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PLASTICS FABRICATION AND RAW MATERIALS INTEGRATION IN DEVELOPING COUNTRIES[1/]

by

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1/ The views and opinions expressed in this paper are those of the author and do not necessarily reflect the views of the secretariat of UNIDO.

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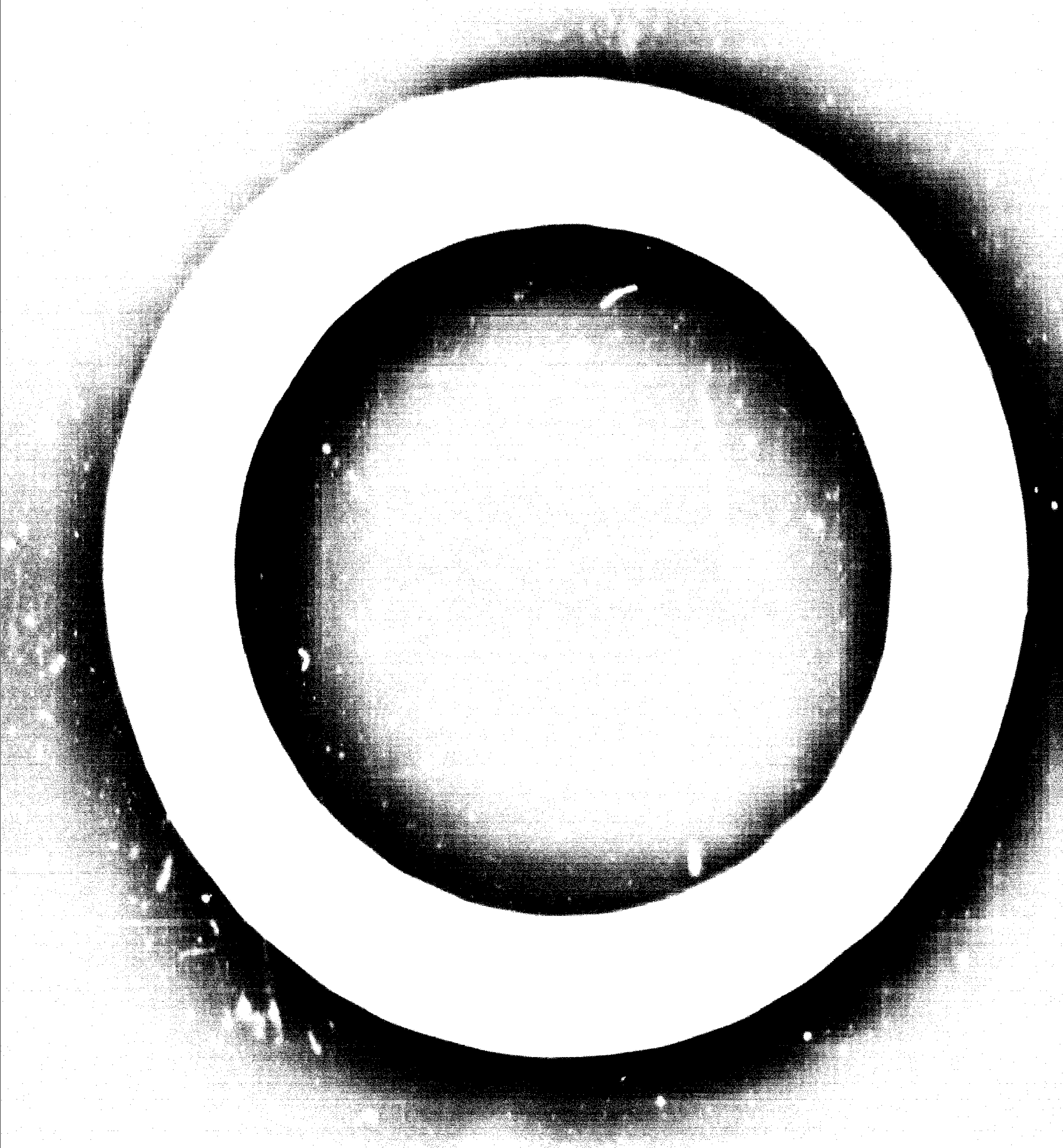


Introduction

1. The diversity among the developing countries in size, physical resources and socio-economic functions makes it impossible 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 strongly 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 utilized as they are. However, many other factors which affect the success of an integrated plastics industry do usually 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.

2. 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 key factors for success. Increased income [illegible], 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 which have contributed to the healthy growth of the plastics industry in developing countries around the world.

3. 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 which influence what is best for the country. However, it is clear that for many countries with the resources necessary for progressing from the stage of recognizing 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 determinant to the success of the venture. The wide latitude in the types 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 semi-finished goods. The expansion of export

similarly strengthens the balance of payments position. The reasons for plastics-petrochemical integration have been well documented. 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.

CHAPTER I PLASTICS INDUSTRY IN DEVELOPING COUNTRIES

Scope and importance of a plastics industry

4. 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 goals 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 from steel and glass respectively. Consumer and industrial plastic products that are imported can be made internally and some portion of production can often be exported. As consumption of polymers for these finished goods grows, the gradual manufacture of intermediates can be planned. In short, the development of a fabricating industry is a key step towards eventual backward integration to basic feedstocks from coal, oil or gas. The successful establishment of an integrated plastics industry affects a broad group of other industries over a period of time, since feedstocks can be upgraded into fibres, fertilizers, detergents, coatings, adhesives, carbon black and so on. The continued substitution of imports in all these areas helps countries lacking in capital resources and foreign exchange. Expanded export similarly strengthen the balance of trade.

5. During the last decade, more and more developing countries have established and 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 the execution of further backward integration.

6. Since it would be difficult to analyse and evaluate the approaches taken by all developing countries, a group of selected countries from the LAFTA (Latin American Free Trade Association) and ECAFE (Economic Commission for Asia and the Far East) regions has been chosen as representative examples. While statistics documenting the nature and growth of plastic industries in these countries vary considerably among several sources, the basic thinking

conditions which 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 encountered in developing a plastics industry

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

(a) Lack of adequate end product demand;

(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.

8. Government restrictions have been a major problem in many countries attempting to start or 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 a low rate of capacity because the government would not allocate foreign exchange for importing resin.

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

10. Many governments have aided the growth of the plastics industry based on the long-range tie-in with establishment of a 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 rebate part or all of the import duties on imported plastic materials that are fabricated into finished goods intended for export.

Fabrication industry

11. The plastics fabrication industries of developing countries often share several common 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. Many of these print and convert film to bags for sale to various end users. Injection moulders rely on proprietary products, usually housewares, toys and other consumer products. Custom moulded components (e.g. appliance housings) is limited in most countries. Smaller fabrication units operate in areas outside the cities. In some countries three or four fabricators account for 50-90 per cent of a specific market. Many are owned in part by resin producers, or vice versa.

12. Extrusion, injection moulding and compression moulding represent well over 90 per cent of resin usage. Blow moulding and foam moulding are introduced during the latter stages of industry growth.

13. Lack of good moulds, credit problems, machine overcapacity and raw material shortages are some of the problems which most fabricators face at one time or another. Production of suitable moulds is expensive and technically demanding. Imports from foreign sources is one alternative. Credit squeezes are almost universal, since 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 prior to 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 and/or moulds. The combination of low-cost materials and uniqueness of product line has been instrumental in the growth of many fabricators operating in extremely competitive conditions. Government restrictions on imports of plastic raw materials have been alleviated in many countries by documented presentations showing the benefits of a healthy plastics industry to the economy.

Moulds

14. 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. The poor quality and delivery problem also decreases 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 starting plant operations.

15. Establishing mould-making facilities is important for the growth of a plastics fabrication industry. This is primarily an educational problem, since mould makers must be carefully trained. Several developing countries have employed foreign specialists to prepare and execute such a programme. Organizations such as the SPI (Society of the Plastics Industry), in the United States of America, GKV in the Federal Republic of Germany, and BPF (British Plastics Federation) in the United Kingdom can help locate suitable personnel. Since it takes a period of 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.

16. 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 know-how for the developing country, and manufacture moulds for his own firm.

Exporting to surrounding areas

17. 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 which cannot be sold in their own land can be exported on the continent where differences in purchasing power or product demand provide a ready market. By taking advantage of these opportunities, economics of production can often be reduced to allow the eventual penetration of local markets.

18. 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, 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.

19. 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 (about US$6.50). On the other hand, soft drink and beer crates 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.

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

Exporting component plastic parts for packaging

21. Market studies usually can determine the products that lend themselves to export. However, a hidden market for developing countries is often in the 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. Only actual testing and approval by the purchaser (importer) can prove its utility in many cases.

Research and development

22. Some developing countries contend that research and development is too costly. During the early period of growth this may be true. Most fabrication operations are owned by one or a few 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 who have expended 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.

23. 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 and/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 talents of fabricators for the good of the industry.

Education

24. 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:

- Modern Plastics (United States)
- British Plastics or Plastics (United Kingdom)
- Kunststoffe or Plastikverarbeiter (Federal Republic of Germany)
- Japan Plastics Age (Japan)
- Poliplasti or Materie Plastiche (Italy)
- Plastiques Batiment (France, construction)
- International Plastics Engineering (United Kingdom, equipment)

Modern Packaging (United States, packaging)
Package Engineering (United States, packaging machinery and design)
Reinforced Plastics (United States)
Journal of Cellular Plastics (United States, foams)
Plastics World (United States, largely applications oriented)
SPE Journal (United States, technical, resins, processing, other)

25. Contact should be made with any of several institutions that have plastics training programmes. These include the Plastics Institute, which has formulated curricula etc. 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.

CHAPTER II PLASTICS PROCESSING EQUIPMENT

26. 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 cost of various types of machines and auxiliary equipment.

27. 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. 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.

28. Once a decision has been reached, it is usually quite easy to secure expert and reliable advice on setting up operations from the major plastics 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 following paragraphs indicate.

Injection moulding and extrusion machinery

29. The reciprocating screw injection moulding equipment has taken over the field from the plunger machines. The older plunger machines metre the resin to the plasticating cylinder by measuring a fixed volume in a special volumetric feeder. The reciprocating screw machine plasticates 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 usually ordered at the present time in small sizes, making

them impractical for screw machines. Another trend taking place is the increased usage of larger capacity machines. This has resulted from the evolution of small plastic fabrications to those weighing several pounds. Very often the large applications result from custom moulding of appliance, automotive and houseware parts.

30. In the extruder field, the most recent technological changes have also come about in the screw design area, 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 utilized.

Thermoforming equipment

31. Little recent technological change has occurred in the field of thermoforming equipment. Most of the break-throughs in thermoforming have resulted in new and novel kinds of mould designs.

Blow moulding equipment

32. Notable in this field is the emphasis on designing equipment geared to specific applications. For example, the Uniloy division of Hoover Ball and Bearing has developed a successfully marketed 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 connexion with a multiple-mould system.

Thermoset moulding equipment

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

General trends

34. 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 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 since the buyer can do "one-stop" buying of his entire plant system.

Major suppliers of processing equipment

35. The annex gives a selected list of reliable machinery suppliers. It should be cautioned that prices do vary greatly with time and 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. (See annex 1 to the first article of this monograph for the addresses of those firms appearing on this chart.) One of the most complete catalogues of available equipment is published by Plastics Technology Magazine (New York).

36. On the following page is a price list of a typical reciprocating screw injection machine manufactured by Van Dorn Plastic Machinery Company (Cleveland, Ohio, USA), a major machinery systems supplier. The point of this inclusion is to illustrate that merely purchasing the US$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 more essential than optional.

MODEL 450 - RS - 35

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 band 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

Prices for special electrical or hydraulic requirements will be furnished upon request.
All prices NET F.O.B. Cleveland, Ohio. Subject to change without prior notice.

VAN DORN PLASTIC MACHINERY COMPANY
A Division of Van Dorn Company

2685 EAST 79TH STREET • CLEVELAND, OHIO 44104 • AREA CODE 216 PHONE 361-5234 • TELEX 098-483

CHAPTER III END PRODUCTS

Categories

37. Table 1 lists typical products made by plastics fabricators in developing countries categorized by end products sector.

Consumer products

38. 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. Since most countries import these products, there is usually an established market which eventually reaches enough volume to justify local production.

Packaging

39. 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

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

Agriculture

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

Table 1

Products made by plastics fabricators in developing countries

Product	Plastics used	Major methods of fabrication
Consumer		
Housewares	PE, PS	IM, BM
Tableware	PE, PS	IM
Toys	PE, PS	IM
Tablecloths	PE, PVC	Cal Ext
Curtain	PE, PVC	Cal Ext
Jewelry	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; Cell Acetate	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-water	PE	Ext
Mulching film	PE	Ext

Key: IM - Injection moulding
BM - Blow moulding
Ext - Extrusion
Cal - Calendering
Vac form - Vacuum forming
PE - Polyethylene
PS - Polystyrene
PVC - Polyvinyl chloride

Product demand

42. It is interesting to note that the industrial sector is often instrumental in creating 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 may 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.

43. Another way of viewing product demand is to use three areas of plastics use as a planning guide: a) consumer, b) in the industrial sector, replacements for products made from established materials (e.g. paper, glass, 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, as table 2 indicates.

Table 2

Consumption of thermoplastics by demand sectors in developing countries

Demand (percentage)

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

Interplastic competition

44. 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 plant capacity of

the substituted material. This occurs most often when either or both of the price-property variables that had directed 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.

45. 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, while polystyrene usually is 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.

46. 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.

CHAPTER IV DEVELOPMENT OF THE PLASTICS INDUSTRY IN SELECTED LAFTA COUNTRIES

Consumption and production

47. 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.

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

49. In all of these countries, polyethylene, polystyrene and polyvinyl chloride were the largest volume plastics. Backward integration has centred around these plastics as a result.

50. The establishment of petrochemical complexes to supply chemical intermediates for poly production has been limited to the higher population, higher GNP countries (Argentina, Mexico and Brazil), where end use demands has 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 first step for some countries. In 1967 Dow Chemical and Petroquimica 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.

51. Even in countries that have established extensive polymer operations, specialty resins continue to be imported since the volume does not justify internal production. For example, in 1965, Argentina produced approximately thirteen polymers, and imported eleven as table 3 indicates.

Table 3

Polymer production and imports in Argentina, 1965

Polymer	Tons of polymer	
	Produced	Imported
Polyethylene	1[illegible],7[illegible]	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

52. Recent data (see table 4) indicate that nearly 240,000 tons of polyethylene, polyvinyl chloride and polystyrene were consumed by eight LAFTA countries. About 54 per cent was produced domestically and 46 per cent was imported.

Table 4a

Plastic consumption in selected LAFTA countries
(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 4b

Estimated plastic consumption distributed by country
(thousands of tons)

Country	PVC	PE	PS	Total
Argentina	17	19	10	46
Brazil	35	18	14	67
Chile	7	6	5	18
Columbia	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

53. 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. Shipments of banana stems wrapped with polyethylene shrouds contributed to the expansion of the film production in several banana producing countries, as did film for protective covering of camelback rubber in a number of rubber producing areas.

54. In 1965 there were five producers of polyethylene in the LAFTA countries. (See table 5.) The figures on these countries do not include recent plants.

Table 5

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
Columbia	-	-	5	5
Mexico	14	18	14	28
Peru	-	-	5	5
Uruguay	-	-	11	11
Venezuela	-	-	11	11

55. 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. The accompanying figure presents this process in diagram form.

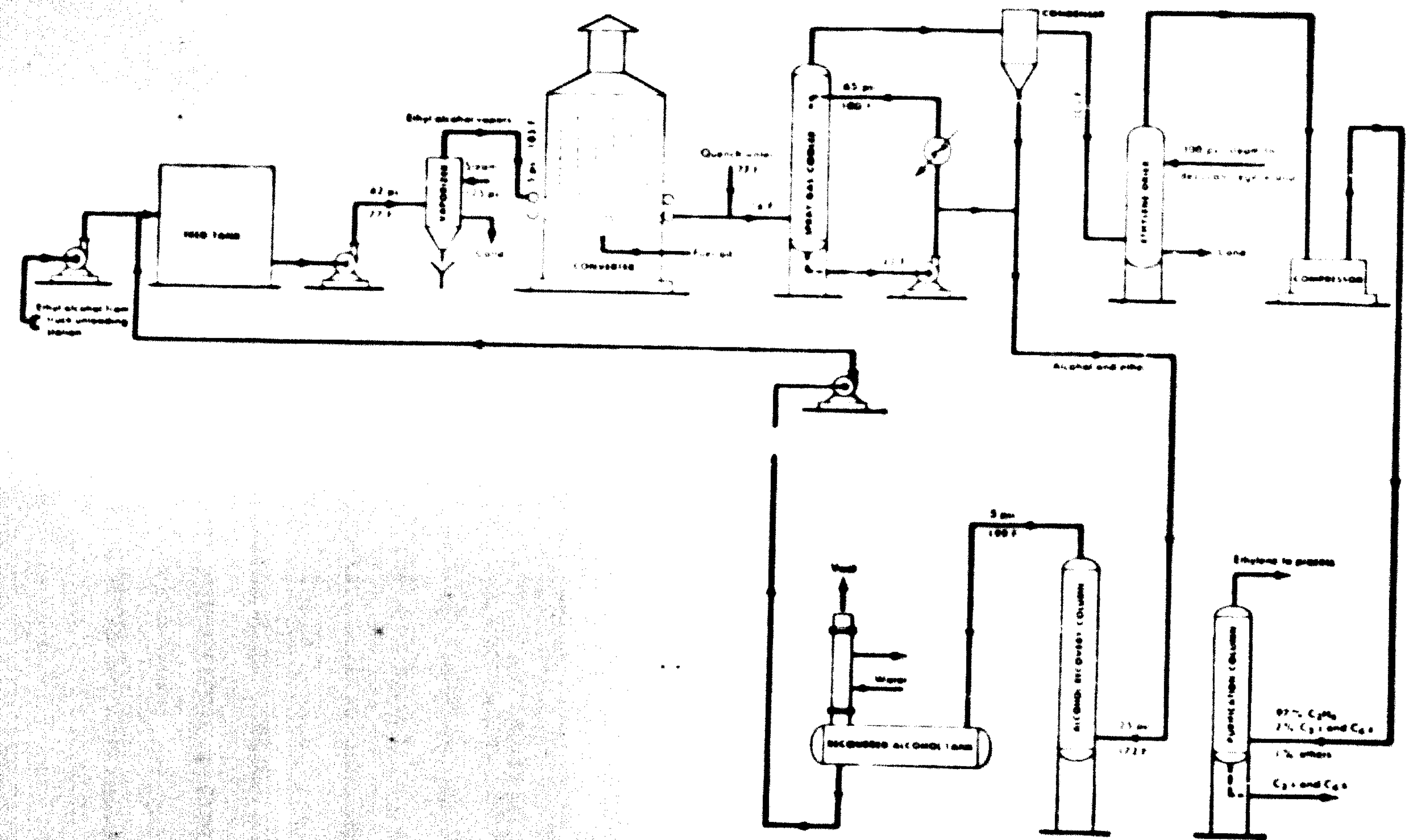
56. The availability of cane alcohol for producing ethylene can be economically advantageous to a country without enough demand for the products required to support a petrochemical venture, or for a country without petroleum reserves. In Brazil, Union Carbide do Brazil SA built a 3 ton capacity ethylene plant in Cubatão in 1958 based on a sugar cane alcohol process. By the end of 1967, capacity had reached approximately 27 tons.

57. Ethylene is produced from ethanol by catalytic dehydration (ethanol is converted from the alcohol). There are several advantages to this approach. Investment is relatively low (the original plant costs about US$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 labour. The efficiency of the plant is about 90-94 per cent, and ethyl alcohol is recovered and recycled.

58. 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 parameters. Beyond the maximum limit, naphtha cracking may be cheaper. (Union Carbides first ethanol dehydration unit in India has been converted to Naphtha cracking.) The other major producer of polyethylene in Brazil, Electroteno, 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.

Figure 1

Process for producing ethylene from sugar cane alcohol



Polyvinyl chloride

59. The consumption of vinyl chloride polymers in the LAFTA region was about 94,000 tons, almost equivalent to the polyethylene demand. However, 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 category of this group.

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

Table 6

Production and consumption of polymers in selected LAFTA countries, 1965

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

61. 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.

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

63. It is not uncommon for producers to incorporate new technology 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

64. Approximately 70-80 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 include 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.

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

66. 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 Petrobas synthetic rubber plant.

CHAPTER V DEVELOPMENT OF THE PLASTICS INDUSTRY IN THE ECAFE REGION

Fabrication

67. 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 are found in the types of products made, availability of raw materials, and socio-economic patterns relative to LAFTA countries.

68. Using five countries as an example (Malaysia, Thailand, Pakistan, Republic of China and the Philippines) the best available data indicate that 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, as shown in table 7.

Polyethylene

69. Packaging is the 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 constitute most of the remaining demand. Caps and bottles are a smaller outlet, but the demand is growing. Blow moulded containers are relatively new. Products packaged include liquid wax. Polyethylene-lined canals have been used for conservation in a few countries, e.g. India. Wire and cable insulation, flexible pipe and a variety of moulded consumer products form the bulk of remaining usage.

Table 7

Estimated consumption of plastics in selected ECAFE countries, 1964-1965[a]
(millions of pounds)

End use	Malaysia	Philippines	Thailand	Pakistan	Republic of China
		Polyethylene (low and high-density)			
Containers	0.5	1.0	0.5	0.5	2.0
Film	4.5	4.0	9.5	6.0	9.0
Cable insulation	0.5	0.5	-	-	1.0
Pipe	Neg	0.5	1.0	0.5	0.5
Mouldings, other[b]	2.5	1.0	2.0	2.0	1.5
Total	8	7	13	9	14
		Polyvinyl chloride			
Floor tile	Neg	Neg	Neg	Neg	0.5
Shoes	0.1	4.0	1.0	3.0	3.5
Pipe, hose	1.5	2.5	1.0	1.5	6.0
Cable insulation	2.0	2.0	2.0	3.0	1.0
Film and sheet	1.0	5.0	-	0.5	12.0
Mouldings, other[b]	0.4	0.5	1.0	1.0	17.0
Total	5	14	5	9	40
		Polystyrene			
Mouldings	1.5	2.0	3.5	2.0	2.5
Packaging	0.5	0.5	-	-	-
Foams	-	-	-	-	-
Appliances	-	0.5	0.5	-	0.5
Total	2	3	4	2	3

a/ These figures include exports.

b/ 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 consumption for 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 or "profile" of resin consumption.

Polyvinyl chloride

Film and sheet

70. Calendered sheet and cloth are used for upholstery in automobiles, for furniture, and for exported products such as baby pants, raincoats and leather cloth.

Shoes

71. Vinyl sandals are a well-established consumer product. They are moulded by shoe firms (e.g. Bata Shoe Company) and independent fabricators. Over-capacity 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

72. 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 extrusion. Heavy imports of wire and cable have held back the expansion of polymer production in some areas.

Pipe and conduit

73. Rigid water pipe is widely accepted for water transmission. 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

74. Several countries have shown preference for vinyl floor tile in new housing. Others such as China (Taiwan) prefer cement.

Polystyrene

75. 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

76. 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.

77. End products using imported resin as a component include 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 include 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 8 indicates consumption by end use.

Table 8

Consumption of finished plastic products in Thailand, 1966

End use	Consumption (thousands of tons)
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	Neg.
Adhesives and coatings for wood and paper	3
Cellulosics	2
Total	39

Backward integration

78. 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 product areas (e.g. plastics, synthetic fibres, detergents, rubber) based on petrochemical feedstocks. Optimum plant economics for intermediates are important so that the finished products can compete in domestic and export markets.

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

80. The production of intermediates and end products from non-petrochemical sources is highly desirable for a developing country. In addition to their availability, they can usually be manufactured in small quantities with respect to investment. This is important when end use markets are still too small to justify a high investment 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.

81. 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 utilized both methods. Similarly, acetylene derived from naphtha is usually cheaper than calcium carbide sources, and petrochemical benzene less expensive than coke oven benzene. Because of the high-cost feedstock (ethylene from alcohol), prices of polyethylene were relatively high and consumer goods could not be fabricated in the volume hoped for.

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

83. 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 production of low-cost ethylene will be used for manufacturing 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 9.

Table 9

Production capacity for NOCIL complex in India

Product	Capacity (ton/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, other liquid fuels	55,000

84. It is interesting to note (table 10) that plastics were the fastest growing segment of the petrochemical-consuming end uses in the long-range plan for petrochemical development in India.

Table 10

Growth in selected industrial segments in India, 1960-1971

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

Source: Data furnished by the First United Nations Interregional Conference on the Development of Petrochemical Industries in Developing Countries, Teheran, 1964.

a/ Estimated.

CHAPTER VI TECHNOLOGY IN PLASTICS

Sources of technical information

85. It is not surprising that countries seeking technology to produce polymers often turn to countries that have been important sources of imported polymer and finished products. 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" know-how, plant design and start-up. Some of the new PVC plants which began with the aid of Japanese technology during the 1965-1967 period are indicated in table 11.

Table 11

Recipients of Japanese PVC technology in Asian countries, 1965-1967

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

86. Note that plant size tends to be in the 6,000-8,000 ton 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.

87. Table 12 gives the extent of American activities in producing polystyrene and PVC in various countries. Some ways in which these ventures may be financed are illustrated in table 13.

Table 12

United States of America technical aid in several countries

Country	Polymer	Supplier of know-how
Argentina		
Monsanto Argentina	Polystyrene, PVC	Monsanto
Ipako	Polystyrene	Koppers
Brazil		
Companhia Brasileira de Plasticos Koppers SA	Polystyrene	Koppers
Geon do Brasil	PVC	B. F. Goodrich
Chile		
Plastiquimica	Polystyrene	Koydot, others
India		
Nandal Koppers Ltd	Polystyrene	Koppers
Polychem	Polystyrene	Dow
Chemicals and Plastics	PVC	B. F. Goodrich
Israel		
Electrochemical	Polystyrene	U.S. know-how
Frutaron	PVC	B. F. Goodrich
Columbia		
Dow Columbia	Polystyrene	Dow
Petroquimica Columbiana	PVC	Diamond Alkali
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
Republic of China		
Tai Ta Chemical	Polystyrene	Mobil Chemical
Lings Petrochemical	Polystyrene	Cosden Oil

Table 13

Financing selected polymer ventures in Argentina

Company	Polymer	Origin of technology	Capital invested	Financial structure
Ipako (Koppers)	Polystyrene Ethylene	Koppers	US $1 mill.	51% US capital investment 49% Argentine capital
Koppers	Polyethylene	Koppers	US $13.4 mill.	Loan, Import-Export Bank, Washington D.C.
Monsanto Argentina	Polystyrene	Monsanto	US $1 mill.	100% foreign investment
Plastico Bernardo	Polystyrene	Internal	40 mill. Pesos	National investment
Duperial	Polyethylene	ICI, others	£5.7 mill. US $16.1 mill.	Foreign capital ICI
Norens-Plast	Methyl methacrylate	Internal, with help from Mitsubishi Rayon	13.8 mill. Pesos	Argentine capital

Source: Gatti, O., R. Beltramino and E. Pasquinelli (1964) La industria petroquimica en la República Argentina, First United Nations Interregional Conference on the Development of Petrochemical Industries in Developing Countries, Teheran, PET/CHEM/CONF.47.

New technology

88. The plastics industry is witnessing a series of important break-throughs 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 of 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 wares,

electrical and packaging products. Some of the newer high temperature polymers include polysulfone and polyphenylineoxide (PPO). Noteworthy nylon materials are nylons 11 and 12, which compete in several nylon 610 markets and specialty areas. It is interesting to note that considerable work has been done by the Northern Regional Research Laboratory (Peoria, Illinois) on the synthesis of nylon 9 from soy-bean oil (nylon 11 and 610 are commercially made from castor oil).

89. Many firms are attempting to introduce plastics which 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 product opportunities.

90. Polymerization processes are also under modification. Solution grades of high-density polyethylene are being replaced by particle from 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-I) are providing better olefin resins. Bulk polymerization of vinyl chloride has been adopted by a number of countries.

91. Fabrication equipment and systems are also undergoing a period of advancement. Radiation offers exciting possibilities for curing and enhancing properties. Cold forming has recently attracted considerable attention. Advantages of this process include the ability to make heavy walled parts that ordinarily could not be made on plastics equipment, high production rates, lower tooling costs, reduction of trimming, elimination of sprues or weld lines, and ability to fabricate high molecular weight polymers. 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 also are important advancements.

92. 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 new, since oil was made from coal in Germany (about 9 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 to conventional refinery systems.

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

Annex

Selected suppliers of plastics machinery

	Type	Clamp force (tons)	Injection capacity (oz/shot)	Plasticizing capacity (lb/hour)	Manufacturer
Injection moulding					
Ram or plunger	H-R	30	2	25	Van Dorn
	H-R	275	10	120	Reed-Prentice
	H-R	1000	80	400	Farrel
Screw	H-IS	17	1.7	17.7	Battenfield
	V-RS	90	13	120	Moslo
	H-RS	220	19	170	Meiki
	H-RS	325	35	250	Natco
	H-RS	4000	280	460	
			420	572	Mannesmann
			720	702	
Thermoset	V-RS	250	22.5		F. J. Stokes

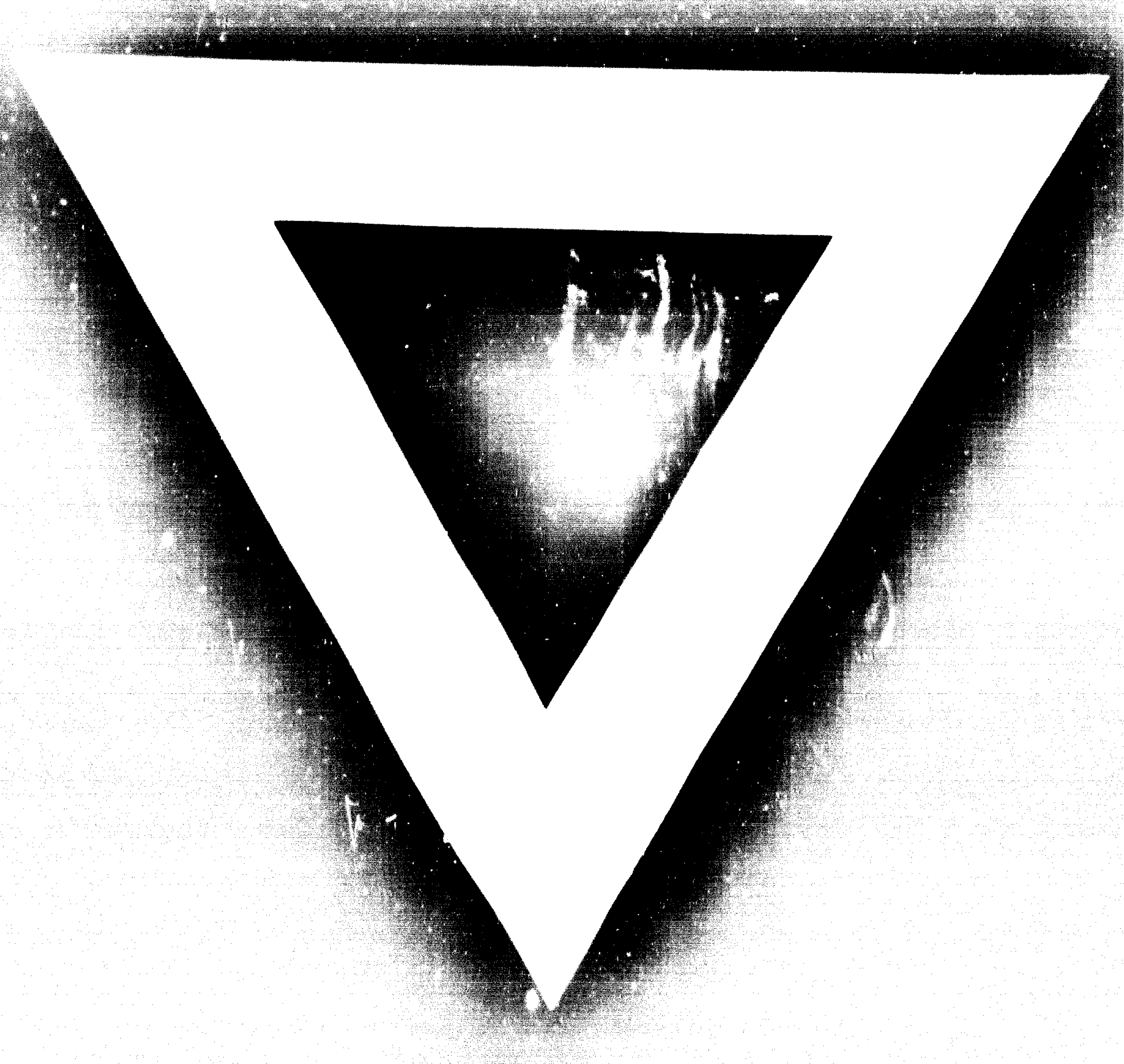
	Maximum container size	Parisons (per cycle)	Parts (per hour)	Manufacturer
Blow moulding	8 oz	1 - 4	2000 - 50	Kantex

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

Extruders	Screw diameter (inches)	L/D ratio	Heating zones	Manufacturer
Single screw	0.5	20	2	Reifenhausen
	2.5	20	3	NRM
	6.0	20	4	Waldron-Hartig
	10.0	21	6	Sterling
Twin screw	2.5	12	4	Anger
	6.0	25	6	Welding Engineering

Compression and transfer moulding	Capacity (tons)	Moulding area (sq. inches)	Manufacturer
Compression	25	390	F. J. Stokes
	100	480	HPM
	300	2835	Schulte
Transfer-compression	25	160	BIP
	100	420	Farrel
	300	230	Triulzi

Thermoforming	Forming area (LxW in inches)	Draw depth (inches)	Feed type (sheet or roll)	Manufacturer
Vacuum	10 x 20	1	Sheet	Precision Products
	20 x 25	6	Roll	Auto-Vac
	30 x 36	29	Sheet	Brown
Pressure	10 x 18	5.5	Roll	Hyd-Chem
	48 x 96	25	Sheet	American Thermoform
Pressure and/or Vacuum	10 x 10	6	Sheet	Comet
	15 x 19	5	Roll	Italmec



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