. For example, polyethylene wrap has been an important business for packaging bananas in several South and Central American countries, while in rubber-producing countries, it has been used for a protective cover for camelback rubber.

*Construction and industry*

Wire and cable insulation has become an important application in many developing countries with the growth of power generation.

*Agriculture*

Plastic piping and, to a lesser extent, film for water conservation and mulching have been established in many areas.

TABLE 9. PRODUCTS MADE BY PLASTICS FABRICATORS IN DEVELOPING COUNTRIES

| *Products* | *Plastics used*[a] | *Major methods of fabrication*[b] |
|---|---|---|
| Consumer goods | | |
| Household wares | PE, PS | IM, BM |
| Tableware | PE, PS | IM |
| Toys | PE, PS | IM |
| Tablecloths | PE, PVC | cal, ext |
| Curtain | PE, PVC | cal, ext |
| Jewellery | PS | IM |
| Buttons | PS | IM |
| Flowers | PE | IM |
| Soap dishes | PS | IM |
| Garden hose | PVC | ext |
| Wallets | PVC | cal |
| Lampshades | PE | ext |
| Shoes | PVC | IM |
| Tooth-brushes | PE, CA | IM |
| Packaging | | |
| Films and bags | | |
| Food | PE | ext |
| Chemicals | PE | ext |
| Textiles | PE | ext |
| Fertilizers | PE | ext |
| Industrial products | PE | ext |
| Others | | |
| Caps, closures | PE | IM |
| Bottles | PE | BM, IM |
| Cups | PS | vac form |
| Boxes | PS | IM |
| Industrial containers | PE | BM, IM |

| | | |
|---|---|---|
| Construction and industry | | |
| Pipe | PE, PVC | ext |
| Conduit | PVC | ext |
| Wire and cable insulation | PE, PVC | ext |
| Floor tile | PVC | IM, cal |
| Upholstery | PVC | cal |
| Chairs | PE | IM |
| Agricultural | | |
| Pipe | PE, PVC | ext |
| Liners-waters | PE | ext |
| Mulching film | PE | ext |

[a]CA = cellulose acetate; PE = polyethylene; PS = polystyrene; PVC = polyvinyl chloride.
[b]BM = blow moulding; cal = calendering; ext = extrusion; IM = injection moulding; Vac form = vacuum forming.

*Product demand*

It is interesting to note that the industrial sector often helps to create enough demand for plastics, thereby making production economics more attractive and permitting lower prices to be charged for consumer items. Without this influence on volume, polymer prices might remain too high during the first years of local polymer production, resulting in finished products that are priced out of the reach of a large segment of the economy. Population growth can be a misleading indicator of consumer demand because of the disparity in the distribution of income. On the other hand, when industrialization requires plastic-coated wire and cable, plastic conduit, piping and related products, the demand for polymer increases substantially without the time consuming promotional efforts needed to sell consumer items.

Another way of viewing product demand is to use three areas of plastics as a planning guide *a)* consumer items, *b)* industrial products, replacements for products made from established materials, such as paper, glass, or metal, and *c)* existing growing applications such as wire and cable insulation. In many cases, PVC tends to dominate the industrial replacement category, polyethylene and PVC the existing industrial applications, and polyethylene and polystyrene the consumer segment (table 10).

TABLE 10. CONSUMPTION OF THERMOPLASTICS BY DEMAND SECTORS IN DEVELOPING COUNTRIES

*(Percentage)*

| *Product area* | *Polyethylene* | *PVC* | *Polystyrene* |
|---|---|---|---|
| Consumer items | 30 | 10 | 35 |
| Industrial replacements | 30 | 40 | 25 |
| Existing applications | 40 | 50 | 40 |

*Interplastic competition*

In addition to competing with long established materials, plastics compete with each other. It is not uncommon for a plastic dominating one market to be replaced by another plastic, thereby affecting output at the plant of the substituted material. This occurs most often when either or both of the price-property variables that had directed the use of a material changes in favour of another plastic. For example, local production of polyethylene in one country made it cheaper than polystyrene for several consumer items. Availability of high-density polyethylene at equivalent prices to styrene was welcomed because of the need for increased rigidity.

Certain applications are more immune to interplastic competition than others. For example, PVC has been used almost exclusively for floor tile, phonograph records, film and sheet for upholstery; polyethylene dominates packaging film for food and soft goods; and polystyrene is usually found in inexpensive consumer items. In other markets for end-products, such as wire and cable, both PVC and polyethylene are used. Similarly, both plastics are used for plastic pipe. (Polyethylene does not compete in rigid, high-pressure irrigation.) Blow-moulded polyethylene has replaced injection-moulded polystyrene in a number of consumer products.

Even in the planning stages, it is important to understand where competition can arise. In forecasting potential consumption by end use for future polymer production, several countries have failed to take these substitutions into account and the result has been overcapacity.

## 2.4 Development of the plastics industry in selected LAFTA countries

*Consumption and production*

Available data show a steady increase in the consumption of plastics by LAFTA countries since the 1950s. Similarly, there has been a marked rise in the number of fabricators, a declining dependence on imports of finished goods, polymers, and intermediates, and a gradual expansion of exports.

During the 1955 1956 period, the LAFTA region processed approximately 35,000 tons of plastics and imported almost 50,000 tons, an apparent consumption of 85,000 tons. By the mid 1960s, the same group of countries was producing 155,000 tons and importing approximately 85,000 tons, an apparent consumption of 240,000 tons. During this interval, the proportions of imported resin and finished goods decreased from 58 per cent to about 36 per cent.

In all of these countries, polyethylene, polystyrene and polyvinyl chloride were the largest-volume plastics. As a result, backward integration has centred around them.

The establishment of petrochemical complexes to supply chemical intermediates for polymer production has been limited to the countries with higher population and higher gross national product (GNP) (Argentina, Brazil, Mexico), where end-use demands have or will reach levels suitable for supporting a petrochemical investment. Other LAFTA countries have selectively started a backward integration based on current and projected end-use growth, availability of raw materials and capital. Fertilizers have been the starting point for some countries. In 1967, Dow Chemical Company and Petroquímica Chilena announced plans to build three plants, each with annual capacities of 15,000 tons, to produce vinyl chloride monomer, PVC polymer and polyethylene. Similar plans are under study by other LAFTA countries.

Even in countries that have established extensive polymer operations, special resins continue to be imported as long as the volume does not justify internal production. For example, in 1965, Argentina produced approximately thirteen polymers and imported eleven (table 11).

TABLE 11. POLYMER PRODUCTION AND IMPORTS IN ARGENTINA, 1965

| *Polymer* | *Tons of polymer* *Produced* | *Imported* |
|---|---|---|
| Polyethylene | 18,700 | 1,637 |
| PVC and copolymers | 17,100 | 358 |
| Polystyrene | 10,400 | 439 |
| Acrylics | 1,600 | 136 |
| Polypropylene | 500 | 599 |
| Urea-formaldehyde | 5,600 | 236 |
| Polyvinyl acetate | 4,500 | – |
| Alkyds, maleics | 4,000 | 167 |
| Phenol-formaldehyde | 3,900 | – |
| Polyurethanes | 1,800 | – |
| Polyesters | 1,500 | 26 |
| Melamine-formaldehyde | 1,200 | – |
| Epoxy | 300 | 54 |
| Polyvinyl alcohol | – | 193 |
| Cellulosics | – | 2,573 |

### *Growth of thermoplastics*

Recent data (tables 12a and b) indicate that nearly 240,000 tons of polyethylene, polyvinyl chloride and polystyrene were consumed by the eight LAFTA countries. Approximately 54 per cent was produced domestically and 46 per cent was imported.

TABLE 12a. PLASTIC CONSUMPTION IN SELECTED LAFTA COUNTRIES, 1965

*(Thousands of tons)*

| *Plastic* | *Estimated consumption* | *Production* | *Imports* | *Estimated 1972 consumption* |
|---|---|---|---|---|
| Polyethylene | 95 | 50 | 45 | 364 |
| PVC | 94 | 68 | 26 | 313 |
| Polystyrene | 50 | 39 | 11 | 137 |
| Total | 239 | 157 | 82 | 814 |

TABLE 12b. ESTIMATED PLASTIC CONSUMPTION DISTRIBUTED BY COUNTRY, 1965

*(Thousands of tons)*

| *Country* | *PVC* | *PE* | *PS* | *Total* |
|---|---|---|---|---|
| Argentina | 27 | 19 | 10 | 46 |
| Brazil | 35 | 18 | 14 | 67 |
| Chile | 7 | 6 | 5 | 18 |
| Colombia | 5 | 5 | 3 | 13 |
| Mexico | 14 | 28 | 9 | 51 |
| Peru | 8 | 5 | 2 | 15 |
| Uruguay | 2 | 3 | 2 | 7 |
| Venezuela | 6 | 11 | 5 | 22 |
| Total | 94 | 95 | 50 | 239 |

## *Polyethylene*

Low-density polyethylene accounts for about 80 90 per cent of the polyolefin demand. Film is the major application; an estimated 50 per cent of production is converted into bags for packaging vegetables, dried foods and meat. Other foods, such as salt, rice and noodles, are also packaged in this manner. Wrapping banana stems with polyethylene shrouds before shipping contributed to the expansion of film production in several banana-producing countries, as did film for protective covering of camelback rubber in a number of rubber-producing areas.

In 1965 there were five producers of polyethylene in the LAFTA countries (see table 13). The figures for these countries do not include recent plants.

TABLE 13. PRODUCTION AND CONSUMPTION OF POLYETHYLENE IN SELECTED LAFTA COUNTRIES, 1965

*(Thousands of tons)*

| *Country* | *Production* | *Installed capacity* | *Imports* | *Total consumption* |
|---|---|---|---|---|
| Argentina | 18 | 25 | 1 | 19 |
| Brazil | 18 | 35 | – | 18 |
| Chile | – | – | 6 | 6 |
| Colombia | – | – | 5 | 5 |
| Mexico | 14 | 18 | 14 | 28 |
| Peru | – | – | 5 | 5 |
| Uruguay | – | – | 11 | 11 |
| Venezuela | – | – | 11 | 11 |

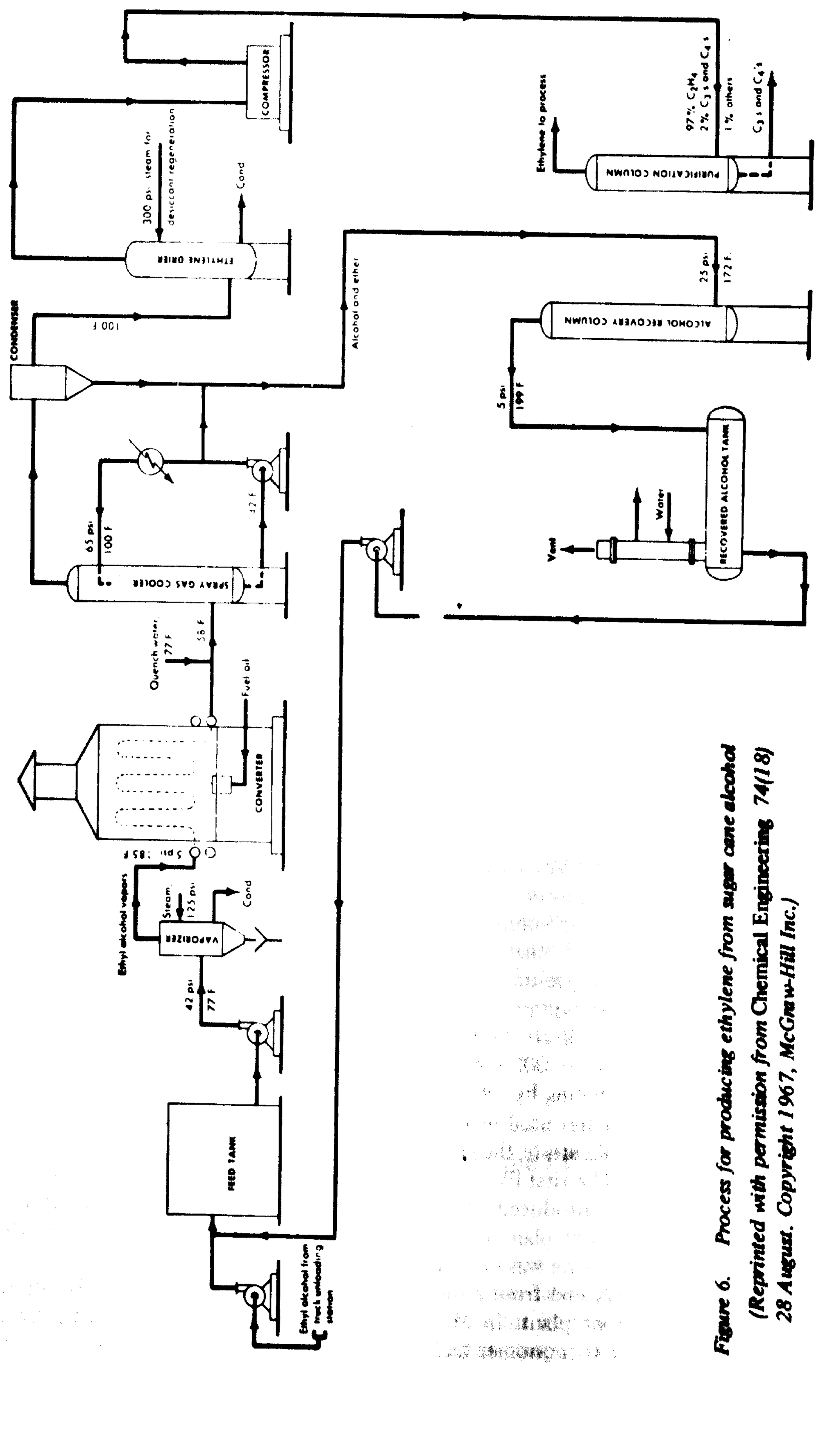


*Figure 6. Process for producing ethylene from sugar cane alcohol*

*(Reprinted with permission from Chemical Engineering 74(18) 28 August. Copyright 1967, McGraw-Hill Inc.)*

The growing consumption of polyethylene-finished products in Argentina, Brazil and Mexico has been aided by low-cost domestic sources of ethylene from petrochemical operations. The development of the Brazilian polyethylene industry is of particular interest for developing countries because of the use of sugar cane alcohol as the source of ethylene. Figure 6 shows this process.

The availability of cane alcohol for producing ethylene can be economically advantageous to a country either without enough demand for the products required to support a petrochemical venture, or for a country without petroleum reserves. In Brazil in 1958 Union Carbide do Brazil built an ethylene plant with a capacity of 3,000 tons per year in Cubatão based on a sugar cane alcohol process. By the end of 1967, capacity had reached approximately 15,000 tons pear year. A 20,000 ton/year low density polyethylene plant owned by Union Carbide will be expanded in the future. A 5,000 ton high density polyethylene plant owned by Electro Chloro (Solvay) is also on stream. Both firms use ethanol based ethylene.

Ethylene is produced from ethanol by catalytic dehydration (ethanol is converted from the sugar cane). There are several advantages to this approach. Investment is relatively low (the original plant costs about $400,000) and the operation can be run with modest labour requirements (the semi-automatic plant in Brazil used only two operators and a part-time supervisor per shift). Expansions can reportedly be made without additional operating labour. The efficiency of the plant is about 90 to 94 per cent, and ethyl alcohol is recovered and recycled.

The economic limits of this process are likely to vary from country to country. Some countries indicate that 25,000 and 40,000 tons per year are the minimum and maximum. Beyond the maximum limit, naphtha cracking may be cheaper. (Union Carbide's first ethanol dehydration unit in India has been converted to naphtha cracking.) The other major producer of polyethylene in Brazil, Electro Chloro, has also used ethanol owing to shortages of ethylene. As ethylene becomes available from petrochemical units, it is often cheaper to divert the production of alcohol to other uses.

### *Polyvinyl chloride*

The consumption of vinyl chloride polymers in the LAFTA region was about 94,000 tons, almost equivalent to the polyethylene demand. Different markets accounted for most of this volume, e.g. wire and cable insulation, electrical conduit, calendered film and sheet, coated fabrics, shoes and records. Wire and cable is the largest application in this group.

The production of polymers has progressed rapidly with twelve producers in eight countries offering a combined installed capacity of 95,000 tons (table 14). Based on production of 68,000 tons, plant utilization was about 70 per cent. Several new plants will be producing by 1970.

The varied approaches used in the manufacture of PVC monomer and polymers by LAFTA countries illustrate the importance of raw material availability, location, plant size and so on. The first PVC producers in Brazil manufactured monomer from acetylene, using both produced chlorine, caustic soda and smaller quantities of calcium carbide. The first plant in Peru (about 5,000 tons) was based on ethylene from ethyl alcohol; chlorine was obtained from a chlorine-caustic plant.

In Colombia, acetylene from a local calcium carbide plant was used for the first vinyl chloride monomer plant. In Mexico, vinyl chloride was imported before the installation of the Pemex monomer facility (20,000 tons per year).

TABLE 14. PRODUCTION AND CONSUMPTION OF POLYMERS IN SELECTED LAFTA COUNTRIES, 1965

*(Thousands of tons)*

| *Country* | *Number of producers* | *Production* | *Installed capacity* | *Imports* | *Total consumption* |
|---|---|---|---|---|---|
| Argentina | 3 | 17 | 21 | – | 17 |
| Brazil | 3 | 35 | 40 | – | 35 |
| Chile | – | – | – | 7 | 7 |
| Colombia | 2 | 2 | 13 | 3 | 5 |
| Mexico | 2 | 14 | 23 | – | 14 |
| Peru | 1 | – | – | 8 | 8 |
| Uruguay | – | – | – | 2 | 2 |
| Venezuela | 1 | – | – | 6 | 6 |

It is not uncommon for producers to incorporate new techniques when capacity must be increased. For example, oxychlorination may be integrated into the existing facility in certain cases. Ethylene from cracking operations can replace alcohol ethylene, and surplus hydrogen chloride can be used with ethylene in an oxychlorination unit.

*Polystyrene*

Approximately 70 to 80 per cent of the 50,000 tons of polystyrene consumed is injection moulded into consumer items; most of the remainder is extruded into sheet, and vacuum formed into refrigerator liners and miscellaneous household items. Some of the moulded items are bottle caps, pens, toys, compacts and so on. Industrial components made in a few countries include radio and television cabinets, toilet seats, and other items.

In Argentina, Brazil, Chile, Colombia, and Mexico, twelve firms accounted for some 37,000 tons of polymer and 4,000 tons of imported material. Peru, Uruguay and Venezuela imported all needed material, totalling 9,000 tons.

It is interesting to note that in Brazil, one monomer producer (Cia Brasileira de Estireno) has supplied the needs of three polymer producers and the Petrobrás synthetic rubber plant.

## 2.5 Development of the plastics industry in the ECAFE region

*Fabrication*

In the ECAFE region the patterns of development in plastics fabrication are parallel to those found in other developing areas. A few fabricators tend to dominate production; polyethylene, PVC and polystyrene are the key materials processed and are targets for backward integration. Differences as compared to LAFTA countries occur in the types of products made, availability of raw materials, and socio-economic patterns.

Using the five countries as an example (China (Taiwan), Malaysia, Pakistan, the Philippines and Thailand), the best available data indicate that the consumption of plastics increased from 8,000 tons (almost all imported) in the 1955 1956 period to well over 62,000 tons by 1965 1966. Estimated consumption by application and plastic illustrates the structure of end-product demand in these countries (table 15).

TABLE 15. ESTIMATED CONSUMPTION (INCLUDING EXPORTS) OF PLASTICS IN SELECTED ECAFE COUNTRIES, 1964/1965

| *End use* | *China* | *Malaysia* | *Pakistan* | *Philippines* | *Thailand* |
|---|---|---|---|---|---|
| *Polyethylene (low and high density)* | | | | | |
| Containers | 2.0 | 0.5 | 0.5 | 1.0 | 0.5 |
| Film | 9.0 | 4.5 | 6.0 | 4.0 | 9.5 |
| Cable insulation | 1.0 | 0.5 | – | 0.5 | – |
| Pipe | 0.5 | – | 0.5 | 0.5 | 1.0 |
| Mouldings, other[a] | 1.5 | 2.5 | 2.0 | 1.0 | 2.0 |
| Total | 14.0 | 8.0 | 9.0 | 7.0 | 13.0 |
| *Polyvinylchloride* | | | | | |
| Floor tile | 0.5 | – | – | – | – |
| Shoes | 3.5 | 0.1 | 3.0 | 4.0 | 1.0 |
| Pipe, hose | 6.0 | 1.5 | 1.5 | 2.5 | 1.0 |
| Cable insulation | 1.0 | 2.0 | 3.0 | 2.0 | 2.0 |
| Film and sheet | 12.0 | 1.0 | 0.5 | 5.0 | – |
| Mouldings, other[a] | 17.0 | 0.4 | 1.0 | 0.5 | 1.0 |
| Total | 40.0 | 5.0 | 9.0 | 14.0 | 5.0 |
| *Polystyrene* | | | | | |
| Mouldings | 2.5 | 1.5 | 2.0 | 2.0 | 3.5 |
| Packaging | – | 0.5 | – | 0.5 | – |
| Foams | – | – | – | – | – |
| Appliances | 0.5 | – | – | 0.5 | 0.5 |
| Total | 3.0 | 2.0 | 2.0 | 3.0 | 4.0 |

[a]Since the 1964/1965 period, there have been new producers (e.g. of floor tile) of products not shown here by volume. There have also been significant decreases in the consumption of other items (e.g. shoes) in some countries, while products such as rope and cord, not shown here, have risen substantially. Therefore, these data should be used only as a guide of "profile" of resin consumption.

### *Polyethylene*

Packaging is a key market in most of the ECAFE sectors. Conversion of film into bags for fertilizer is responsible for much of the recent growth in film production. This, of course, is related to increased fertilizer production. Packaging of textiles, sugar, chemicals and food articles forms most of the remaining demand. Caps and bottles are a smaller outlet, but the demand for them is growing. Blow-moulded containers are relatively new. Products packaged include liquid wax. Polyethylene-lined canals have been used for water conservation in several countries, e.g. India. Wire and cable insulation, flexible pipe and a variety of moulded consumer products form the bulk of remaining products.

### *Polyvinyl chloride*

#### *Film and sheet*

Calendered sh[illegible]d cloth are used for upholstery in automobiles, for furniture, and for exported products such as baby pants, raincoats and leather cloth.

#### *Shoes*

Vinyl sandals are a well-established consumer product. They are moulded by shoe firms (e.g. Bata Shoe Company) and independent fabricators. Overcapacity occurs often in this industry, resulting in severe price competition. Calendered vinyl-backed cloth for shoe uppers is also produced in some areas.

#### *Wire and cable insulation*

The expansion of hydroelectric power in developed and developing territories has increased demand for insulated wire and cable in power, telephone, household and related systems. Electric utilities account for a major share of extruded products. Heavy imports of wire and cable have held back the expansion of polymer production in some areas.

#### *Pipe and conduit*

Rigid water pipe is widely accepted. In Malaysia, it is used in tin mines and for irrigation of rubber plantations. The consumption of electrical conduit has increased with the growth of wire and cable installations. Other extruded products such as poultry feeders are marketed.

#### *Floor tile*

Several countries have shown preference for vinyl floor tile in new housing; others, e.g. China (Taiwan), prefer concrete.

### *Polystyrene*

General-purpose grades of polystyrene are used in a variety of consumer items including combs, housewares, flowers, toys, advertising displays, tooth-brushes, tumblers, and packaging. Smaller quantities of high-impact resins are consumed in a few countries for appliances, including vacuum-formed refrigerator liners, moulded radio cabinets, air conditioners, and other components. Polystyrene foam has been sold in small amounts for cold storage applications.

### *Plastics industry in Thailand*

The plastics industry in Thailand has grown dramatically in the last fifteen years. During this period, the number of registered fabricators has increased from less than ten to over 250. Production is directed towards consumer items and packaging. In 1966, an estimated 39,000 tons of finished plastic products imported and produced locally were consumed. This compares with 2,000 tons of consumption in 1955–1956.

End products using imported resin as a component included insulated wire and cable, coated paper, glues and resins, and paint. Finished plastic products imported were toys, footwear, novelties, signs, and furniture surfacing. Products fabricated from plastic raw materials included toys, containers, dinnerware, novelties, electrical fittings, expanded polystyrene products, rope, tape, drinking straws, footwear, rigid and flexible pipe, and film and bags for packaging. Table 16 indicates the consumption by end-use.

TABLE 16. CONSUMPTION OF FINISHED PLASTIC PRODUCTS IN THAILAND, 1966

*(Thousands of tons)*

| *End-use* | |
|---|---|
| Films and bags (packaging) | 11 |
| Flexible film and sheet goods | 6 |
| Moulded or extruded toys, novelties, containers, trays | 6 |
| Rope, cord and tape | 5 |
| Pipe and hose | 2 |
| Insulated wire and cable | 2 |
| Electrical fittings | 0.5 |
| Paint (polymer content) | 0.4 |
| Furniture, laminated sheets | 0.4 |
| Signs and novelties | 0.3 |
| Expanded polystyrene products | 0.2 |
| Moulded footwear | 0.1 |
| Polyurethane foam insulation | – |
| Adhesives and coatings for wood and paper | 3 |
| Cellulosics | 2 |
| Total | 39 |

*Backward integration*

In many ECAFE countries, the development of a petrochemical industry is still several years away. The demand must be strong enough to support several end-use areas (e.g. plastics, synthetic fibres, detergents, rubber) based on petrochemical feedstocks. Optimum plant economics for these intermediates are important so that the finished products can compete in domestic and export markets.

Countries such as India, Iran and Pakistan have had increasing demand in petrochemical-consuming end-use markets and this has justified the establishment of petrochemical complexes. India is an interesting case history for developing countries, because before the installation of naphtha stream crackers, organic chemicals of non-petroleum origin were used to supply the growing end-product demand. These chemicals include fermentation alcohol (e.g. from molasses), coal-derived aromatics, and acetylene from calcium carbide.

The production of intermediates and end-products from available non-petrochemical sources is highly desirable for a developing country. They can usually be manufactured in small quantities with less investment. This is important when end-use markets are still too small to justify a costly petrochemical complex. Furthermore, a material such as alcohol can be converted into ethylene without by-products (e.g. propylene, butadiene). A petrochemical venture would have to secure outlets for these by-products.

TABLE 17. PRODUCTION CAPACITY OF NOCIL COMPLEX, INDIA

| *Product* | *Capacity (tons/year)* |
|---|---|
| Ethylene | 32,500 |
| Ethylene oxide | 4,000 |
| Ethylene glycol | 1,000 |
| Diethylene glycol | 750 |
| Polyethylene glycol | 1,000 |
| Ethylene dichloride | 3,000 |
| Vinyl chloride | 8,000 |
| PVC | 16,500 |
| Isopropyl alcohol | 2,000 |
| Dimethyl ketone | 7,000 |
| Diacetone alcohol | 2,000 |
| Methyl isobutyl ketone | 3,500 |
| 2-ethyl hexanol | 7,500 |
| N-butyl alcohol | 5,000 |
| Butadiene | 7,000 |
| Benzene | 13,500 |
| LPG (liquefied petroleum gas), other liquid fuels | 55,000 |

But when one considers long-range plans, the production of non-petrochemicals may not be desirable for a developing country. The high cost of production is a major problem. Ethylene produced from alcohol has been much more expensive than ethylene from naphtha in many countries that have used both methods. Similarly, acetylene derived from naphtha is usually cheaper than that from calcium carbide, and petrochemical benzene is less expensive than coke-oven benzene. Because of the costly feedstock (ethylene from alcohol), prices of polyethylene were relatively high and consumer goods could not be fabricated in the volume hoped for.

In order to build a base for low-cost products petrochemical feedstocks are usually necessary. This is particularly true if plastic end-products are to replace imported products made from cotton, steel, wool and other items. At one time, India imported over $350 million of these materials. Competitively priced plastic products are also essential for participation in the world export market.

The establishment of a petrochemical industry in India is well documented. Several complexes are now in operation, e.g. UCIL (Union Carbide India Ltd) and NOCIL (National Organic Chemical Industries Ltd), and others are planned. The low-cost ethylene will be used for making polyethylene, PVC and other products. Propylene will be used largely for internal needs (ketones, alcohols). Outlets for butadiene and high-purity benzene are under study. The production capacity for the NOCIL complex is indicated in table 17.

It is interesting to note (table 18) that plastics were the fastest growing segment of the petrochemical consuming end-uses in the long-range plan for petrochemical development in India.

TABLE 18. GROWTH EXPECTED IN SELECTED INDUSTRIAL SEGMENTS IN INDIA, 1960–1971

| *End-use* | *Production (thousands of tons)* 1960/1961 | 1965/1966 (estimated) | 1970/1971 (estimated) | *Annual compounded growth rate (percentage)* |
|---|---|---|---|---|
| Plastics and resins | 10 | 74 | 320 | 42 |
| Surface coatings | 53 | 140 | 210 | 15 |
| Dye-stuffs | 54 | 94 | 13.4 | 10 |
| Synthetic fibres | – | 20 | 60 | 25 |
| Synthetic detergents | 1.2 | 20 | 30 | 38 |
| Synthetic rubber | – | 50 | 123 | 20 |

*Source:* First United Nations Interregional Conference on the Development of Petrochemical Industries in Developing Countries, Tehran, 1964. Sales No. 67.II.B.2. (2 vols).

## 2.6 Technology in plastics

*Sources of technical information*

It is not surprising that countries seeking a method of producing a polymer often turn to others that have exported polymers and finished products to them. For example, Japan is a leader in vinyl technology and a supplier of resin to ECAFE countries. Many of the new plants in the ECAFE region are based on Japanese technology, which is often provided as a complete "package", including know-how, plant design and start-up. Some of the new PVC plants that began with the aid of Japanese technology during the 1965–1967 period are indicated in table 19.

TABLE 19. RECIPIENTS OF JAPANESE PVC TECHNOLOGY IN ASIAN COUNTRIES, 1965–1967

| *Country* | *Year* | *Capacity (tons/year)* | *Licenser* | *Recipient* |
|---|---|---|---|---|
| China (Taiwan) | 1965 | 8,500 | Sumitomo | Cathay Chemical |
| China (Taiwan) | 1966 | 12,000 | Shin-Etsu | China Plastics |
| China (Taiwan) | 1966 | 11,000 | Kangafuchi | Yee Fong Plastics |
| India | 1965 | 7,000 | Shin-Etsu | Delhi Cloth and Mills |
| Pakistan | 1966 | 6,000 | Shin-Etsu | Reyez-O-Khalid |
| Philippines | 1965 | 6,000 | Shin-Etsu | Mabuhay Rubber |
| Republic of Korea | 1966 | 7,000 | Chisso | Laehan Plastics |
| Republic of Korea | 1967 | 12,000 | Shin-Etsu | Koyoei Vinyl |

Plant size tends to be in the 6,000 to 8,000 tons per year range. Countries with established markets (e.g. wire and cable), such as China (Taiwan) or the Republic of Korea, can support larger installations. The ability to captively fabricate polymer into finished products is important in reducing selling costs and planning production schedules. The Reyez-O-Khalid plant (Arokey Chemical Industries) converts about 45 per cent of its PVC production to pipe and about 35 per cent to calendered sheet.

Table 20 gives the extent of US activities in producing polystyrene and PVC in various countries. Some ways in which these ventures may be financed are illustrated in table 21.

TABLE 20. TECHNICAL COLLABORATION BETWEEN US COMPANIES AND SEVERAL COUNTRIES

| *Country and company* | *Polymer* | *Supplying company* |
|---|---|---|
| Argentina | | |
| Monsanto Argentina | Polystyrene, PVC | Monsanto |
| Ipako | Polystyrene | Koppers (Sinclair) |
| Brazil | | |
| Cia Brasileira de Plásticos Koppers | Polystyrene | Koppers (Sinclair) |
| Geon do Brasil (Matarazzo) | PVC | B. F. Goodrich Chemical |
| Chile | | |
| Plastiquímica | Polystyrene | Kaydot, others |
| China (Taiwan) | | |
| Tai Ta Chemical | Polystyrene | Mobil Chemical |
| Colombia | | |
| Dow Colombia | Polystyrene | Dow Chemical |
| Petroquímica Colombiana | PVC | Diamond Alkali |
| India | | |
| Nandal Koppers Ltd | Polystyrene | Koppers (Sinclair) |
| Polychem | Polystyrene | Dow Chemical |
| Chemicals and Plastics | PVC | B. F. Goodrich |
| Israel | | |
| Electrochemical | Polystyrene | —— |
| Frutaron | PVC | B. F. Goodrich |
| Mexico | | |
| Monsanto Mexicana | Polystyrene | Monsanto |
| Union Carbide Mexicana | Polystyrene | Union Carbide |
| Geon de Mexico | PVC | B. F. Goodrich |
| Monsanto Mexicana | PVC | Monsanto |
| Peru | | |
| W. R. Grace | PVC | W. R. Grace |

TABLE 21. FINANCING SELECTED POLYMER VENTURES IN ARGENTINA

| *Company* | *Polymer* | *Origin of technology* | *Capital invested ($ million)* | *Financial structure* |
|---|---|---|---|---|
| Ipako (Koppers) | Polystyrene, ethylene | Koppers (Sinclair) | 1 | 51% US capital investment<br>49% Argentine capital |
| Koppers | Polyethylene | Koppers (Sinclair) | 13.4 | Loan, Import-Export Bank<br>Washington D.C. |
| Monsanto Argentina | Polystyrene | Monsanto | 1 | 100% foreign investment |
| Plástico Bernardo | Polystyrene | Internal | 0.11 | National investment |
| Duperial | Polyethylene | ICI, | 16.0 | Foreign capital from |
| | | others | 16.1 | Imperial Chemical Industries |
| Norens-Plast | Methyl methacrylate | Internal with help from Mitsubishi Rayon | 0.04 | Argentine capital |

*Source:* Gatti, O., Pasquinelli, E. A. and Beltramino, R. F., *The petrochemical industry in Argentina*, from *Studies in petrochemicals* presented at the First United Nations Interregional Conference on the Development of Petrochemical Industries in Developing Countries, Tehran, 16–30 Nov. 1964. Sales No. 67.II.B.2 (vol.2).

*New technology*

The plastics industry is witnessing a series of important breakthroughs in polymer and fabrication technology. Most of the new polymers that have or will be introduced are high-priced engineering materials that will find little demand in developing countries. It is conceivable that in the future some of these may become large-volume, low-cost resins which might provide opportunities for fabrication into products for export. For example, poly-1-butene has very favourable properties for film, pipe and wire, and cable insulation. Chlorinated polyethylene is an important component for several PVC systems used for floor tile, pipe, sheet and containers. Ionomers have made strong headway in packaging, and 4-methyl-1-pentene is being used for laboratory ware, electrical and packaging products. Some of the newer high temperature polymers include polysulphone and polyphenylene oxide (PPO). Nylon materials worthy of note are nylons 11 and 12, which compete in several nylon 610 markets and special areas. Considerable work has been done by the Northern Regional Research Laboratory (Peoria, Illinois) on the synthesis of nylon-9 from soybean oil (nylon 11 and 610 are commercially made from castor oil).

Many firms are attempting to introduce plastics that combine the best properties of two materials. Blends of acrylic and polyvinyl chloride, polycarbonate and ABS are examples. Glass-reinforced thermoplastics have only begun to find use. Various types of other fillers, including asbestos, and metallic fibres are providing a whole spectrum of new products.

Polymerization processes are also under modification. Solution grades of high-density polyethylene are being replaced by particle-form resins in blow-moulding and eventually in selected injection-moulding applications. In the future, gas-phase polymerization could lower production costs even more. Copolymers of ethylene with other monomers (e.g. hexene-1) are providing better olefin resins. Bulk polymerization of vinyl chloride has been adopted by a number of countries.

Fabrication equipment and systems are also undergoing a period of advancement. Radiation offers exciting possibilities for curing and exhancing properties. Cold forming has recently attracted considerable attention. Advantages of this process include high production rates, lower tooling costs, reduction of trimming, elimination of sprues or weld lines, the ability to fabricate high molecular weight polymers and to make heavy-walled parts that ordinarily could not be made on plastics equipment. Reinforced thermoplastic sheet that can be stamped has been introduced in a few countries. Microwave curing of reinforced polyesters may reduce joining time considerably. The injection blow moulding and extrusion casting of composite films are also important advances.

Even the technology of basic raw materials is undergoing changes. The Office of Coal Research (Department of the Interior) in the United States has sponsored Project COED (Char Oil Energy Development) to develop an economic process for converting coal to a gas, a liquid, and a solid, and to upgrade the coal substance and decrease the delivered cost of coal energy. The same agency has also sponsored work on the conversion of coal to more valuable fuels. This is not a new idea; oil was made from coal in Germany (approximately 5 million tons a year) during the Second World War. However, continued advances in coal conversion involving hydrogenation, gasification and oxygen manufacture provide hope that economically feasible operations will be able to take advantage of the coal resources available in many areas. Furthermore, there is a possibility that petrochemicals could be produced some day at investments that would be very attractive in comparison with conventional refinery systems.

Although the myriad new polymers, fabrication and polymerization processes and changing feedstock technology may not be of benefit in the immediate future for all developing countries, the possibility of incorporating only one or two new ideas may well repay the time spent on studying recent advances.

*Part 3*

# ESTABLISHING AN INTEGRATED COATINGS AND ADHESIVES INDUSTRY IN DEVELOPING COUNTRIES

A viable coatings and adhesives industry can be set up even in the smaller and less developed countries. Local raw materials, especially starches and vegetable oils, can play an important role in production. In addition, petrochemicals derived from petroleum and natural gas can be the basis for the manufacture of a selected few resins which can fill most of the needs of the industry. The best coatings and adhesives industry for a country is one that fits into the industrial ecology of the region, utilizing its natural or manufactured raw materials, and turning out products needed by the economy.

## 3.1 Coatings

The world's yearly production of coatings (paints, varnishes, sizes, lacquers and so on) is approximately 3,000 million US gallons. More than three fourths of the total is accounted for by the eight major producing countries–Canada, France, the Federal Republic of Germany, Italy, Japan, the United Kingdom, the Union of Soviet Socialist Republics, and the United States of America.

In the United States, the yearly consumption of paints and other coatings has now reached about five US gallons *per capita*, with a value at the manufacturer's level of about $15. In other highly industrialized countries, usage varies from one to four US gallons per person. Discounting the eight major producing countries, the rest of the world, including the smaller highly industrialized countries, have an average consumption of less than one-half gallon *per capita*. Consequently, for developing countries, the typical usage might be one-fourth gallon per person, but there are wide variations.

Coatings have two main functions: protection and decoration. They are applied over steel, wood, paper, concrete, textiles, leather, and many other substrates.

The essential ingredient of any organic coating is a polymer – a resin or rubber that is capable of forming a continuous film, usually hard and tough.

In the industrial countries where a large variety of materials is available, of twenty different polymers, each has at least 1 per cent of the market for binders. Many other polymers are used to a lesser extent. Obviously in a developing country it would not be feasible to build a coatings industry with such a complexity of raw materials. Fortunately, however, it is not necessary to do so. It is possible to manufacture paints and other coatings that will satisfy nine tenths of the needs with only four basic materials, two natural and two synthetic: unsaturated vegetable oils, alkyd resins, vinyl acetate polymers, and starch. These materials need not be used in precisely the same manner as in the developed countries.

Along with the organic binder, various other ingredients are necessary, such as pigments and fillers. These may also be selected according to availability. Thus, the finished formulations may be quite different from those in the United States.

As the coatings industry and its customers become more sophisticated, the number of binders can be expanded greatly with little or no change in the equipment for making the resins or compounding the finished paints and other coatings. Thus, an alkyd resin kettle lends itself to the manufacture of amino resins, phenolics, epoxy esters, and urethanes. A system capable of producing vinyl acetate polymer emulsions can also be used for acrylic resins and vinyl chloride resins (PVC). Similar equipment capable of withstanding higher pressures may be employed for styrene resins and a variety of synthetic rubbers.

If polyethylene resin is being manufactured for film and injection-moulded plastics, a suitable grade can be used for the extruder coating of paper to make inexpensive waterproof containers for food. A petroleum refinery may have, as a by-product, waxes that are good coatings for paper. Bituminous coatings can be made from petroleum-derived asphalt, coal tar or natural mineral deposits, if these are available. In the unlikely event that casein (from milk) is available in excess of food requirements, this product is a valuable coating constituent. Thus, local conditions of supply can determine the nature of the formulated coatings.

### *End-uses*

In the United States, about one half of all paints go into "trade sales" markets, i.e., they are sold to home-owners and painting contractors for the painting of houses and other buildings. Wood is a significant construction material in most parts of the United States, so are brick and concrete. Concrete is usually painted, but brick and stone are not. In any case, home interiors are almost always painted, over such substrates as wood, plaster and paper-covered gypsum wallboard.

In Western Europe, interior decorating practices are similar to those in the United States, but the exteriors in Europe are far more often unpainted brick.

In the developing countries, there is and will continue to be a variety of building materials available. The use of paint on wood and concrete can increase the life of these materials. Furthermore, the use of white or light-coloured paints is not only aesthetically pleasing, but it also helps to radiate heat from the sun, keeping buildings cooler.

In addition to the part they play in architecture and construction, coatings go into a wide variety of industrial and maintenance applications. In the United States, iron and steel are the most important surfaces that must be coated in order to protect them from rust and to improve their appearance. Automobiles, machinery, metal furniture, ships, cans for food and beverages, and pipe are some of the major outlets. In the developing countries, there is little or no original metal equipment of manufacturers to be coated, but there is a considerable quantity of imported metal products whose useful life can be lengthened by periodic maintenance painting.

In addition to the binder, the pigment is important in protecting metal parts from corrosion. The historic anti-corrosive pigment was red lead, but now metallic zinc is taking its place. These two materials will be discussed later in the section on pigments.

The largest demand in coatings for paper is for those which make the paper more readily printable. A pigment, usually clay, is blended with a small proportion of binder in order to provide an opaque coating that can be printed on two sides and through which the ink will not penetrate. While not all grades of clay are equally good, many types are adequate, along with other pigments common throughout the world.

## *Oils*

Oils and fatty acids are widely distributed in the world. They are obtained from seeds, nuts, beans, fish, and as by-products from the kraft wood-pulping process. These vegetable and animal oils are esters of glycerine with three fatty acid groups. For centuries they were the sole binders in most paints. They are still used alone, but are now employed to an even greater extent in conjunction with other resins, mostly alkyds, to make epoxy esters and oil-modified urethanes.

The unsaturated oils and fatty acids are liquids that harden by air oxidation. The oxygen causes the unsaturated molecules to link up with each other, a process called polymerization. Sometimes the oils are used as obtained. At other times they may be boiled with metallic driers, "blown" by passing air through them, or "bodied" in some other manner to make them more viscous and enable them to harden faster.

The ease with which the various oils are capable of hardening depends upon the extent and kind of unsaturated groups they contain. Those having the most unsaturated groups are usually the fastest to react. Table 22 lists the oils in order of reactivity, and their usage in the United States is compared with that of linseed oil. Also listed are late 1967 quotations for the various materials. The price fluctuates widely according to supply and demand.

TABLE 22. OILS USED IN COATINGS IN THE UNITED STATES OF AMERICA, 1967

| *Oil* | *Average unsaturations per fatty acid* | *Usage index (linseed = 100)* | *Price (cents per pound)* |
|---|---|---|---|
| Tung | 2.7 | 10 | 12.3 |
| Oiticica | 2.4 | 5 | 17.0 |
| Linseed | 2.1 | 100 | 13.2 |
| Marine (menhaden) | 2.0 | 10 | 9.5 |
| Safflower | 1.7 | 10 | 12.5 |
| Soy | 1.5 | 30 | 9.0 |
| Tall oil fatty acids | 1.4 | 30 | 7.5 |
| Castor | 1.0[a] | 10 | 22.0 |

[a]Can be increased to about 2.0 by dehydration.

Linseed oil, from flax seed, is obtained principally from Argentina and Uruquay. Other important sources are India, the Union of Soviet Socialist Republics and the United States of America. Regions with similar climates could also presumably produce flax.

Tung oil, obtained from the nut of a tree, is also known as China wood oil. It is produced in Burma, China (Taiwan). India, Indonesia, various South American countries (including Argentina, Brazil, Paraguay), the USSR, the USA and elsewhere. The most favourable condition is a warm climate with a cold season but no frost. In the USA, tung oil production is subsidized by the Government, which pays the producer a "pool support price" of $0.24 per pound no matter what the market price may be. In many developing countries, however, it could be a profitable crop and an aid to an integrated coatings industry because it dries quickly and provides a very hard coating.

Oiticica oil, also a nut extract, is obtained from Brazil. It competes with tung oil, usually at prices closer together than those indicated in the table.

Marine oils are obtained from various fish, particularly menhaden, but also from sardine, hake, and pilchard. In view of their low cost, they are a useful partial replacement for linseed oil in many applications. Most of the menhaden oil used in the United States is obtained off the mid-Atlantic coast. There are no doubt many other regions in the oceans of the world where oily fish can be caught.

Safflower oil, extracted from the safflower seed, is a viable crop in several western states of the United States, and therefore, should be all the more attractive in developing countries with moderate climates. It grows wild in northern India.

Soy oil is available in China and several other countries of Asia. Soy beans are now grown in the United States, particularly in the North Central states. Soy oil is a food as well as a raw material for paints. With less unsaturation than linseed oil, it is also less reactive and is classified as a semi-drying oil.

Tall oil fatty acids are by-products of the kraft or sulphate process for manufacturing paper and paperboard. Rosin, another by-product, is also useful in paints. The kraft process is utilized principally with pine-wood, available in northern Europe, northwestern United States and Canada.

Castor oil, from the castor bean, has many uses besides coatings, such as soaps, medicines, and lubricants. The castor plant grows well in Brazil, India, southern USA and other semi-tropical areas.

Many other oils are used only to a minor extent in paints for various reasons: they may be too saturated, hence unreactive, or more valuable as food, or not readily available. Important examples are the oils from coconut and cotton seed. Others include tobacco seed, walnut, sunflower, rape seed, perilla, isano, and mustard. It is feasible for developing countries to utilize various indigenous nuts and seeds as sources of unsaturated oils, provided that proper modifications are made in the preparation of the coating materials in accordance with the chemical composition of the oils.

About one half of the oils in finishes are used only as binder. In this case, it is necessary to employ linseed oil or other highly unsaturated oils, so that air oxidation causes enough cross-linking of the molecules to convert the liquid into a solid film.

Linseed oil and similar unsaturated oils are usually bodied if they are to be used as the sole binders. This thickening process is accomplished by heating the oils in agitated kettles, often over an open flame. The cost of the equipment is moderate if the quality requirements are not too demanding. To make a blown oil, a stream of air is passed through the liquid at a moderately high temperature. Stand oils are made by heating the liquid to much higher temperatures without an air stream.

The oil-based coatings have excellent adhesion to wood, but exposure to sunlight, with its ultra-violet component, tends to make them brittle and yellow. The most unsaturated materials are the worst offenders. When pigmented (usually with titanium dioxide in the United States if the colour is white), the air-oxidized oils are degraded at a much slower rate.

Alkyd resins, made partly from oils, have a much smaller tendency to yellowing since there is less unsaturation, but they are more expensive.

*Alkyd resins*

The alkyds, developed forty years ago, are the synthetic resins most widely used in the coatings industry, especially for metal coating. A typical alkyd resin contains three main constituents:

*(a)* A polyacid or anhydride, such as phthalic anhydride or maleic anhydride;

*(b)* A polyol (polyalcohol), such as glycerine or pentaerythritol;

*(c)* Fatty acids, usually unsaturated, such as tall fatty acids or those derived from oils: linseed, soy, castor, marine, tung, safflower, coconut, and so on.

The most common alkyd resins are phthalic anhydride, glycerine and linseed oil, soya oil, or tall fatty acids.

To prepare an alkyd, the ingredients are heated with agitation, and the water formed by esterification is removed. A direct fired kettle (i.e. an open flame) can be used, but better results are obtained with a jacketed kettle containing the heat transfer medium in the jacket. In either case, there must be provision for mixing.

In modern equipment, a condenser is provided to cool the steam formed by esterification, but some open kettles are also still in use. These, of course, are much cheaper.

For best control, the viscosity of the alkyd batch is kept low by incorporating a solvent, such as xylene. The solvent also helps to remove the water of esterification. Hydrocarbon solvents involve a danger of fire or explosion. Therefore, in a developing country where personnel may be inexperienced, it would be advisable to use the safer solvent-free process, using fusion, even though this requires higher temperatures and does not give as uniform a product.

The reaction is continued until the acidity of the contents in the kettle has dropped to some predetermined value. In the most modern plants, elaborate instrumentation is provided for optimum quality control. However, acceptable products can be made without these expensive accessories, using only the simplest devices and techniques for determining temperature, viscosity and acid number.

It is possible to complete two or three batches per 24-hour day. If we assume only one batch a day, a 1,000-gallon kettle operated at 70 per cent of capacity for 250 days per year can make 170,000 gallons per year. (The 70 per cent filling allows room for subsequent thinning with solvent. Manufacturers in the United States often handle two or even three batches per day per kettle.) Initially this might be enough alkyd resin to serve the needs of several million people in a developing country.

Phthalic anhydride, the main polyacidic constituent of alkyd resins, is made either from naphthalene (from coal tar) or from orthoxylene (from petroleum). Glycerine can be a by-product from the rendering of fats to make soap. In the United States, however, glycerine is a petrochemical, so is pentaerythritol.

Alkyds are classified according to the amount of oil they contain:

*(a)* Long-oil alkyds: more than 60 per cent oil,

*(b)* Medium-oil alkyds: 40 per cent to 60 per cent,

*(c)* Short-oil alkyds: less than 40 per cent.

The long-oil and medium-oil types are air drying, whereas the article being coated with a short-oil alkyd must be baked after application in order to complete the reaction. The long-oil alkyds are tougher and withstand impact better; the short-oil alkyds are harder and more scratch resistant. The drying oils constitute about half the weight of alkyd resins in highly industrialized countries, and could attain an even greater proportion in the developing countries. When one adds to this the glycerine which can also be derived from natural fats and oils, it is apparent that alkyd resin manufacture can be started with a minimum of imports even before a petrochemical industry has been established.

It is necessary, however, to dissolve the alkyd resin in hydrocarbon solvents in order to reduce its viscosity enough to enable it to be brushed or sprayed. The solvent is usually a mixture of aliphatic and aromatic hydrocarbons. The former are cheaper, and can be used exclusively for long-oil alkyds; short-oil alkyds, however, require some proportion of aromatic solvents, such as toluene and xylene. The aliphatic solvents are available from petroleum refining processes; the aromatics can also come from this source, or they are by-products in the manufacture of coke from coal.

*Polyvinyl acetate*

Vinyl acetate resins for paints are made by polymerization in emulsion. This process is used also for the manufacture of other paint resins, notably styrene-butadiene and acrylic resins. Styrene-butadiene resins are more hazardous to make, however, and their use in paints is declining because of inferior light resistance. The acrylics are significantly more expensive than the vinyl acetate resins. Therefore, it would be advisable for a developing country to concentrate on the vinyl acetate materials.

Vinyl acetate is a liquid monomer with a vinegary odour. It is made by reacting either acetylene (derived from coal or oil) or ethylene (from oil or natural gas) with acetic acid (now a petrochemical). It is one of the cheaper and more abundant of the monomers, the liquid building blocks that are combined to make solid polymers.

Two classes of vinyl acetate resins are in common use in paints: the homopolymers, in which vinyl acetate is the only building block; and the copolymers, in which vinyl acetate is combined with acrylates, maleates or fumarates. The homopolymer is easier to make and is cheaper, but its films can be brittle. An inexpensive way to overcome the brittleness is to add a small amount of a liquid plasticizer, such as dibutyl phthalate. The copolymers of vinyl acetate with acrylate esters etc. provide a more sophisticated answer to the brittleness problem. Copolymerization can be undertaken once the manufacture of homopolymers has been mastered.

In the United States, the size of the kettles for making polyvinyl acetate in emulsion is at least 2,000 US gallons. However, it might be prudent for a developing country to begin with kettles of 1,000 gallons. Since vinyl acetate is a combustible and volatile monomer, the kettles must be enclosed and jacketed for indirect heating. The emulsion is commonly made in approximately 55 per cent solids content, with water as a carrier. A small percentage of hydroxyethylcellulose or polyvinyl alcohol is employed as a protective colloid. A 1,000-gallon kettle could produce approximately 130,000 gallons per year if operated solely on a single shift using the redox process. Batch times in the United States vary from six to ten hours, making it feasible to double or even triple the output from one kettle by working around the clock. Thus, a single kettle of 1,000 gallons might initially satisfy the interior house paint needs and some of the exterior needs of several million people.

In exterior paints, the vinyl acetate resins are particularly good for coating concrete and stucco.

### *Starch*

Starch, as already noted, is the most widely used binder for the clay coating of paper. In the United States, starch is derived from maize. Also used are tapioca starch from Indonesia and potato starch from the Netherlands.

Starch is available, of course, from many other vegetables, including rice. The various starches differ in their properties, e.g. the relative amounts of the crystalline amylose fraction and the amorphous amylopectin fraction, but it is possible to modify processing techniques so that most starches can be utilized.

The starches are treated with heat or acid catalysts to convert them into dextrins of various kinds: white, canary, and British gum. The white dextrins and the lighter types of British gums are the materials most widely used for colour coating, i.e. the clay coating of paper. In addition to clay, it is possible to incorporate into the coating calcium carbonate, titanium dioxide (for whiteness) or satin white.

Among the materials competing with starch in paper coating are polyvinyl acetate, casein and soy protein. Starch is adequate for most printing paper; and other materials may be preferred for the coating of paper for cartons that need some degree of water resistance.

### *Other polymers*

As the technology of a developing country becomes more sophisticated, a larger number of binder materials should be examined. At first, it will be preferable to import them from the highly industrialized countries. Later on, at least some of them can be made domestically.

#### *Phenolic resins*

Phenolic resins (phenol-formaldehyde resins) are made by the reaction of phenol and substituted phenols with formaldehyde. Formaldehyde and phenol are made synthetically from petroleum; phenol is also a product of the distillation of coal tar. Various cresols and other substituted phenols are also employed in the manufacture of coatings, especially when solubility in cheap hydrocarbon solvents is desired.

The main outlet for these materials is in metal finishes, both for maintenance and for original equipment of manufacturers. They are used on ships, trucks, buses, cans, motors and other electrical equipment, e.g. as wire enamels and for miscellaneous metal decorating. They may either be primers or top coats. They are being used to some extent in the water-borne primers being applied to metal articles by the new electrocoating techniques. Some phenolics, especially the modified oil-soluble types, go into trade sales coatings to be applied to floors and other surfaces that are exposed to heavy traffic.

The phenolics produce hard, durable, chemical-resistant surfaces. They may be slightly yellow to dark brown in colour, but this is usually not an objection.

*Amino resins*

Amino resins are made by the condensation of urea with formaldehyde or melamine with formaldehyde, often followed by reaction with butanol or isobutanol to give alkylated resins. The resins based on urea are less expensive, but those based on melamine have greater heat resistance. Both types have excellent colour.

Although they may be used alone, amino resins are more often blended or reacted with alkyds, epoxies or acrylics, in order to produce hybrids that combine the best features of the various constituents.

Metal finishing is again the main use for these thermosetting coatings. They are applied to cans, machinery, appliances, autos and trucks, railroad cars, and metal furniture, and may also be used on wood furniture and other wooden articles. Shrink-proof textiles are produced by treatment with melamine resins.

The amino resins are easy to manufacture. Furthermore, urea resins are among the staples in the manufacture of particle board and other adhesive-bonded wood products. These are discussed below. An amino resin manufacturing operation could readily serve both the coatings and adhesives fields.

*Acrylic resins*

Acrylic resins may be prepared either in emulsion or in solution, and may be either thermoplastic or thermosetting. Thermoplastic acrylic emulsions, made by polymerization of acrylic esters such as ethyl acrylate, methyl methacrylate and 2-ethylhexyl acrylate, are used for trade sales paints which must have very good resistance to ultra-violet light. As many of the developing countries are in the tropics, thermoplastic acrylic emulsion paints may have special merit as top coats for outdoor structures, over wood and other substrates. However, they are somewhat more expensive than vinyl acetate paints, and will be at a further comparative disadvantage in developing countries since vinyl acetate polymers are dual purpose materials used extensively in adhesives and in paints.

The solution-based acrylics, mostly thermosetting, are now being used extensively as top coats in automobiles and appliances. Again, their excellent colour and colour retention when exposed to light are important justifications for their use. The thermoplastic types are comprised principally of acrylate and methacrylate esters. The thermosetting types may consist partly or primarily of styrene, along with acrylate esters and acrylic acid or acrylamide. Cross-linking is brought about by reaction with the acid or amide groups or their derivatives, using amino resins, epoxies, and other resins.

*Styrene-butadiene resins*

Styrene-butadiene copolymers are popular in the United States as trade sales coatings for interior use. In Europe they are considered to be too light sensitive. In countries with hot climates and intense ultra-violet exposure, this key disadvantage of styrene-butadiene resins would be magnified. Furthermore, butadiene has such a high vapour pressure under polymerization conditions that it requires a high-pressure reactor and is dangerous to handle. For these reasons, styrene-butadiene resins are not recommended for developing countries. In both the United States and Europe, they are used as binders for the clay coating of paper, but they can be replaced by vinyl acetate polymers which can be made with less danger and in less expensive equipment.

*Vinyl chloride resins*

Vinyl chloride resins, homopolymers and copolymers, are widely used for the top-coating of textiles and for the internal coating of food cans. The latter operation calls for copolymers that require rather sophisticated know-how. On the other hand, the PVC resins for fabric coating would be more within the competence of technologists in developing countries.

The resins are applied to textiles in the form of plastisols and organosols. A plastisol is essentially a dispersion of resin in a high proportion of plasticizer, usually phthalate and adipate esters. An organosol is similar, except that some of the plasticizer is replaced by volatile solvents. Vinyl-coated fabrics go into upholstery, clothing, automobiles, washable wallpaper, and many other end-uses.

Vinyl chloride is among the cheapest of monomers, with the exception of the olefins, ethylene and propylene. The polymerization of vinyl chloride is well understood and "package plants", completely designed and instrumented, are available from many companies.

*Epoxy resins*

Epoxy resins are among the most useful of the newer base materials for both coatings and adhesives. They have excellent adhesion to metal and outstanding corrosion resistance, and consequently are used for auto primers, coatings of tin cans, marine coating, appliances, maintenance finishes etc. Two types are available. In the epoxy esters, the epoxy resin is reacted with unsaturated fatty acids to give a one-component, solution-based coating that dries by air oxidation. In two-component epoxies, the epoxy resin is mixed with a reactive amine hardener shortly before application to the surface. These are more expensive and more troublesome to use, but offer far better mechanical properties and corrosion resistance.

The technology of making epoxy resins is quite difficult and requires heavy capital investment. Therefore, it does not appear feasible for a developing country to go into the manufacture of these materials. On the other hand, imported epoxy resins can be easily used for formulating coatings and adhesives.

## *Pigments*

A paint may contain as many as a dozen different ingredients, the two most essential being the binder and the pigment. In the United States, the most important pigment for paints is titanium dioxide of the rutile type. About two thirds of paint pigments are titanium dioxide or other whites.

Modern technology for producing titanium dioxide from ilmenite is beyond the scope of most developing countries at the present time. Although the United States is the leading source of titanium ores they are found also in other parts of the world, notably Africa. Rutile ore itself is available in Sierra Leone.

Before the development of modern techniques for making titanium dioxide, the white lead pigments were much more prominent. These are still used to a minor extent in the developed countries, and have the advantage of providing a very thorough "dry", i.e. hardening property, with unsaturated oils. The largest deposits of lead are found in Australia and North America, but lead is also available in various Asian, North African and South American countries, as well as in Europe. The lead compounds of greatest interest for coatings are white lead itself, basic sulphate white lead and basic silicate white lead.

For corrosion resistance, the main pigments are red lead, basic lead silico-chromate, zinc yellow, and metallic zinc. Red lead is simply lead oxide made by roasting litharge. Zinc yellow, also known as zinc chrome, is a chromate pigment. Zinc deposits are often found in the same locations as lead ores.

The International Lead and Zinc Study Group (an intergovernmental body working in association with the United Nations) has published a report on lead and zinc consumption. Of the Asian countries (excluding Japan), India is the leading consumer of lead, with consumption for each of the past five years in excess of 40,000 metric tons. Mexico, Argentina and Brazil are the leading Latin American consumers.

Zinc is being utilized in sheet galvanizing plants in Argentina, Brazil, China (Taiwan), the Democratic Republic of the Congo, Ethiopia, Kenya, Malaysia, Mexico, Peru, the Philippines, Nigeria, the Republic of Korea, Thailand and Venezuela. In addition, there are continuous strip galvanizing plants in Argentina, India and Mexico. Roofing, siding, conduits, fuel drums and water storage tanks are main uses for the galvanized sheets steel.

Developing areas can receive advice on the use of zinc and lead from the Zinc Development Association and the Lead Development Association in London, as well as the Indian Lead Zinc Information Centre in Calcutta.

### *Examples of development*

According to a 1961 review by the Agricultural Information Division on paint in the Philippines, there were eighteen paint plants, fourteen of which employed 829 workers in 1960. Five of these fourteen plants were Philippine owned, while three others were Philippine controlled. The others were controlled or owned by American, British, Chinese or Swiss interests. Local raw materials included red oxide from iron scrap, inert pigment extenders from mineral deposits, alkyd resins, and local drying oils: lumbang oil, dehydrated castor oil, and even kapok oil.

In Somalia, a 1961 study indicated a need for a working capital of $34,300 to produce 25,000 US gallons of paint in 250 working days of one shift each with a staff of twelve employees. White lead was to be the principal pigment. The projected sales price was $4.43 per US gallon. The equipment required, at a delivered cost of $12,800, included two pebble mills, two portable paint mixers, twenty drums, three hand trucks, one platform scale, laboratory control equipment, miscellaneous scoops, ladles, measuring tins, maintenance tools, and spare parts.

A plant of similar capacity proposed for Honduras had a smaller capital investment, $6,240, because it had less equipment: one pebble mill, one portable paint mixer, ten drums, and two hand trucks.

From a 1966 pre-feasibility study of an expanded paint products industry in West Africa, one calculates an average consumption of paint per person per year varying from one pound or less for Nigeria and Sierra Leone to two pounds or more for Ghana, the Ivory Coast, and Senegal. Usage includes automobile lacquers and baked enamels for vehicle assembly plants in Ghana, Guinea, the Ivory Coast, Nigeria and Senegal, also furniture, office fixtures, and marine finishes.

For emulsion paints, polyvinyl acetate is imported dry from Europe, then redispersed with the aid of a Cowles disperser. Oil-based paints are made from drying oils, such as linseed oil, tung oil or castor oil, or from resin-modified drying oils or semi-drying oils, or rosin-modified oil. Both air drying and baking types are in use.

The formulations are mostly of European derivation and are not designed to take advantage of local materials. There is a dearth of competent paint technologists able to make effective changes in formulation.

## 3.2 Adhesives

As with coatings, the United States probably leads the world in adhesives usage *per capita:* approximately $4 worth per year at the adhesives compounder's level. Although the evidence of coatings usage is all around us, adhesives are generally not visible in the finished product. They are nevertheless all-important constituents for a score of products, e.g.:

Plywood
Particle board
Packaging
Water-moistened tapes, labels and envelopes
Pressure-sensitive tapes and labels
Tires
Brake linings
Other automobile components
Shoes
Books
Foundry sand moulds
Coated and bonded abrasives
Building components
Consumer and other small package adhesives
Mobile homes
Aircraft
Non-woven fabrics
Flocked fabrics

A developing country would be unlikely to have such applications as aircraft and automobiles. On the other hand, there should be good opportunities in many countries to develop at least the various wood industries that make use of adhesives.

Since many applications use more than one type of adhesive, the adhesives industry is discussed below on the basis of end-products rather than materials.

### *Wood products*

In the United States, plywood is made mostly from softwood, particularly the Douglas Fir that grows in the northwestern United States and southwestern Canada. More recently, the southeastern states have become sites for plywood manufacture, using fast-growing Southern Pine. The favoured resin for American plywood manufacture is phenol-formaldehyde, which permits the manufacture of a grade of plywood that can stand heat and humidity, alone or in combination.

Grades of plywood suitable for indoor use, where they will not stay damp, are made in the United States from plywood veneers with urea-formaldehyde resin as the adhesive. Some imported cheaper grades of plywood have even used starch as the binder.

Many woods can be put into plywood, including the hardwoods, such as Philippine mahogany. Thus, it is possible for almost any country with forests to make plywood.

Various other materials have been or can be used, e.g. casein, polyvinyl acetate, soy flour mixed with animal blood. However, phenol-formaldehyde gives by far the best quality of product, and is especially desirable if the plywood is to be used outdoors or below ground. In tropical countries, the necessity for durability of phenolic resins becomes all the more imperative.

Both phenol and formaldehyde are derived petrochemically in the United States. Phenol is also available as a product of the coal tar industry.

Softwood plywood is used primarily in buildings, e.g. wall panels, flooring, roofing and so on. Hardwood is used in furniture where the beauty of the top veneer is important.

In particle board, wood particles, usually flat chips, are bonded together with urea-formaldehyde resins. Many types of wood have been used and in some factories, even blended. The particle board, 0.75 inch thick, is a useful underlay on which plastic tile can be glued. With suitable veneers it can be fashioned into furniture that is dimensionally stable and attractive.

Other wood products that make use of adhesive resins include hardboard, laminated doors, edge-glued and end-glued timber. Adhesive resins have high wet strength and are used by the paper industry to provide honeycombs for laminated doors and partitions.

For gluing furniture joints, animal glue was the standard adhesive until a few years ago. The hide glues are strongest, the bone glues cheapest. Fluctuating supply and price have caused many animal glue users to shift to other materials. However, in a thinly populated country, where the ratio of animals to humans is high, the animal glue industry should be a profitable by-product of the meat industry.

In the United States vinyl acetate resins are rapidly replacing animal glue for furniture, bookbinding and various other uses.

### *Packaging*

In the United States, packaging is almost as important an outlet for adhesives as the wood industry. Food and other articles are placed in paper bags, bottles or cans with adhesive-bonded labels, set-up boxes, envelopes and paper tubes. Smaller containers go into corrugated cartons made with adhesives, which themselves must be sealed with adhesives. To these can be added laminates, cigarettes, paper-backed tapes (both pressure-sensitive and re-wettable), postage stamps, fibre drums and so on.

As industry grows in the developing countries and as channels of distribution become more complex, there will be an increased need for containers and the adhesives with which to make or seal them.

The main adhesives for packaging in the developing countries and in the United

States will certainly be starch and dextrin. Animal glue, if available, can be most useful, especially as an adjunct to dextrin in the manufacture of re-wettable gummed products. Where moisture resistance or high strength is required, polyvinyl acetate will be the preferred adhesive.

### *Building products*

Many types of adhesives are used in the building industry of the United States. There, as in a developing country, cost is a key criterion for the selection of adhesives.

One of the cheapest building materials in the United States, gypsum board, is made by bonding hydrated calcium sulphate, which is widely available, with dextrin and other inexpensive adhesives. Additional adhesive is required for the application of the paper facings, sometimes for replacing nails in fastening the board to the studs, and also for finishing the wall to present a smooth appearance. For the latter purpose, both casein-based joint cement (dry) and polyvinyl acetate joint cement (wet, ready-mixed) are employed.

Glass wool insulation is still another adhesive-bonded product. Phenol-formaldehyde resin has been found to be the cheapest adhesive that meets the needs of this product in resistance to heat and humidity.

Resilient flooring, typified by vinyl asbestos tile, has been growing in the United States as a means of covering concrete, particle board or wooden sub-flooring. A variety of adhesive compositions are employed, many of them based on petroleum-derived asphalt. Natural bitumens could also be used.

### *Shoes*

In the developing countries, particularly those with cooler climates, the shoe industry will be turning more and more to adhesives for making products similar to those used in the United States. Adhesives are used for attaching thin soles to uppers, for bonding fabric to leather and leather to leather in the uppers, and for manufacturing built-up heels and box-toes. Neoprene rubber and natural rubber are two of the most important adhesive materials. The rubbers are used both as solvent cements and as latexes. Natural rubber is likely to be available in at least some of the developing countries. It is an outstanding adhesive when properly formulated, and should be adequate for most applications in the shoe industry.

### *Examples of development*

Borden Chemical Company has had considerable experience with the manufacture of adhesives in South America. In Brazil, they started with casein glues, then proceeded to vinyl acetate-based adhesives, phenol-formaldehyde and epoxies. Rhodesia has a pilot plant for making vinyl acetate monomer, but it has been necessary to import this essential intermediate from the United States. Epoxy resins are imported from Europe. The Bungeborn Company makes phenol from benzene supplied by Petrobrás of Brazil.

Borden obtains formaldehyde from methanol, which it makes from Bunker C oil by oxidation. The company is now progressing to naphtha reforming for making the methanol. In Argentina, on the other hand, formaldehyde is made from natural gas.

The use of casein in adhesives is decreasing even in Argentina, formerly the leading exporter of casein. It is still being exported to the United States as a binder for the clay coating of paper, but there, as well, it is being replaced by soya protein or synthetics. The chief reason for the decline of casein as an industrial raw material is the increased consumption of milk as food.

Professor Ben S. Bryant of the University of Washington has provided interesting information on the feasibility of even very small adhesives operations for the manufacture of plywood and other bonded wood products in China (Taiwan).

There are about nineteen active plywood plants in Taiwan. These plants peel logs of Philippine mahogany or similar woods brought in from the Philippines and Malaysia, which are largely exported in the form of plywood and associated millwork lumber to the United States. Taiwan enjoys about one fifth of the American market for imported Philippine mahogany plywood made in the Far East. Japan and the Republic of Korea are equally large producers. Because of the type of plywood manufactured, interior (types 2 and 3 non-water resistant bonds), nearly all of the adhesive used is extended urea resin.

As wheat is not produced locally and is expensive to import, the urea resin is not extended with wheat flour as it is in the United States, but instead with cassava flour. This is a starchy, tuberose root that is cultivated in China (Taiwan) and elsewhere in countries of South East Asia. It is a relative of tapioca and furnishes the primary local source of starch.

The only technical man in some plywood plants is likely to be the glue mixer, who has his own formulation for plywood, which he probably keeps secret from the other plants.

Taiwan is a principal source of urea in the Far East as a result of its low-cost hydroelectric power. Urea fertilizer is exported. Phenol, on the other hand, is imported from Japan. With the growing petrochemical industry in Taiwan, however, local sources of formaldehyde are available. While most plywood plants and some board plants manufacture their own adhesives, there are two plants not connected with plywood manufacture which produce the following resins: urea-formaldehyde, melamine-formaldehyde, epoxy, vinyl acetate polymer and phenol-formaldehyde.

In the Philippines, two American companies have plants for making liquid phenolic resin. In addition, powdered phenolic resin is imported from the Federal Republic of Germany.

In Brazil, one of the largest forest products companies makes its own phenolic resin and phenolic paper glue line for gluing aluminium foil to the surface of corrugated plywood. This company also makes a phenolic-impregnated paper overlay to be glued to plywood used for concrete formwork.

## *Conclusions*

In both coatings and adhesives it is possible to take advantage of the materials and resources of the region to make products that can be utilized within the region. The coatings and adhesives technologies of developing countries can be greatly simplified compared with those employed in the United States. The economics of production on a small scale are favourable for polyvinyl acetate, alkyd resins, phenolic resins, starches and dextrins and animal glues. With the aid of unsaturated oils and natural rubber, if these are available, one can adjust the technique to make almost all the desired end-products.

Initially, the petrochemicals (or coal chemicals) can be imported. As a petrochemical industry is built up in the region, phthalic anhydride, vinyl acetate, phenol and formaldehyde can be among the first intermediates to be produced.

Coatings and adhesives are only two phases of the polymer industries, along with plastics, fibres, and elastomers. The equipment and technology for making these few resins is applicable for many other polymers and end-products.

Where does an entrepreneur or a government in a developing country go for technical assistance in building a coatings or adhesives industry? There are two main sources of information.

First, many chemical construction companies design and build package plants, as so-called "turn-key operations", in which everything is prepared so that the user, in theory at least, need only turn the key to start the operation. Obviously, the ease with which such a plant can be started and made functional depends on the experience and skill of the people who operate it.

The other source of assistance, overlapping and complementary to the first, is the consulting firm with relevant experience. A list of chemical consultants qualified to handle a particular topic may be obtained from the Association of Consulting Chemists and Chemical Engineers, Inc., 52 East 41st Street, New York, New York 10017.

The chemical construction companies are usually more able to provide plants for the manufacture of phthalic anhydride, vinyl acetate, phenol, and other basic chemicals. On the other hand, the consultants are better adapted to provide information on manufacturing formulated products, such as coatings and adhesives, and especially on taking advantage of local raw materials.

# ANNEXES

## ANNEX 1. RAW MATERIALS FOR PLASTICS: SELECTED SUPPLIERS, PROCESSING METHODS AND COSTS

| *Resin type* | *Selected major producers[a] and resin trade names* | *Processing methods applicable* | *Typical uses* | *US prices: cents per pound* | *US prices: cents per inch³* |
|---|---|---|---|---|---|
| Thermoplastics | | | | | |
| Acrylonitrile-butadiene-styrene (ABS) | Marbon Chemical Div., USA, (Cycolac)<br>Uniroyal, Inc., USA, (Kralastic)<br>Bayer, Germany, 509, (Novodur)<br>Anchor Chemicals, England, (Cycolac)<br>Ugine, France, (Kralastic)<br>Mazzuchelli Celluloide, Italy, (Sicoflex)<br>Toyo Rayon Co., Japan, (Toyolac) | Injection moulding<br>Extrusion<br>Thermoforming | Pipe and fittings<br>Industrial parts<br>Containers<br>Telephone housings | 28 – 36 | 1.07 – 1.4 |
| Acetal resins | Celanese Plastics Corp., USA, (Celcon)<br>Du Pont, USA, (Delrin)<br>ICI, England, (Kematal)<br>Hoechst, Germany (Fed. Rep.), 6230, (Hostaform)<br>Polyplastics Co. Ltd., Japan (Duracon) | Injection moulding<br>Blow moulding<br>Extrusion | Industrial parts | 65 | 3.34 |
| Acrylics | Du Pont, USA, (Lucite)<br>Rohm Haas Co., USA, (Plexiglas)<br>Resart, Germany, 65, (Resarit)<br>ICI, England, (Diakon)<br>Altulor, France, (Altulite)<br>Sumitomo Chemical Co. Ltd., Japan, (Sumipex – B) | Injection<br>Extrusion<br>Castings<br>Thermoforming | Signs<br>Shoe heels<br>TV lenses<br>Displays | 45.5 | 1.96 |

| | | | | | |
|---|---|---|---|---|---|
| Cellulosics | Celanese Plastics Co., USA, (Forticel)<br>Eastman Chemical Products, Inc., USA, (Tenite)<br>Bayer, Germany, 509, (Cellidor and Triafol)<br>Daicel Ltd., Japan, (Acetyloid) | Injection<br>Extrusion<br>Thermoforming | Pens and pencils<br>Brushes<br>Industrial parts<br>Blister packaging | Cellulose acetate 40–52<br>CAB–CP 62 | 1.83–2.38<br>2.71 |
| Nylon | Allied Chemical Corp., USA, (Plaskon)<br>Celanese Corp., USA<br>Du Pont, USA, (Zytel)<br>ICI, England, (Maranyl)<br>BASF, Germany, 6700, (Ultramid)<br>Toyo Rayon Co., Japan, (Amilan) | Injection moulding<br>Blow moulding<br>Extrusion<br>Casting direct from type 6 monomer | Zippers<br>Film<br>Gears<br>Wire insulation<br>Bristles<br>Bobbins | 87.5[b] | 3.60 |
| Polycarbonates | General Electric Co., USA, (Lexan)<br>Mobay Chemical Co., USA, (Merlon)<br>Bayer, Germany, 509, (Makrolon)<br>Mitsubishi Edogawa Chemicals, Japan, (Jupllon)<br>Teijin Chemical Co., Japan, (Panlite) | Injection moulding<br>Blow moulding<br>Extrusion<br>Thermoforming | Glazing<br>Coil forms<br>Camera parts<br>Gears | 80 | 3.47 |
| Polyethylene-high-density | Allied Chemical Corp., USA, (Grex)<br>Celanese Plastics Co., USA, (Fortiflex)<br>Du Pont, USA, (Alathon)<br>Phillips Petroleum Co., USA, (Marlex)<br>Hoechst, Germany (Fed. Rep.), 6230, (Hostalen G) | Injection moulding<br>Blow moulding<br>Extrusion<br>Thermoforming<br>Coating | Bottles<br>Automotive parts<br>Seating<br>Toys<br>Containers<br>Pipe | 0.17 | 0.6 |

ANNEX 1 *(continued)*

| *Resin type* | *Selected major producers[a] and resin trade names* | *Processing methods applicable* | *Typical uses* | *US prices* cents per pound | *US prices* cents per inch$^3$ |
|---|---|---|---|---|---|
| | Shell Chemical Co., England, (Carlona)<br>Solvay & Cie. SAS, Italy, (Eltex)<br>Mitsui Petrochemical Industries, Ltd., Japan, (Hi-Zex) | | | | |
| **Polyethylene-low-density** | Du Pont, USA, (Alathon)<br>Union Carbide Corp., USA, (Bakelite)<br>U.S. Industrial Chemicals Co., USA, (Petrothene XL)<br>BASF, Germany, 6700, (Lupolen)<br>ICI, England, (Alkathene)<br>Celene, Italy<br>Sumitomo Chemical Co. Ltd., Japan, (Sumikathene) | Injection moulding<br>Blow moulding<br>Extrusion<br>Thermoforming<br>Coating | Household ware<br>Toys<br>Squeeze bottles<br>Industrial and packaging films<br>Pipe<br>Paper coatings | 0.15 | 0.5 |
| **Polypropylene** | AviSun Corp., USA, (Olefane)<br>Eastman Chemical Products, Inc., USA, (Tenite)<br>Enjay Chemicals, USA<br>Hercules Inc., USA, (Hi-fax)<br>Hoechst, Germany (Fed. Rep.), 6230 (Hostalen PP)<br>Monteshell Petrochimica, Italy, (Moplen)<br>ICI, England, (Propathene)<br>Mitsui Petrochemical Industries Ltd., Japan, (Noblen) | Injection moulding<br>Blow moulding<br>Extrusion<br>Thermoforming<br>Coating | Packaging films<br>Mono and multifilament<br>Household ware<br>Toys<br>Industrial parts | 0.18 | 0.6 |

| | | | | | |
|---|---|---|---|---|---|
| **Polystyrenes** | Dow Chemical Co., USA, (Styron)<br>Rexall Chemical Co., USA, (El Rexene)<br>Sinclair-Koppers Co., USA, (Dylene)<br>Union Carbide Corp., USA, (Bakelite)<br>BASF, Germany, 6700, (Luran, Styropor, Styrofan)<br>Dow Chemical, S.p.A., Italy, (Styron)<br>Monsanto, France, (Lustrex)<br>Asahi Dow, Japan, (Styron) | Injection moulding<br>Blow moulding<br>Extrusion<br>Thermoforming<br>Coating | Containers<br>Toys<br>Housewares<br>Foams<br>Packaging films<br>Industrial parts | 17–27 | 0.64–1.00 |
| **Polyurethanes** | B. F. Goodrich Chemical Co., USA, (Estane)<br>Mobay Chemical, USA<br>Reichold Chemicals, USA<br>Bayer, Germany, 509, (Vulkollan and Desmopan)<br>Takeda Chemical Industries, Ltd., Japan, (Takenate) | Injection moulding<br>Extrusion<br>Casting<br>Foaming | Cushioning<br>Insulation<br>Padding | | |
| **Vinyls** | B. F. Goodrich Chemical Co., USA, (Geon)<br>Borden Chemical Co., USA<br>Diamond Alkali Co., USA, (Diamond)<br>Union Carbide Corp., USA, (Bakelite)<br>BASF, Germany (Fed. Rep.), 6700, (Lutofan, Vinoflex)<br>Péchiney-Saint-Gobain, France, (Lucolene)<br>ICI, England, (Corvic, Welvic)<br>Japan Geon Co., Japan, (Geon) | Injection moulding<br>Blow moulding<br>Extrusion<br>Thermoforming | Packaging and industrial films<br>Industrial parts<br>Phonograph records<br>Pipe fittings<br>Tiles<br>Shoes | 10–30 (depending on type and form) | |

ANNEX 1 *(continued)*

| *Resin type* | *Selected major producers*[a] *and resin trade names* | *Processing methods applicable* | *Typical uses* | *US prices cents per pound* | *US prices cents per inch*$^3$ |
|---|---|---|---|---|---|
| **Thermosets** | | | | | |
| **Phenolics** | General Electric Co., USA,<br>Hooker Chemical Corp., USA, (Durez)<br>Reichold Chemicals Inc., USA, (Plyophen)<br>Union Carbide Corp., USA, (Bakelite)<br>La Bakélite, France, (Bakelite)<br>Plastugil, France, (Progilite)<br>BASF, Germany (Fed. Rep.), 6700, (Kauresin)<br>ICI, England, (Mouldrite)<br>Sumitomo Bakelite Co., Japan, (Sumikon) | Compression and transfer moulding<br>Casting | Electrical and electronic components<br>Appliance handles and knobs<br>Ducts and blowers | 20–115 (depending on fillers) | |

[a]See annex 2 for names and addresses of resin suppliers listed.
[b]Present price 75 cents per pound.

## ANNEX 2. SELECTED MAJOR PRODUCERS OF RAW MATERIALS FOR PLASTICS

| *Producer* | *Address* |
|---|---|
| **THERMOPLASTICS** | |
| Acetal resins | |
| Celanese Plastics Co. | Newark, New Jersey, USA |
| E.I. Du Pont de Nemours & Co. | Wilmington, Delaware, USA |
| Imperial Chemical Industries, Ltd | London, England |
| Farbwerke Hoechst AG | Frankfurt/Main, Germany (Fed. Rep.) 6230 |
| Polyplastics Co. Ltd | Osaka, Japan |
| Acrylonitrile-butadiene-styrene (ABS) | |
| Marbon Chemical Div., Borg-Warner Corporation | Washington, West Virginia, USA |
| Uniroyal, Inc. | New York, New York, USA |
| Farbenfabriken Bayer AG | Leverkusen, Germany (Fed. Rep.) 509 |
| Anchor Chemical Co. Ltd | Manchester, England |
| Ugine | Paris, France |
| Mazzuchelli Celluloide | Castiglione Olona, Varese, Italy |
| Toyo Rayon Co. | Tokyo, Japan |
| Acrylics | |
| E. I. Du Pont de Nemours & Co. | Wilmington, Delaware, USA |
| Rohm & Haas Co. | Philadelphia, Pennsylvania, USA |
| Imperial Chemical Industries, Ltd | London, England |
| Altulor | Paris, France |
| Resart Gesellschaft, Kalkhof und Rose Chemische Fabrik | Mainz, Germany (Fed. Rep.) 65 |
| Sumitomo Chemical Co., Ltd | Osaka, Japan |
| Cellulosics | |
| Celanese Plastics Co. | Newark, New Jersey, USA |
| Eastman Chemical Products, Inc. | Kingsport, Tennessee, USA |
| Farbenfabriken Bayer AG | Leverkusen, Germany (Fed. Rep.) 509 |
| Daicel Ltd | Osaka, Japan |
| Nylon | |
| Allied Chemical Corporation | Morristown, New Jersey, USA |
| Celanese Plastics Co. | Newark, New Jersey, USA |
| I. E. Du Pont de Nemours & Co. | Wilmington, Delaware, USA |
| Imperial Chemical Industries, Ltd | London, England |
| Badische Anilin- & Soda-Fabrik AG | Ludwigshafen/Rhein, Germany (Fed. Rep.) 6700 |
| Toyo Rayon Co. | Tokyo, Japan |
| Polyethylene (high-density) | |
| Allied Chemical Corporation | Morristown, New Jersey, USA |
| Celanese Plastics Co. | Newark, New Jersey, USA |
| E. I. Du Pont de Nemours & Co. | Wilmington, Delaware, USA |
| Phillips Petroleum Co. | Bartlesville, Oklahoma, USA |

ANNEX 2 *(continued)*

| *Producer* | *Address* |
|---|---|
| Farbwerke Hoechst AG | Frankfurt/Main, Germany (Fed. Rep.) 6230 |
| Shell Chemicals Ltd | London, England |
| Solvay & Cie, SAS | Milan, Italy |
| Mitsui Petrochemical Industries Ltd | Tokyo, Japan |
| Polyethylene (low-density) | |
| E. I. Du Pont de Nemours & Co. | Wilmington, Delaware, USA |
| Union Carbide Corporation | New York, N.Y., USA |
| U.S. Industrial Chemicals Co. | New York, N.Y., USA |
| Imperial Chemical Industries, Ltd | London, England |
| Badische Anilin- & Soda-Fabrik AG | Ludwigshafen/Rhein, Germany (Fed. Rep.) 6700 |
| Celene, SA | Milan, Italy |
| Sumitomo Chemical Co., Ltd | Osaka, Japan |
| Polypropylene | |
| AviSun Corporation | Philadelphia, Pennsylvania, USA |
| Eastman Chemical Products, Inc. | Kingsport, Tennessee, USA |
| Enjay Chemical Co. | New York, N.Y., USA |
| Hercules, Incorporated | Wilmington, Delaware, USA |
| Farbwerke Hoechst AG | Frankfurt/Main, Germany (Fed. Rep.) 6230 |
| Imperial Chemical Industries, Ltd | London, England |
| Monteshell Petrochimica, SA | Milan, Italy |
| Mitsui Petrochemical Industries Ltd | Tokyo, Japan |
| Polystyrenes | |
| Dow Chemical Co. | Midland, Michigan, USA |
| Rexall Chemical Co. | Paramus, New Jersey, USA |
| Koppers Company, Inc. | Pittsburgh, Pennsylvania, USA |
| Union Carbide Corporation | New York, N.Y., USA |
| Badische Anilin- & Soda-Fabrik AG | Ludwigshafen/Rhein, Germany (Fed. Rep.) 6700 |
| Dow Chemical, S.p.A | Milan, Italy |
| Monsanto | Paris, France |
| Asahi Dow | Tokyo, Japan |
| Polyurethanes | |
| B. F. Goodrich Chemical Co. | Cleveland, Ohio, USA |
| Mobay Chemical Co. | Pittsburgh, Pennsylvania, USA |
| Reichold Chemicals Inc. | White Plains, New York, USA |
| Farbenfabriken Bayer AG | Leverkusen, Germany (Fed. Rep.) 509 |
| Takeda Chemical Industries Ltd | Osaka, Japan |
| Vinyls | |
| B. F. Goodrich Chemical Co. | Cleveland, Ohio, USA |
| Borden Chemical Co. | New York, N.Y., USA |
| Diamond Alkali Co. | Cleveland, Ohio, USA |
| Union Carbide Corporation | New York, N.Y., USA |

| | |
|---|---|
| Badische Anilin- & Soda-Fabrik AG | Ludwigshafen/Rhein, Germany (Fed. Rep.) 6700 |
| Imperial Chemical Industries, Ltd | London, England |
| Péchiney-Saint-Gobain | Paris, France |
| Japan Geon Co. | Tokyo, Japan |

THERMOSETS

Phenolics

| | |
|---|---|
| General Electric Co. | Pittsfield, Massachusetts, USA |
| Hooker Chemical Corporation | Hicksville, New York, USA |
| Durez Div., Hooker Chemical Corporation | North Tonawanda, New York, USA |
| Union Carbide Corporation | New York, N.Y., USA |
| Badische Anilin- & Soda-Fabrik AG | Ludwigshafen/Rhein, Germany (Fed. Rep.) 6700 |
| La Bakélite | Bezons, France |
| Plastugil | Paris, France |
| Sumitomo Bakelite Co. | Osaka, Japan |

## ANNEX 3. INJECTION-MOULDING MACHINERY AND ITS SUPPLIERS

| *Type* | | *Clamp force (tons)* | *Injection capacity (oz/shot)* | *Plasticizing capacity (lb/hour)* | *Manufacturer* |
|---|---|---|---|---|---|
| **Ram or plunger** | H–R | 30 | 2 | 25 | Van Dorn Plastic Machinery Company, Cleveland, Ohio |
| | H–R | 275 | 10 | 120 | Reed-Prentice Division, Long Meadow, Mass. |
| | H–R | 1,000 | 80 | 400 | Farrel Corp., Rochester, N.Y. |
| **Screw** | H–IS | 17 | 1.7 | 17.7 | Battenfield Corp. of America, Chicago, Ill. |
| | V–RS | 90 | 13 | 120 | Moslo Machinery Co., Cleveland, Ohio |
| | H–RS | 220 | 19 | 170 | Meiki Co. Ltd., Nagoya, Japan |
| | H–RS | 325 | 35 | 250 | National Automatic Tool Co., Richmond, Ind. |
| | H–RS | 4,000 | 280 | 460 | |
| | | | 420 | 572 | Mannesmann AG, Düsseldorf, Germany (Fed. Rep.) |
| | | | 720 | 702 | |
| **Thermoset** | V–RS | 250 | 22.5 | | F. J. Stokes Corp., Philadelphia, Pa. |

Key: H = Horizontal; V = Vertical
R = Ram; S = Screw
RS = Reciprocating screw; IS = In-line screw plastizer injector

## ANNEX 4. BLOW-MOULDING MACHINERY AND ITS SUPPLIERS

| *Maximum container size* | *Parisons (per cycle)* | *Parts (per hour)* | *Manufacturer* |
|---|---|---|---|
| 8 oz | 1 – 4 | 2,000–50 | Kantex, Germany (Fed. Rep.) |

## ANNEX 5. EXTRUDING MACHINERY AND ITS SUPPLIERS

| *Type* | *Screw diameter (inches)* | *4D ratio* | *Heating zones* | *Manufacturer* |
|---|---|---|---|---|
| Single-screw | 0.5 | 20 | 2 | Reifenhausen, Germany (Fed. Rep.) |
| | 2.5 | 20 | 3 | NRM Corp., Akron, Ohio |
| | 6.0 | 20 | 4 | Waldron-Hartig Division, Midland-Ross Corp., New Brunswick, N.J. |
| | 10.0 | 21 | 6 | Sterling Extruder Corp., Linden, N.J. |
| Twin-screw | 2.5 | 12 | 4 | Anger Plastic Maschinen, Munich, Germany (Fed. Rep.) |
| | 6.0 | 25 | 6 | Welding Engineers Inc., Norristown, Pa. |

## ANNEX 6. COMPRESSION AND TRANSFER-MOULDING MACHINERY AND THEIR SUPPLIERS

| *Type* | *Capacity (tons)* | *Moulding area (sq. inches)* | *Manufacturer* |
|---|---|---|---|
| Compression | 25 | 390 | F. J. Stokes Corp., Philadelphia, Pa. |
| | 100 | 480 | HPM Div., Koehring Co., Mt. Gilead, Ohio |
| Transfer-moulding | 25 | 160 | British Industrial Plastics Ltd., Warley, England |
| | 100 | 420 | Farrel Corp., Rochester, N.Y. |
| | 300 | 930 | Triulzi S.p.A., Milan, Italy |

## ANNEX 7. THERMOFORMING MACHINERY AND ITS SUPPLIERS

| *Type* | *Forming area L X W (inches)* | *Draw depth (inches)* | *Feed type (sheet or roll)* | *Manufacturer* |
|---|---|---|---|---|
| Vacuum | 10 X 20 | 1 | Sheet | Precision Products and Controls Inc., Tulsa, Okla. |
| | 20 X 25 | 6 | Roll | Auto-Vac Co., Tabor City, N.C. |
| | 30 X 36 | 29 | Sheet | Brown Machine Co., Beaverton, Mich. |
| Pressure | 48 X 96 | 25 | Sheet | American ThermoForm Corp., Pico Rivera, Calif. |
| Pressure and/ or vacuum | 10 X 10 | 6 | Sheet | Comet Industries Inc., Bensonville, Ill. |
| | 15 X 19 | 5 | Roll | Italmec, Bologna, Italy |

## ANNEX 8. PRICE LIST FOR RECIPROCATING-SCREW INJECTION MACHINE

### PRICE LIST

*(Effective from October 6, 1966)*

# RECIPROCATING SCREW INJECTION MACHINE

**Complete** with:

- THREE ZONE PYROMETER CONTROL (MODEL 272P WHEELCO OR JP WEST)
- BIJUR AUTOMATIC OIL LUBRICATION SYSTEM
- GENERAL PURPOSE SCREW WITH NON-RETURN VALVE
- ELECTRIC MOTOR SCREW DRIVE
- STANDARD NOZZLE
- HYDRAULIC SYSTEM ELECTRIC MOTOR
- POWER OPERATED SINGLE POINT DIE HEIGHT ADJUSTMENT
- SCREW-TECTOR ELECTRO-MECHANICAL SAFETY SYSTEM
- LOW PRESSURE CLOSING . . . . . . . . . . . . . . . . . . . . **$50,750.00**

### STANDARD OPTIONAL EQUIPMENT

| | |
|---|---|
| Nozzle Temperature Control: | |
| Powerstat Control in cabinet, heater band and open extended standard or nylon nozzle | $275.00 |
| Pyrometer Control in cabinet, heater hand and open extended standard or nylon nozzle | 465.00 |
| Standard Nozzle 1/2" or 3/4" radius | 55.00 |
| Extended Standard or Nylon Nozzle 1/2" or 3/4" radius | 100.00 |
| 15 KVA Transformer to reduce incoming voltage to 220 volt, single phase for heating circuit and 110 volt for control circuit (second breaker kit not required) | 450.00 |
| Hopper Magnet | 140.00 |
| One (1) set of Wedgemount Mounting Pads (10) | 170.00 |
| 2-3/4" dia. General Purpose Screw (does not include Non-Return Valve)) | 775.00 |
| General Purpose Non-Return Valve comprising Tip, Sleeve and Sleeve Seat | 250.00 |
| 2-3/4" dia. PVC Screw (less Smear Tip) | 825.00 |
| PVC Tip | 100.00 |
| PVC Nozzle | 55.00 |
| Screw Pull Back (see Supplement for Sequence) | 400.00 |
| Center Hydraulic Ejector (see Supplement for Sequence) | 1,750.00 |
| Plate Type Hydraulic Ejector (see Supplement for Sequence) | 1,800.00 |
| Stop Arrangement for intermediate platen positioning | 225.00 |
| Sterlco Water Saver Valve installed | 125.00 |
| Screw Feed Throat Thermometer | 35.00 |
| Color requirements other than standard (vista-green) | 150.00 |
| Key Reset Electrical Cycle Counter | 100.00 |
| Intrusion Mold Kit | 250.00 |
| Core Pull Arrangement "A" | 1,100.00 |
| Core Pull Arrangement "B" | 1,100.00 |
| Core Pull Arrangement "A" or "B" (selective) (See Supplement for Core Pull Sequences) | 1,250,00 |
| Export Boxing Charge | 1,500.00 |

All prices NET F.O.B. Cleveland, Ohio. **Subject to change without prior notice**

***Source:*** **Van Dorn Plastic Machinery Company, Cleveland, Ohio.**

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**United Nations publication**

**68-2084–February 1970–4,250**

**Sales No.: E.69.II.B.32**

**ID/SER.J/3**

14. 12. 73