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Baku, USSR, 21 - 31 October 1969

THE IMPORTANCE OF THE APPLICATION OF PLASTICS IN DEVELOPING COUNTRIES

(A COMPARISON BETWEEN TRADITIONAL AND SYNTHETIC MATERIALS)[1]

by

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SUMMARY

THE IMPORTANCE OF THE APPLICATION OF PLASTICS IN DEVELOPING COUNTRIES [1]

by

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In an introductory chapter the authors discuss the reasons for the rapid increase in the consumption of plastics, show how this is broken down between different types and how the consumption per capita has varied over a number of developed and developing countries. They emphasise that consumption refers to plastics processed not to plastics products consumed, the latter would be the ideal figure but information is not available.

Flowsheets are next given showing how the major plastics are obtained from their raw materials.

The major part of the paper then deals with the use of plastics in different applications and industries.

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Bibliography

We regret that some of the pages in the microfiche copy of this report may not be up to the proper legibility standards, even though the best possible copy was used for preparing the master fiche.

(a) Agriculture and water supply

The author deals with soil improvement, irrigation, mulching, protection of fruit, hot houses, silo linings and, of course, packaging of agricultural products.

(b) Clothing and footwear

The growth in the use of synthetic fibres, treatment with or coating of fabrics with plastics, leather substitutes and in particular, footwear applications are dealt with.

(c) Building and construction

Many tables are given showing the growth of plastics in building and the breakdown of their applications. It is noted that mass produced building materials: bricks etc. can only be replaced to a very limited extent. The importance of flooring as an application is stressed while major sectors deal with the use of plastics foam in insulation and plastics in water supply. Unconventional methods of construction in which plastics are load-bearing are discussed.

(d) Electrical engineering

Here the use of plastics for electrical accessories of all types is discussed while a major section deals with the use of plastics in cables.

(e) Thermal insulation

The information already given under the building section is amplified and the properties of the major plastics given in this respect. Details of some more general application are given.

(f) Gluing and improving of woo

This section deals with the production of plywood, chipboard as well as ad-hoc applications. Penetration of wood cavites by plastics is discussed and some attention given to surface improvements.

(g) Varnishes and coatings

The change over from oil type varnishes to synthetic resin based varnishes is discussed. PVC coatings, wood varnishes and water soluble stoving enamels are given attention.

(h) Packaging and containers

Tables showing the breakdown of packaging materials in West Germany and of plastics in particular in their different application in USA are followed by a brief description of the types of plastics packaging, the plastics used and the methods by which they are converted. Some attention is given to "one way" (throw away) plastics.

(i) Transport

Use of plastics in railway coaches and motor vehicles is discussed and the various techniques used briefly described. Application in small boat construction and as accessories in larger vessels are considered. The potential of plastics in the aircraft industry is briefly mentioned.

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1. Introduction

Problems of immense importance arise in view of the alarming growth of our planet's population and of unmistakable trends to raise the living standard of inhabitants of developing countries. Measures for the provision of food and clothing and for the creation of adequate living space have become an absolute necessity. In the following the extent to which plastics can contribute to the solution of these eminently important problems will be investigated.

Even if plastics show extraordinarily great differences regarding chemical structure, physical properties, forms of delivery, applicabilities and, though they are widely and readily adaptable to particular needs, a few factors can be singled out as characteristic. Making a general and comparative valuation the following main facts determine the use of plastics:

a) lower in weight and more resistant to fracture or temperature changes than glass and ceramics,

b) more insensitive to humidity and chemical influences but at the same time less strong and more sensitive to temperature than steel,

c) non-swelling and more resistant to decay, micro-organisms and insects than wood,

d) better thermal and electrical insulating properties than some of the traditional materials, and

e) the ability to be dyed in the material which dispenses with coating and varnishing.

Even if the price of plastics per kg may be higher than that of traditional materials some economic advantages result from the low specific weight and from the fact that intermediate products can be manufactured in standard sizes or in practically endless lengths and that finished parts can be produced by non-cutting methods practically without any waste. Besides it should not be left out of consideration that different from other industrial raw materials, the market prices of plastics show a distinctly falling tendency (in Western Germany the price of polyethylene dropped in the period between 1955 and 1965 by 68 % that of polystyrene by 60 % and the price of PVC by 48 %).

The great majority of current plastics are obtained by polymerisation, polycondensation or polyaddition of low molecular substances of petrochemical origin. As a matter of fact 95 % of the total output of USA - the world's biggest manufacturer of plastics - is produced from petrochemical raw materials. A similar trend can be recognized also in other highly developed countries though standards attained in those countries are not everywhere the same.

In the year 1967 world production and consumption of synthetic fibres was 2.9 million tons, of synthetic rubber 3.5 million tons and of plastics 18 million tons. The percentage breakdown is given in table 1.

As can be seen from table 2 the average consumption of plastics per capita is very different. Whereas in Western Germany the average consumption was 31 kg in 1966 and 36 kg in 1967 most of the developing countries have an annual consumption which is less than 0.5 kg. That means that one quarter of the world population consumes more than 4/5 of the total production of plastics, while the remaining 1/5, i.e. about 3.6 million tons, is divided among the rest of the human race (i.e. about 2.5 thousand million people).

Simplified Scheme of the Production of the most important Plastics

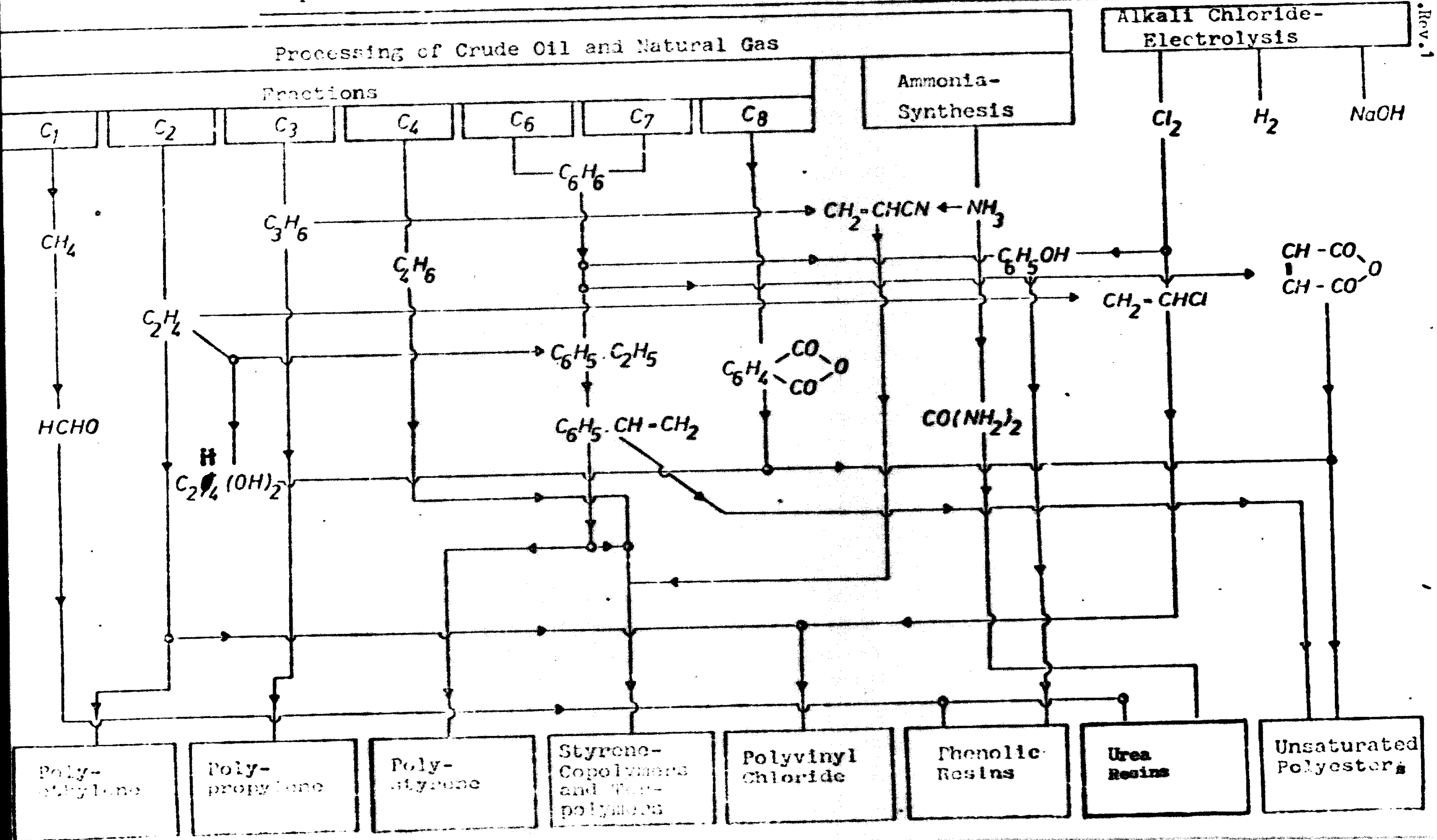

Table 1: Breakdown of the total consumption of synthetics

a) Plastics

Class:	% of total amount:
Polyolefins	26
Polyvinyl chloride	25
Polystyrene (including copolymers with styrene)	12
Aminoplasts	11
Phenoplasts	8
Unsaturated Polyesters	7
Acrylic resins	2
Epoxy resins	1
Others 1/	8

b) Fibres

Class:	% of total consumption: 2/
Wool	7.7
Cotton	60.2
Cellulose based man-made fibres	17.5
Synthetic fibres 3/	14.6

1/ "Others" include Polyamides, Polyacetals, Polycarbonates, Polyurethan as well as Polyvinylalcohol and its derivatives.

2/ Total world consumption amounts to 19.6 million tons.

3/ The "Synthetic fibres" include Polyamides (48 %), linear Polyesters (24 %), Acrylic fibres (19 %) and others (9%).

Table 2: Consumption of plastics in different countries (kg per capita)

	1962	1965	1966	1967
Western Germany	21.5	26.2	31.2	36.3
USA	15.7	24.6	28.3	
Belgium	14.5	24.8	27.6	
Sweden	14.4	24.8	27.5	
Austria	11.6	17.1	20.0	22.8
Japan	8.3	14.1	18.1	
The Netherlands	10.6	16.4	17.7	
France	9.7	13.9	17.6	
Great Britain	10.2	15.1	17.4	19.6
Italy	10.2	12.9	16.0	
German Democratic Republic		10.5		
Czechoslovakia		9.9		
United Arab Republic		0.3		
Morocco		0.2		
India	0.1			

The figures refer to plastics raw materials processed in the respective countries; imported finished products have not been included.

It is obvious that in starting production of plastics in a developing country emphasis should first of all be given to the most important plastics (Polyolefins; Polymers of vinylchloride; Polymers, Copolymers and Terpolymers of styrene; Aminoplasts; Phenoplasts and unsaturated Polyesters). The statements in the following sections are, therefore, confined to applications for which the above mentioned materials are suitable. Other plastics, if required for special applications, would have to be imported.

On the following page a simplified scheme for the production of the most important plastics is outlined. The scheme is simplified inasmuch as for reasons of clarity there have not been included all intermediate products. In each case only one production method is quoted. There exists, however, a great number of such:

Vinylchloride can be obtained also by means of the addition of HCl to acetylene.

Styrene can also be made from benzene and acetylene or from benzene and ethylene chloride.

The technical and economical effects of the use of plastics can be very different. In no case does their main significance lie in the fact that they can directly replace traditional materials which are not at all or only in insufficient quantities available in the respective developing country. The use of plastics is much more important in cases where they bring about advantages by simplification or rationalization of working processes and particularly in those cases where they make it possible to cope with problems which would be insoluble using traditional materials. It should be clearly pointed out that combinations of traditional materials with plastics can compensate deficiencies and bring forth fully the valuable specific properties of both materials.

If only the needs of developing countries were considered, a more extensive use of plastics appears to be appropriate in the following branches of national economy:

Securing food supply, using plastics in agriculture and packaging,
Clothing and shoeing,
Creation of living and working space using plastics in building construction. This includes water-supply systems, electrical-engineering, thermal insulation, adhesives, varnishes and coating materials.
Plastic containers for various applications,
The use of plastics in transportation,
Protection against corrosion with the help of plastics.

2. The most important plastics and their various applications

2.1. Agriculture and Water Supply

The cultivation of crops in new areas and the intensification of agricultural production are of greatest importance in view of the steady growth of the world population. Plastics can be a valuable help in attaining those goals.[1/]

Heavy and closed, especially clayey soils can be loosened, better aerated, rendered more permeable to water and more easily cultivated by ploughing in flakes of expanded closed-cell polystyrene known e. g. as "Styromull".[2/] On the contrary, open-cell foams of plastics, particularly those from condensation products of urea and and formaldehyde, act altogether differently; they behave like peat accumulating water and nutritive salts and releasing them little by little to the plants.[2/] Thus dry and sterile sandy soils can be exploited which are not able to be cultivated at all without such additional agents. Under the trade name "Hygromull" foamable condensation products of urea and formaldehyde are brought into the market. They contain the least possible amount of unreacted formaldehyde because the latter damages or even prevents the generation of soil bacteria. Since "Hygromull" is made on the spot from liquid intermediates, there are no transportation problems barring often the use of peat. Results of large scale experiments have been reported - for instance from Saudi Arabia. First a 35 cm thick layer of loose sandy soil was removed, then a 5 cm layer of urea foam was sprayed on the ground and this layer was covered with the soil, which had been removed. Citrus trees developed there superbly and without any losses, whereas in control experiments, without a foam layer about 50 % of the planted trees died. Soil tests proved that after 3 weeks of exposure to sunlight (48°C in shadow) the foam layer still contained 2.6 litres of water per m^2.[3/] Erosion of the topmost sand layer could be reduced by spraying a plastic film on it, e. g. from urea formaldehyde condensation products. Dark-coloured films increase the soil temperature by about 4° to 6°C, whereas light coloured films favourably influence growth and ripening by means of light reflection.[6]. Near Antwerp drift sand areas were satisfactorily made green in a few weeks by spraying them with foamable urea-formaldehyde condensation products, water, nutritive salts and grass or lupine seeds.[4/5]

A further step leads to the cultivation method known as "Plastoponics" where a urea-formaldehyde foam takes over the role of humus and is the carrier of nutritive salts, of trace elements and of water which is indispensable for the growth of plants.[3] If such cultures are grown in tower-type greenhouses, complete automation of the cultivation process can be accomplished; the plant boxes are carried by a paternoster through all floors of the tower going at the lower turning point through a bath which supplies them with the necessary amounts of water and nutritive salts.[7]

For the watering of agricultural areas polyvinyl chloride or polyolefin pipes were successfully used. Due to their low weight and easy laying (polyethylene and grooved polyvinylchloride pipes can be delivered wound on drums in any length so that pipe joints are unnecessary) installation can be carried out by untrained persons. An attempt was made at growing under extremely unfavourable conditions i. e. in the Sahara desert, cultures at minimal water expenditure laying in the soil flexible plastic pipes with holes at regular intervals. The plants were set so that the knobs of the roots were placed directly over the holes of the pipes. Thus the supplied water served almost completely to benefit the plant and evaporation losses were reduced to a minimum.[8]

Perforated or slit polyvinylchloride or polyolefine pipes are successfully used for drainage purposes. Compared with traditional clay tubes they are substantially lower in weight and can be laid at the speed of 2 km per hour.[8/9]

Pipe-lines carrying milk from mountain farms or alpine pastures directly to the dairies in the valley are an interesting application of plastic pipes. If not used for the transportation of milk, the same pipe-line can serve as the means of supplying water to the dairy.1/

Plastic sheeting is extensively used for the cultivation of fruit and vegetables or on plantations because it helps to accelerate growth and to increase crop yields. For instance bunches of bananas hanging on the tree are enclosed in a coloured polyethylene hose tied off at the top and open at the lower end increasing growth by 20 to 25 %. During shipment the plastic hose provides efficient protection against damage.10/ By covering the plants to be cultivated or the hotbeds with transparent PVC-sheets growth is furthered by the accumulation of heat and humidity as well as an efficient protection against wind and thus the harvest time is advanced by 2 to 4 weeks; eventually even an additional cultivation and harvesting cycle may be inserted 11/ 12/. Using perforated sheeting laid on half-arc type mounting supports the resulting tunnel-shaped coverings assure good ventilation besides the above mentioned effects11/.

By covering cultivated soils with black "mulching sheets" the heat and humidity balance of the soil is favourably influenced, incrustation of clayey soils as a result of heavy rainfalls is prevented and weed growth is repressed. Moreover, e. g. in the cultivation of strawberries, the berries are protected against contact with the ground and thus cannot be contaminated by sand or earth 11/ 13/ 14/. Surprising success with mulching was also attained in the cultivation of tomatoes, cucumbers, beans and lettuce as shown in the following table 3.

Table 3: Crop yields of a [illegible] programme using black polyethylene [illegible] for mulching[13]

Plant species	Covering [illegible]		
	none	with black PE-sheeting	
	(t/hectare)	(t/hectare)	Increase in%
Bush beans	3.75	4.80	28
Lima beans	5.72	9.48	66
Cucumbers	14.80	35.50	140
Tomatoes	8.25	20.50	148

Plastics also play an important part in the construction of hot-houses. Transparent plastic sheets stretched over wooden or plastic frames and properly assembled serve as a covering for hot-beds or for hot-houses of light construction. In order to improve resistance to wind, the use of transparent PVC-sheets reinforced with meshed plastic threads or metal wires is recommended.[14] The troublesome problem of corrosion with steel framework constructions can be solved either by coating the steel parts with polyethylene or PVC or by using glass reinforced polyester instead of steel.[15] If transparent PVC sheets are stretched under the glazing, heat losses can be reduced thus achieving considerable savings in heating costs.[14]

For hot-water heating of stable hot-houses pipes of polyethylene of high density or of polypropylene can be successfully used.[14]

The hitherto quoted applications have brought about results which would have not been attained without the use of plastics. Certainly such improvements often involve considerable expense. However, it should not be overlooked that the cultivation of additional areas and the increase in yield are results to be achieved at any price, if famine with all its consequences, a nightmare for a great part of the world's population is to be removed. In this connection dikings of polders planned and partly accomplished with foresight in the Netherlands are worth mentioning. Even if the costs are enormous, they will prove a success and should be repaid in the future.

Furthermore, numerous applications of plastics aim at the rationalization of labour in agriculture. Since it would be impossible to quote all of them a few interesting examples only are given in this report. Forage silos of concrete are lined with plastics to prevent the effect of fermentation acids on the concrete or entire silos are made of glass reinforced polyester.[1] For the covering of the top plastic sheets or plastic coated fabrics from fully synthetic fibres are used.[1] The required pressure and sealing from the outside is attained by filling these container-like constructions with water. For agricultural equipment such as vats, baskets, buckets and troughspolyethylene is especially recommended because its low weight reduces physical labour considerably.[16] Owing to their corrosion resistance plastics are preferred for stable and feeding equipment too. Large milk and wine containers are made from glass reinforced polyester coated or not coated with PVC and even sometimes covered with a layer of polystyrene foam which assures good thermal insulation. Furthermore numerous parts and coverings of agricultural machines are made of plastics thus avoiding damage caused by corrosion in case of scarce attendance or of no service at all. Thanks to good emergency-running characteristics a satisfactory functioning is assured.[17] [18]

Finally, plastics also play an important part in the packing of materials for agriculture and in the packing of agricultural products. At present fertilizers are delivered exclusively in bags made of plastics or woven from polyolefine ribbons which, contrary to paper and jute bags used in the past, are resistant to decay. Bags woven from plastic ribbons, however, have to be coated with a film of the same material to be moisture-resistant. Also such bags are best suited for the delivery of agricultural products like potatoes, onions, bread and forage corn.[1] For fruit, tomatoes and eggs deep-drawn inserts of PVC-foils are preferred. Milk cans made of polyethylene and polypropylene are widely used.

However, the opinions of the consumers are not unanimous. For small packing bags of polyethylene coated paper, boxes of coated cardboard as well as polyethylene bottles come more and more into consideration. The latter serve as multi-way or one-way packings and have already gained a certain importance in USA but involve additional expenses.[19] Butter and cheese are expediently packed in PVC or polyethylene sheets with or without an aluminium coating. The selection has to be made according to the particular requirements regarding light protection, permeability to water vapour, oxygen and fermentation gases.[20] Those questions will be discussed in detail in section 2.8 (Packaging and Containers).

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2.2. Clothing and Footwear

The future growth in the need of clothing and footwear will be greater than the increase in the world's population because the rise in the standard of living which can be predicted and hoped for leads one to expect higher figures per head especially in developing countries. For instance it can be expected that in

1980 the demand for textiles and leather will surpass by about 30 % the production estimated on the basis of present conditions. Among natural textile fibres the production of wool cannot be raised proportionally to the demand because the possibilities of animal breeding are limited by the amount of forage which will be at disposal. An essential help in the supply of textile raw materials can therefore be expected mainly from cotton - insofar as sufficient cultivable areas are available and the local climate permits cultivation at all -, and from synthetic fibres. The figures in the following table 4 show the general trend of the consumption of textile fibres.

Table 4: World consumption of textile fibres between 1950 and 1967

	1950	1960	1965	1966	1967
Total consumption (1000 t) of that	9800	15100	18400	19200	18900
Cotton (in %)	75.5	68.6	62.5	61.5	60.2
Wool (in %)	10.6	9.5	8.2	8.0	7.7
Rayon and synthetic wool made of cellulose (in %)	13.4	17.2	18.3	17.5	17.5
Synthetic fibres (in %)	0.5	4.7	11.0	13.0	14.6

Among synthetic fibres the consumption of polyamide-fibres still occupies the first place but their yearly rate of increase dropped considerably in the last few years whereas the rate of increase of polyester fibres has almost maintained its position so that optimistic predictions for the future are justified. Those trends can clearly be seen from the figures in the following table 5.

Table 5: Annual rate of increase (in %) of the most important synthetic fibres

	1963/64	1964/65	1965/66	1966/67
Polyamide	+ 23	+ 17	+ 13	+ 10
Acrylnitrile	+ 43	+ 33	+ 18	+ 17
Polyester	+ 33	+ 34	+ 33	+ 28

The present report should deal, however, exclusively with plastics in the narrower sense.

Low weight fabrics are coated with plastics, preferably with plasticized PVC and processed to work clothes and waterproofs. Extremely low weight raincoats are made of sheets using predominantly plasticized PVC or less often low density polyethylene.1/ The main problem is to obtain an adequate breathing activity, i. e. good permeability to air and water vapour which is decisive for a pleasant "wear feeling". Nevertheless, it has to be admitted that this goal has not yet been solved satisfactorily in spite of numerous efforts. It is also difficult to estimate at present to what extent fibres of polypropylene brought to the market in the last few years will be used for clothing.

For knockabout winter clothing textile fabrics, possibly PVC coated combined with polyurethane soft elastic open cell foam have been successfully used.2/ Thanks to the good insulating properties of the foam against the cold the fabrics can be of relatively low weight and price. Such combinations weighing 250 to 300 grams per square meter are equivalent regarding insulation capacity, touch and wear comfort to winter cloths of 750 grams per square meter. The impregnation of coating with PVC makes such textiles rainproof. Accessories for the clothing industry like buttons, patent fasteners, buckles, zippers etc. are made of plastics, e. g. on the basis of polystyrene, with stability of shape.

Plastics have attained great significance as leather substitutes. Mainly plasticized PVC sheets and woven or knitted fabrics coated with PVC come into consideration. Some inconveniences like being hard to the touch and brittleness at low temperatures have now been overcome and standard products which are on the market fulfill regarding appearance and quality all the requirements made by bag-makers of first-class material. Compared with animal leather they display several advantages such as water resistance, easy cleaning with water and soap as well as the possibility of dyeing. As a consequence the wearing out by scouring is less visible than on coloured or patent natural leather. The supply of "artificial leather" in rolls of uniform width has, if compared with natural hides, the advantage that there are practically no cutting losses.

For the shoemaking industry materials based on PVC or polyethylene are also important. Certain limitations, however, have to be taken into account because in spite of all endeavours it is at present still impossible to reach the water absorption capacity and the permeability to air and water vapour of animal leather. Therefore "artificial leather" does not satisfy fully the requirements of upper leather of solid and knockabout shoes. Nevertheless, it is used successfully for lowweight ladies shoes, sandals and gym and beach shoes because in these cases the problem of ventilation is solved by perforating or by dissecting the upper part of the shoes into a network or straps 3/ 4/ 5/. Artificial upper leathers developed recently are produced from polyurethanes. Their trade names are "Corfam", "Orlex", "Xylec" etc.

Snow shoes and weather boots are manufactured from plasticised PVC - by injection moulding or by the dipping process - using different compositions for the upper parts and the soles. 5/ 6/ They are absolutely fit for normal use because it is now possible to reduce brittleness at low temperatures to such an extent that shoes stand at -10°C in a specially developed testing machine 100,000 bends without the formation of cracks.[13] Rubber could only maintain its place, in the manufacture of heavy work shoes to be worn at extremely low temperatures. It should be mentioned that PVC-boots can be manufactured such that they are permanently resistant to mineral oils. Work shoes of the type of the famous dutch wooden shoes are made of an elastic polyethylene.[11] Crosslinked polyethylene is also used by the shoemaking industry.

The main fields of application for plastics - especially polyvinyl chloride and polyethylene - are component parts and accessories of shoes e. g. inner and intermediate soles, stiff cap and heel parts but above all soles and heels.[3] At present soles and heels are often made in <u>one</u> piece and consist almost exclusively of plasticised PVC with or without the addition of nitrile rubber. They have succeeded to such an extent that e. g. the British shoemaking industry still furnished in 1946 82 % of its total production of shoes with leather soles whereas 20 years later only 15 % of 200 million pairs are brought on to the market with leather soles.[5] High and slender heels for ladies shoes which have to stand an overstrain are made of plastics reinforced with metal inserts;[7] normally polyacetals and polyamides, but sometimes also polypropylene [8] and polyesters [c], are used for that purpose.

The significance of plastics for the shoemaking industry consists not only in the eminently important broadening of the raw material base, but also in the fact that with their help it is possible to reduce the number of subsequent working operations and to rationalise the manufacturing process. Beach sandals of polyethylene or of PVC are made fully automatically in <u>one</u> working operation on injection moulding machines. Polyvinyl chloride soles are glued, welded or directly injected onto the upper part of them whereas the fastening of a leather sole according to traditional working methods requires not less than 20 single operations.[5]

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2.3. Creation of Living and Working Space; Building Construction and Water Supply

The possibilities of the application of plastics in building construction are extraordinarily manifold. Indeed it can be seen from the following table 6 that 20 to 30 % of the total production of plastics in highly developed countries go to the building trade and as a consequence it comes to a condiderably high consumption per capita.

Table 6: Percentage portion of building construction of total consumption of plastics; Quotas of plastics per capita

Country:	Portion of building trade: (in %)			Quotas per capita: (in kg)
	1961	1964	1966	1966
Western Germany	19	28	31	9.7
Italy	19	28	30	4.8
France		22		
Great Britain	12	19	21	3.2
USA	17	20	22	6.2

As far as the application of plastics in building construction is concerned two fundamentally different ways must be considered: plastics are either used instead of traditional materials in traditional building construction or new methods of building construction are introduced allowing full exploitation of the specific properties of plastics, e.g. low weight, good tensile strength even with thin wall thickness, low thermal conductivity, high corrosion and weather resistance. Especially the second way of application could become important for the construction of smaller buildings in developing countries as will be discussed later.

Application of plastics in traditional construction methods

The following table 7 gives an approximate survey of the importance of plastics in US building construction.

Table 7: Plastics in US building construction (in 1,000 tons) x/

	Polyolefins	Polyvinyl chloride	Polystyrene	ABS-Polymers	Polycarbonates	Polyacetals	Polyurethanes	Acrylic resins	Cellulose derivates	Phenoplasts	Aminoplasts	Polyesters	Epoxy resins	Glass reinforced plastics	Total
Floorings		187	18				7				1	2	3		251 xx/
Bonding agents for wood										68	112				180
Thermal insulation		1	36				12			55					104
Decorative panels										48	23	3	1		75
Electrical insulation		1			3	1				16	17	6	1		45
Wall facings for indoors	37		8												45
Pipings, sanitary installations	2	12	2	12	1	2		3						9	43
Lighting		4	17		2			4	1		1			2	31
Glazing		1			1			7						21	30
Insulation against moisture	27	2													29
Various profiles	2	22													24

x/ See Modern Plastics 45 (January 1968) 105.

xx/ About 33,000 tons are other materials, mainly "asphalt tiles".

To give a close-up of the financial side the next table 8 shows the gross production values of construction units from plastics in Western Germany.

Table 8: Gross values (in million DM) of plastics used in the most important groups of materials for construction [1]

	1963	1966	1967
Flooring	391	629	632
Foam plastics	70	259	268
Laminates as panels	164	231	238
Pipes and sanitary installations	126	192	202
Profiles	122	161	161
Building panels	89	122	131
Building units	45	110	128
Revolving shutters	44	87	85
Windows	2	11	16
Doors	4	8	10
Total Value	1,269	2,017	2,034

It must be said, however, that cheap mass-produced construction materials as bricks, lime, sand and cement can hardly be replaced by plastics for reason of price. Plastics are used almost exclusively as non load-bearing construction units, insulations, panellings etc. Plastics may even have loadbearing functions in constructions which are appropriately adapted to the specific properties of the material as will be shown later.

By far the greatest part of plastics applied in building construction is used for flooring mainly made of PVC.[2/ 3/] In contrast to wooden floors they have a dense closed surface which allows easy cleaning and maintainance. Plastic flooring is supplied in various degrees of hardness and types (tiles, rolls or carpets). Highly strained industrial floors are made of priming materials, e.g. also of polyesters with adequate fillers.

In concrete construction and in the production of building stones based on concrete plastics play an important part. If, for example, a particularly smooth, specially patterned, structured, or profiled surface is desired the concrete forms are lined with glass-reinforced polyester,4/ or with smooth or deep-drawn foils of rigid PVC.5/ Inserts of polystyrene foam adhere to the concrete even after removal of the form ("lost form") and thus directly provide the desired thermal insulation.6/ Embedded blocks or hollow pieces of polystyrene foam connected with the use of comparatively simple wooden forms provide construction units which in spite of their greatly reduced weight offer high loading capacity. After dismantling the construction the foam can be removed, e.g. by burning away, so that suitable recesses and openings for construction or installation purposes will be obtained.7/ Low weight concrete building stones are made by adding flakes or previously expanded granules of polystyrene foam to the concrete.7/ Buildings can be faced with glass reinforced polyester which provides a dense, attractive, impermeable and water-repellent surface and makes plaster unnecessary.8/

Insulating sheets of polyethylene or soft PVC have been successfully used as protection against the rising of ground-water.9/

Foam plastics are also important for thermal and acoustical insulation.10/ Foams with predominantly closed cell structure based on polystyrene or phenolic resins are excellently suitable for heat or cold insulation. A 2-cm-thick foam sheet insulates as strongly as a 40-cm-thick brick wall. Foam plastics are laid on walls, ceilings and particularly under flat roofs. Appropriate regulations have been worked out by different authorities.11/ 12/ Additional informations will be given in section 2.5. ("Thermal insulation"). Foams with open cell structure based on urea resins provide efficient sound absorption, especially in combination with plaster or stucco slabs fixed to ceiling and walls.[13]

Perforated sheets of polystyrene foam are also recommended for the same purpose. Good footfall sound attenuation on "floating floor finishes" can be attained by underlaying highly resilient polystyrene foam.[14]

In the field of water supply and distribution as well as that of sanitary installations plastics are an important factor.[15] [16] Drinking water lines are made from polyethylene or PVC pipes which offer a number of advantages in comparison with traditional steel pipes. Their weight is substantially lower thus facilitating installation considerably. Their good chemical resistance prevents chemical attack from inside as well as from outside, e.g. by salty or marshy soils. Deposition of scale from water and of dirt in sewer lines is prevented by the noncorroding, smooth and water repellent inner surface of plastic pipes so that they are less susceptible to clogging.[17] The problem of warm-water lines made of plastic pipes has not yet been entirely solved; experimentally installed pipes of chlorinated PVC or of polybutene-1 have been standing the tests quite well up to the present.[18] PVC has been successfully used for eaves and rain gutters. In this respect positive results of long time tests were reported from Eastern Germany.[19] For gas lines polyethylene pipes cannot be used at all whereas pipes of PVC or of ABS-polymers (terpolymers of styrene with acrylnitrile and butadiene) can only be applied if the passing gas is practically free of aromatic compounds.[20]

Complete bathroom blocks consisting of wall facing, bath tub, wash basin and bidet as one unit have been brought to the market in France and in the USA. To install such bathroom units only water supply and drain need be connected. These units are said to have proved to stand the tests.[21] Special installation units which contain the pipe distribution system for sanitary installations and which are fixed to the wall save troublesome and dirt producing chipping work during mounting.[22] Water tanks for flushing lavatories and siphons for sinks are made of PVC or of polystyrene blends, toilet seats of moulding materials based on phenoplasts or aminoplasts and bath tubs of glass reinforced polyesters or sometimes of polypropylene.[23]

Hollow as well as massive doors are produced from plastics too.[24] In the first case frames of wood or aluminium are covered from both sides with sheets of PVC, glass reinforced polyesters or decorative laminates coated with aminoplasts. Massive doors are sandwich constructions which consist of two covering sheets glued to a low weight core. The latter is made either of rigid foam or of a honey comb structure. This honey comb structure may be built from phenolic resin coated paper or from styrene which is thermoformed to special polymeric sheets.[23] Garage doors are also manufactured as sandwich laminates preferably from glass reinforced polyesters. In special cases, e.g. because of lack of space, folding doors from plasticized PVC have proved successfull.

The traditional window constructions with wooden frames and casements are liable to warp under the influence of changing humidity which makes, especially in new buildings, a reliable sealing against the outside atmosphere hardly possible; apart from that wood is easily affected by decay in warm climates. These difficulties can be overcome by use of metal window constructions but then rust is a very serious problem. Plastic windows made from PVC or glass reinforced polyester do not show any of these tages mentioned above.

Expensive coatings which have to be renewed in relatively short intervals become unnecessary because plastics can be dyed in the material. To compensate the not negligible thermal dilatation of PVC and to make the frames and casements sufficiently stiff and distortion-free a great number of constructions have been developed in which a) cores of traditional materials are coated or surrounded with plastics or b) window frames and casements are made entirely of plastics.[25] For revolving shutters PVC is used predominantly.[26]

For heat insulating layers in flat-roof constructions[12] foams or polystyrene or phenolic resins are used;[11] [12] [21] reinforced PVC foils are applied for roof skins[28] reinforced polyesters for transparent roofing glass. Applications of the latter do not only include low weight roofs of house entries, of parking places for bicycles and of filling stations made from corrugated sheets[29] but also single-dome or double-dome transparent cupolas of various sizes[29] [30] up to transparent roofs of halls having large dimensions. By adequate construction of the elements stiffness and load-bearing capacity of the whole construction can be increased considerably.[31]

For non-load-bearing casing of, e.g. balcony parapets, corrugated sheets are used which are normally made of glass reinforced polyesters[29] but also of rigid PVC.[32]

On the whole transparent plastics are widely applied for the construction of "translucent units".[33] These are transparent construction units, e.g. partition walls, pillars, or the like which allow to bring daylight to dark rooms and/or serve as decorative elements. Screen walls of glass reinforced polyester[29] and transparent wall units composed of several extruded sections[33] should also be mentioned.

Interior architecture and decoration makes extensive use of plastics.

Wall coverings are made from PVC or polystyrene plastic flags. Plasticized PVC in rolls or decorative laminates in sheets are used for coverings and casings of large dimensions. Furniture facings are made either of decorative laminate sheets[35] or of PVC veneers. Attachment of these materials has been facilitated in such a way that they offer themselves for "do it yourself" at home.[36] Small pieces of furniture are not rarely manufactured entirely from styrene plastics or are assembled from single parts of such plastic materials.[34] Building and furniture fittings of impact resistant polystyrene, hinges of polypropylene, plastic wall panels of various plastics may serve as a few examples for a great number of possibilities.

Casings of facades made of PVC or glass reinforced polyester 37/ 38/ or of plastic coated iron plates are constructed as sandwich laminates; the technique of production has already been explained. If such laminates are used instead of masonry for the covering of steel or concrete skeletons they are made somewhat thicker. The low weight core is usually a heat insulating plastic foam and the outside facing is of PVC, glass reinforced polyester sheets, plastic coated iron plates, boards of minerally bonded wood-shavings, or asbestos cement. The facing towards inside is often covered with stucco cardboard. Such units are often manufactured in considerably large dimensions (up to 20 m^2 and even more), have recesses for doors and windows and can therefore be regarded as finished products. It is said that the setting up of such units does not require more than 1 minute per m^2. 39/

The above described method may be regarded as a transition to unconventional ways in building construction which will be discussed in the following.

Application of plastics in unconventional methods of construction 40/

An increase in the amounts of plastics used in the building trade which exceeds the quoted extent of 20 to 30 % of the overall consumption of plastics can only be achieved if traditional construction methods are replaced by methods allowing full exploitation of the possibilities of plastics. For that purpose, however, pioneering trains of thought have to be followed which will perhaps be accepted more easily in developing countries because there architectural tradition will not be opposed to the new concepts. In addition there is no doubt that in smaller buildings construction units are exposed to less stress than e.g. in skyscrapers so that even load-bearing functions can be fulfilled by plastic parts.

For temporary use as meeting halls and warehouses or for provisional accomodations of a great number of people in cases of disaster "self-supporting inflatable halls" are the ideal solution.[41] They are made of plastic coated fabrics blown up by a slight overpressure of air so that they form an arch like a cupola. If they are not required any longer the air supply is interrupted, they collapse and can be quickly and easily transported somewhere else. Their weight is about 1 kg per m^2 whereas roofing constructions of glass reinforced polyester weigh approximately 10 kg and traditional roofings about 100 kg per m^2. If after erection smaller "self-supporting inflatable halls" are sprayed on the inside with foamable plastics, e.g. carbamide resins, they are even after stopping of the overpressure of air stiff enough to make a "self-supporting" igloo.[42] Since all those low weight constructions can be erected without a foundation they are indeed resistant to earthquakes and need only be secured against being blown away by winds.

Starting from similar ideas habitations have been constructed consisting of a barrel-shaped metal body which is thermally insulated by a foam lining and can be partitioned by plastic walls as requested. Since such a habitation with a living area of 70 m^2 weighs only 2.5 tons, is erected without a foundation lying on the ground like a barrel it is also earthquake resistant. As further advantages the builders claim resistivity against termites as well as low price.[43]

Out of other novel constructions using plastics only a few should be mentioned. Cupola shaped constructions are assembled from bands of polystyrene foam or wound from them and strengthened by automatic continous glueing or welding. Such a cupola can be covered with concrete or with glass reinforced polyester.[40] All plastic houses consist of dwelling units made of glass reinforced polyester sandwich laminates which can be built together in different ways. It is also possible that sandwich laminate panels which if necessary have strengthened borders may serve as coverings or linings for steel frame structures. There is a variety of ways to assemble such dwelling units to houses which then have very different ground-plans and varying but not too large dimensions. Test types have been erected in almost all industrial countries and in many cases have been furnished with built-in plastic furniture. By critical observation of their use during a period of several years valuable informations have been gained on the practical applicability of certain dwelling units.

With the mentioned prototypes the self-supporting constructional parts have to fulfil specific functions. In other cases they are specially designed body frame constructions made of glass reinforced polyester which e.g. bear the glazing of shed-roofs 22/ or form the skeleton of a fillign station. 44/ For large exhibition halls vault-like roof parts resting on glass reinforced polyester pillars have been arranged regularly around a centre part or vaulted plastic sheets have been mounted on the steel network of a spherical hall thus stiffening the whole construction very strongly.

If polyester sheets have to be set in metal frames it is often practical to cast the plastic material directly into the metal frame in order to obtain a joint between plastic and metal thus protecting the latter against rust.

For small habitations of the "do it yourself"-type which every non-professional is able to build hollow "bricks" of PVC are available which are specially shaped so that they fit into one another and give a good joint like the parts of some building-box toys. To make such habitations sufficiently stable the hollow spaces of the plastic "bricks" are filled with sand. 46/

It must finally be mentioned that plastics in connection with building construction are also used as mere auxiliary materials and therefore do not show up in the finished buildings. Fresh concrete is covered with polyethylene or plasticized PVC foils to prevent premature drying.45/ Temporary glazings of carcase works with plastic foils allow construction works to be continued even under very unfavourable climatic conditions. Indeed complete buildings have been erected under gigantic inflatable self-supporting halls whichaare not removed before completion of the work.

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2.4. Electrical Engineering

About 50 years ago the increased quality requirements of the electrical industry led to the discovery of "Bakelite", the first fully synthetic plastic. Today electrical engineering is still steadily stimulating improvements of plastic materials though other industrial branches have become leading in regard to tonnage.

It is obvious that the successful and rapid increase of the electrical industry is due to the development of new insulating materials and it was only when plastics with high-grade insulating properties became available that this enormous progress started.

It is only a small number of specific branches where plastics have to face considerable competition from mica, ceramic and bituminous insulating materials, insulating papers, and rubber. Even if dielectric characteristics of certain plastics are excellent they are of moderate temperature stability and often a strongly marked inflammability must be taken into account. The following table 9 gives a survey of the properties of the most important insulating materials (measured values are not reported because they can very strongly be influenced by admixed materials).

Table 9: Comparison of Electrical Insulating Materials based on their properties

	Ceramics	Bitumen	Insulating Cable Paper	Rubber; Ebonite	Thermoplasts	Thermosets
Weight	4	3-4	3	2	1	2-3
Impact Strength	1	1	-	2	2-4	2-3
Temperature Stability	4	1	2	2	2-3	3
Dielectrical Properties	4	3-4	4 x/	4	4	2-3
Moisture Resist nce	4	4	o	3	4	3-4
Oil Resistance	4	0	4	2	0-4	4

x/ in absolutely dry condition only

Note: The highest figure of the classification scale indicates the highest property value (o= unsuitable).

Plastics are used in electrical engineering not only as insulating materials but also for component parts (e.g. motor casings from glass reinforced polyester[1]) allowing to make them smaller and more compact because the electrically insulating plastic reduces the danger of breakdown by surface conduction. Laminated insulating materials consist of paper, cotton fabric or, if high temperature stability is required, of asbestos felts, glass fibre fleeces or fabrics which are bonded together with phenol-formaldehyde resins or polyester resins.[2] [3] Laminated materials with pressed on or galvanized metal coatings[4] [5] are suitable for the manufacture of printed circuits which play a very important part in modern swich- and control systems. Flexible materials of this kind are on the market too.[5]

Installation materials like plugs and sockets, switches, junction and distributor boxes as well as bodies for coils [21] are usually made of phenoplasts or aminoplasts. Only in cases where relatively moderate thermal stability and comparatively high inflammability are of minor importance styrene polymers or copolymers come into consideration.[6] Strongly strained parts of larger dimensions are preferably made from glass reinforced polyesters which combine improved tensile strength with good non-tracking qualities.

Polypropylene [7] or impact resistant polystyrene [8] are used for the casing of storage batteries particularly because of impact and vibration strain which automobile batteries have to stand. Separating sheets for storage batteries are today almost exclusively made from polyolefins or PVC. The necessary strictly limited permeability can be accomplished by powder-sintering or incomplete impregnation of fibre fleeces with synthetic resins. Pores of the required size can also be obtained by adding soluble ingredients to the plastic before manufacturing and subsequent dissolution.

Plastics have become important in the production of low- and high-voltage wires and cables. Insulating wire-enamels are either made of phenolic resins plasticized with polyacetals 9/ or of PVC.10/ The polymer blend is applied as a varnish whereas PVC is sinter-fused. Polyethylene and plasticized PVC are extensively used in the manufacture of cables. Besides their excellent dielectrical properties these plastics are absolutely insensitive to humidity. Cables of this kind do therefore not require any of the necessary precautionary means for paper insulated cables 11/ and a coat of polyethylene makes them excellently capable of being used as submarine cables.12/ The thermal stability of polyethylene as cable material can be substantially improved by cross-linking the polyethylene molecules with peroxides so that such cables work satisfactorily even under increased thermal strain.13/ Moreover, the application of plastics for insulating cables allows the construction of various special types which would otherwise be impossible. If e.g. metallic sodium is embedded in a polyethylene sheathing the weight of such a cable can be reduced to one third.14/ It is out of question that , in consequence of elimination of the traditional lead sheathings, cables covered with plastics are very substantially reduced in weight so that transportation and installation costs are lower. Cable sheathings of PVC can be made oil resistant which is another obvious advantage in comparison to rubber cables.

In addition to the above mentioned advantages it should be noted that the use of plastic insulated cables helps to rationalise wiring and to establish electrical connections clear of strays.15/

Insulating tubes or sheaths for the installation of electric conduits are for the most part made from rigid PVC or from polyethylene in order to avoid the troublesome corrosion of metallic insulating tubes which is due to a reaction with mortar or concrete. 16/ 17/

Insulating varnishes, particularly those for impregnation of windings 18/, plastic bonded magnets 19/, insulating tapes 20/, and various small parts (e.g. insulating screws and nuts) can only be mentioned.

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The problem of thermal insulation has already been discussed in section 2.3. ("Building Construction") as it is important for the protection of buildings against heat and cold. Much higher demands are made however, as far as cooling and particularly deep-freezing systems are concerned. The following qualities are required:

(a) minimum heat conductivity within the whole temperature range that must be expected during application,

(b) maximum diffusion resistance against water vapour,

(c) good dimensional stability to prevent subsequent formation of cavities which could effect thermal insulation,

(d) good thermal stability as well as good compatibility with adhesives and sealing compounds, and

(e) high resistance against humidity, oxidation and microorganisms.

As heat insulators plastic foams based on polyestyrene, phenolic and urea resins come into consideration in contrast to traditional insulating materials like cork and glass wool. At present rigid polyurethane foams are being used more and more for thermal insulation application. They have the advantage of being capable of being produced on sites from their raw materials.

A comparison of the properties of thermal insulating materials is given in table 10.

Table 10: Properties of thermally insulating materials

	Density	Heat-transfer coefficient (kcal/m h °C)	Diffusion resistance against water vapour (comparative figures)	Weight increase in air with 95 % relative humidity (Vol. %)	Inflammability x/
Polyurethane foam	[illegible]2 kg/m^3	0,015	n.a.	ca. 3	1
Polystyrene foam	20 kg/m^3	0,027	100	0,03	2 or 3
Polystyrene foam	30 kg/m^3	0,025	150	0,03	2 or 3
Phenolic resin foam	40 kg/m^3	0,027	30	1,0	1 or 2
Phenolic resin foam	80 kg/m^3	0,024	180	1,1	1 or 2
Urea resin foam	18 kg/m^3	0,025	3	31	1
Glass wool	100 kg/m^3	0,051	1,5	12	0
Glass wool	300kg/m^3	0,050	1,7		0
Cork sheets	50 kg/m^3	0,029			2
Cork sheets	100 kg/m^3	0,032	2,5		2

x/ Figures mean: "0" not burning
"1" self-extinguishing
"2" difficult to burn
"3" easy to burn

It can ben seen that with the exception of glass wool the listed insulating materials do not show great differences regarding thermal conductivity provided that they are absolutely dry. On the other hand a high moisture content reduces the insulating property greatly. Therefore glass wool and urea resin foam can insulate satisfactorily only if they are protected by absolutely tight screening from moist air whereas polystyrene is scarcely affected in this respect. Contrary to cork insulations foam plastics are distinguished by their resistance against moisture and micro-organisms. A disadvantage of polystyrene foam is its limited thermal stability; with phenolic resin foam it is the smell of phenol that cannot be completely eliminated. 1/ 2/

In addition to the above mentioned properties favourable vibration strength and abrasive resistance are required in case of movable cooling systems or containers. Rigid PVC foams are most suitable for that purpose but polystyrene foams with not too low unit weights have also proved successful.3/ These problems will be discussed below in section 2.9. ("Transportation").

If extreme temperature differences exist between the outside atmosphere and the inside of the cooling system it is absolutely necessary to use a vapour lock to prevent condensation of diffused water vapour. Composite foils consisting of plastic and aluminium are very well suited for that purpose.

By making the inner and outer casings of cooling systems from a deep-drawn styrene plastic or from glass reinforced polyester as well as by using plastic screws, spacers, etc. it is possible to avoid the formation of heat conducting bridges thus improving the insulating effect.4/

Since the upper temperature limits of plastic foams are not very high (60° to 130°C according to the type of plastics) such materials are applied mainly for thermal insulations in building construction and in cooling systems. Plastic foams cannot be used for steam lines, thermal power stations etc.

In some cases thermal insulation is necessary to protect free liquid surfaces against frost or against losses by evaporation. Hollow plastic spheres floating on the liquid surface and screening it efficiently against the atmosphere are used for that purpose. According to the type of liquid small spheres from phenolic resins ("microballons") or somewhat larger ones from polypropylene are applied.[5] Plastic spheres have also proved successful as odour barriers.[6]

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2.6. Gluing and Improving of Wood

For improvement of natural wood plastics can be used in different ways:

(a) as glues and bonding agents,

(b) as impregnating material, and

(c) as substrates for surface treatment.

The industrial gluing of wood concerns first of all the production of plywood preferably using urea and phenolic resins which can quickly and safely be cured by heat treatment. These materials compete with cold setting casein glues which, however, are surpassed by the synthetic glues in regard to quick setting, good water resistance, and resistivity against mildew and decay. These properties are particularly important for application in countries with warm and moist climates.1/ 2/ Which of the mentioned synthetic glues should be preferred does not only depend on the type of wood and on its moisture content but also on the type of loan materials available which can substantially influence the gluing process. Moreover, the technology of this process can be modified in many ways. The glue may be applied as liquid or intermediate layers of papers impregnated with synthetic glues may be inserted. The curing heat may come from the plates of a press or may be produced in the straight-glued joint by resistance heating (TEGOWIRO-process) or by high-frequency.

The production of wood chip boards preferably uses water soluble urea resins as bonding agents which can be cured by heat and pressure; the necessary heat input can be effected from outside or from inside.1/

Gluing of wooden workpieces either outdoors at the building site or in the workshop can be carried out with cold setting adhesives based on phenolic or urea resins. For such purposes, however, adhesives from dispersions of polyvinylacetate are usually preferred owing to their more simple and convenient handling. In cases where requirements of adhesive strength and weather stability are very high, as in constructions of halls with self supporting roofs, bridge constructions, etc., phenolic resin glues modified with resorcin are applied.[4]

For long, specialists of wood processing have been engaged in the problem concerning the improvement of low quality wood by filling its cavities with plastics. Solutions of macromolecular substances are, however, of high viscosity and therefore do not penetrate deeply enough into the wood even if vacuum and pressure are applied so that only the outer layers will be improved. Only recently satisfactory results have been obtained by impregnating wood with monomers, e.g. styrene, which are polymerized in situ by means of chemicals or by irradiation with gamma-rays.[5] Similar methods are used for the improvement of wood-fibre boards.[6]

Technological processes which improve wood surfaces, e.g. coloration, polish or designing, hardness and resistance against scratches or moisture and chemicals, have become very important. Besides varnishing, which will be discussed in section 2.7. sheets of wood can be glued with laminates or plastic foils.[7] Such composite materials can be obtained in <u>one</u> single operation placing plastic foils or several layers of paper impregnated with synthetic resin on top of veneers or wood shavings or other materials furnished with glue. The composite material is then cured with heat and under pressure.[8] [9] If only one layer of paper impregnated with synthetic resin is used the surface structure of the core material remains visible. Metal foils as top laying materials require provisions for a possible moisture exchange between the core material and the outside atmosphere.[10]

Surface improvements of the above mentioned type offer first of all the advantage that surfaces can be obtained which are very attractive, durable, and of great resisting power. There is no doubt that thus improved surfaces surpass varnished ones in every respect. During subsequent treatment, however, scars and scratches have to be carefully avoided. Edges should be treated with respect to the specific properties of the materials. The narrow, dark-coloured lines visible on the cut edges of the covering materials are often used as decorative element by designers. As a matter of fact products of wood covered with plastics are widely used for the interior decoration of dwelling houses, ships and railways and in the furniture industry.

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2.7. Varnishes and Coating Materials

Recent developments in the field of varnishes and coating materials are characterized by a more or less complete replacement of previously used oil and natural resin varnishes as well as that of water soluble coating materials based on casein by synthetic products. For example, in [illegible] in Western Germany only 6.7 % of the total output of varnishes were oil varnishes whereas 25 % were alkyd resins modified with oil and the remaining 68.3 % were varnishes based on oil free synthetic resins.[1] Not only the production process could thereby be considerably simplified because melting out and boiling down processes are no longer necessary but also the drying process of the coating materials could be accelerated to such an extent that modern conveyor-line varnishing procedures became possible. Moreover, the properties could be adapted to particular needs and requirements to a degree which formerly was impossible.

As raw materials practically all synthetic resins nowadays produced are applied.[2] In this respect, however, only those synthetic resins are taken into consideration which are based on mass-produced plastics and those of their derivatives which can be obtained without any great expenditure on equipment. Anticorrosive coating with good chemical resistance, wood varnishing, and dispersion painting for masonry can be regarded as preferred fields of application.

Coatings with high chemical resistance are preferably produced on the basis of polymers of vinylchloride. Their solubility can be increased to the desired level either by further chlorination[3] or by copolymerisation of vinylchloride with vinylacetate and maleic acid. Chemical and weather resistivity of such coatings are so good that they can stand extraordinarily high strains, e.g. continuous action of crude oil and sea water.[4]

Similarly to wood which can be coated with laminates from thermosets or with foils of thermoplasts instead of being varnished steel or light-metal plates and strips can be coated with plastics and subsequently processed in the usual ways, e.g. folding, bending, punching, foaming, cutting, etc. Among the plastics used for this purpose PVC leads the list followed by polyethylene. Coating can be carried out by spreading the plastic in liquid form, by sintering it in powder form, or by rolling or pressing plastic foils on the metal surfaces.[5] [6] This technique has succeeded so far that in 197[illegible] in USA presumably 40 % of the total metal plate consumption will be further processed in the precoated state. Among the most important applications steel furniture, containers, facing plates for building constructions, [illegible] tins for preserves should be quoted.[6]

Wood varnishes are at present mainly based on unsaturated polyesters crosslinked with styrene or on amino-plast resins cured with acids. If compared with the formerly used copal varnishes synthetic ones are distinguished by greater hardness and resisting power. Moreover, they have the advantage of requiring less or no volatile solvents at all because monomeric styrene functioning as solvent will be chemically bonded for the most part and remain in the varnish film. In order to avoid inhibition of the polymerization of styrene by atmospheric oxygen, however, adequate measures have to be taken. [7] [7]

Imitations of fine woods with cheap timbers as their base are produced industrially. First a coat of alkyd resins, of aminoplasts cured with acids, or of unsaturated polyesters is laid on the timber base. On this layer the grain of the fine wood is printed by means of photographic reproduction. Finally a transparent, hard and scratch-resistant varnish layer is spread on the surfaces. Such imitations are often used in series production of furniture.[5]

Efforts to avoid organic, mostly inflammable and also physiologically dangerous solvents led to the development of water soluble stoving enamels made of phenolic-, urea- or melamine resins modified with ammonium or [illegible] salts of acid macromolecular materials, e.g. polyacrylic acid or alkyd resins which possess COOH-groups. The transformation into a hard and insoluble as well as infusible varnish is effected by a [illegible] treatment at increased temperature, e.g. also by infrared radiation.[5] Such varnishes are used as rustproof priming and as single-layer varnishings of passivated metals.

Dispersions based on copolymers of styrene with butadiene or styrene containing oils are suitable as coatings for porous materials if no gastight film but, on the contrary, a limited gas permeability is required. The main application is the coating of facades of which very favourable results have been reported.[9]

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2.8. Packaging and Containers:

In this branch which can be appropriately subdivided into consumer packings, transport packings, and containers of larger dimensions plastics have reached a remarkable position. Table 11 gives a survey of the Western German packaging industry.1/

Table 11: Breakdown of Gross Output of the Western German Packaging Industry 1/

Materials for packing	Results in 1967 (Millions of DM)	%	Changes in comparison to 1966
Paper and Cardboard	4126	47,5	- 2,4 %
Metal	1957	22,5	- 1,4 %
Plastics	1522	17,5	+ 10,6 %
Glass	769	8,9	- 2,0 %
Wood	251	2,9	- 10,7 %
Fabrics	34	0,4	- 12,5 %
Others	30	0,3	
Total	8689	100,0	- 0,3 %

From the total amount in 1967 the fact arises that each Western German spent 151 DM for packings including more than 26 DM for plastic packings. These expenses presuppose, however, a relatively high standard of living which for the time being cannot be expected in developing countries. One of the most important arguments favouring plastic packings is that they can be used as one-way packings. [illegible] collecting, returning and cleaning, which [illegible] of interest in industrial countries with [illegible]. On the other hand one-way packings [illegible] in sparsely populated countries [illegible] of transport [illegible] to be taken into account.

Although a slight decline [illegible] occurred because of the recession in 1967 it should be noted that the plastic packaging branch has increased its output [illegible] (see table 11, last column). This is obviously due to the progressive development of the production of canisters, [illegible] and other larger containers.

In 1967 the total output of plastics for purposes of packaging in the UK was 1,178,0[illegible] tons.[3]

Table 12: Breakdown of Use of Plastics in the UK Packaging Industry

Foils:	457,000 tons (80 % polyethylene)
Boxes and Cases: (including [illegible])	23[illegible],000 tons (18 % polystyrene)
Coatings:	203,[illegible] tons ([illegible] % polyethylene)
Bottles and [illegible]:	1[illegible],[illegible] tons ([illegible] % polyethylene)
Bottle Closures:	43,000 tons (various plastics)
Adhesives:	43,[illegible] tons (various plastics)

The most important plastics used are polyolefins, rigid as well as plasticised PVC, and in particular cases also biaxially oriented polystyrene. Polyethylene or plasticised PVC are applied as wrapping foils or are processed to form [illegible] and bags. It has been estimated that [illegible] American supermarkets are packed [illegible].[4] The [illegible] impermeability of the packing material [illegible] to the particular requirement [illegible] of several layers or by careful [illegible] e.g. in case of the packaging of certain sorts of cheese or of the vacuum packaging of coffee, fats, etc.[4] The various types of transparent packings known as bell-, blister-, skin-, stretch-, and shrink-film packings allow to pack objects attractively and keep them visible to the customer at the same time. In certain cases the foil clings to the object like a transparent skin.[2]

Large sacks for contents of 25 kg, 50 kg or even more are made of foils from plasticized PVC or polyolefins[6] or of woven strips from stretched polyolefins.[7] [8] In contrast to the formerly used jute or paper sacks those made of plastics have the advantage of extraordinary resistivity laminated with a foil, of being waterproof too. Consumption has already reached a considerable degree and shows a high rate of growth. In 1970 Scandinavia alone expects a demand for 650 million sacks.[6]

Papers and cardboards as well as metal plates are coated with plastics. For paper and cardboard polyolefins and sometimes PVC come into consideration. In comparison with the formerly used wax and paraffin coatings those made from plastics show improved heat stability and abrasion resistance.[9] [10] Paper products coated with plastics, e.g. drinking cups, packaging of milk, and of deep-frozen provisions, have gained great importance. Metal plates used for the production of tins for preserves are precoated with polyolefins, PVC, or with varnishes based on phenolic or melamine resins.[11] [12]

Cups and boxes as well as their lids can be manufactured from various plastics by different processing methods:

<u>Thermosetting moulding materials</u> of phenolic and urea resins are formed under pressure and cured in heated steel moulds (compression moulding).

<u>Polyolefins and styrene plastics</u> are formed by injection or blow moulding or thermoformed from intermediate products from these materials.

Rigid PVC is processed besides blow moulding mainly by thermoforming (deep-drawing, blowing, or under vacuum).

The most appropriate method of processing is determined not only in accordance with the chosen plastic but also with respect to the final shape of the product and particularly to its wall thickness.[13]

Receptacles of larger dimensions, as canisters and barrels, if not consisting of glass reinforced polyester, are preferably made from polyethylene by blow-moulding or by powder sintering. Among others typical examples are petrol canisters blow-moulded from high density polyethylene,[14] oil barrels,[15] fuel oil tanks,[16] and beer barrels;[17] numerous other receptacles used in industry, agriculture and households, e.g. tubs, buckets, vats, baskets etc., are made of polyolefins.

Large containers having a volume of several thousand litres usually consist of glass reinforced polyester or if made of other plastics are reinforced with glass.[18] Such containers are used either for the transportation of liquids, an application which will be discussed in section 2.9., or for storage of mineral oil products, wine, chemical products etc. For these storage purposes glass reinforced polyester containers having a volume of 100 m^3 were put in operation.[19] Containers with extremely high capacities which can be folded up when empty consist of synthetic fabrics coated with suitable plastics, e.g. PVC. Such a container with a capacity of 1,500.000 litres weighs only 1.000 kg when empty.[20]

In recent years special attention has been given to the problem of one-way plastic bottles made of polyethylene or rigid PVC. The most frequently used manufacturing method is blow-moulding. Apart from that deep-drawn bottle halves are welded to a complete bottle. On the whole technical problems can be considered as solved. Nowadays pharmaceutical and cosmetic products as well as cleaning agents are brought to the market in plastic bottles almost exclusively. A milk bottle made of high density polyethylene weighs only 28 grams whereas a glass bottle of the same volume weighs 750 grams.21/ Bottles produced from PVC were successfully used for wine, salad oil, and vinegar. Bottles suitable for beer are manufactured from PVC too. Calculations of viability, however, differ from country to country because specific economic conditions determine to what extent the higher prime-costs of plastic bottles can be compensated by other savings, e.g. elimination of return transport, of cleaning and of losses by breakage as well as by a possible reduction of transportation costs. In 1965, for instance, France had an overall need of 300 million plastic bottles, among them 100 millions for sweet-oil and 25 million for wine.22/ In the USA the so-called "bottle-pack" process has been developed in order to solve the transportation problem of empty bottles by manufacturing, filling and closing of milk bottles in one operation in the dairy itself. 23/

Stoppers and screw caps as well as crown corks come into consideration as bottle closures.24/ Stoppers made of polyethylene are usually hollow so that the enclosed air in the hollow space forms an elastic cushion. Screw caps are made of thermoset moulding materials or styrene polymers. Snap lids and tear-off closures are produced from polyolefins.24/ For crown cork seals doubled PVC or polyethylene foils are most suitable.

Finally special methods for the packaging of particularly fragile goods should be mentioned. Such objects are either wrapped in foam plastic foils 25/ or put into polystyrene foam blocks the shape of which is exactly adjusted to the object to be packed.26/ At last, to complete the examples, air filled bags made of PVC foils should be mentioned that can be used for cushioning shipping boxes.

As a matter of principle any interaction between the packaged goods and the packing material must be prevented. This fact has to be carefully considered in each case with respect to e.g. tempera-

[illegible] given

above [illegible]

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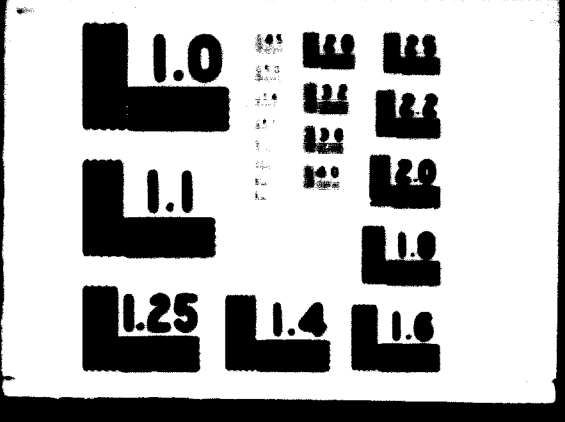

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2.9. Transportation

The application of plastics in the field of transportation ranges the construction of cars, ships, and aircraft to the production of transport containers and other auxiliary means of transportation.

Plastics used as structural elements in railway carriage constructions are always reinforced with fibreglass and are applied for the stream-lined carriage ends of high-speed trains 1/ and for the doors of such carriages. [illegible] on railway carriages are produced as sandwich construction consisting of [illegible] filled honey-comb cores covered with layers of glass reinforced polyester.[2] This construction allows considerable savings in weight and a corresponding increase of [illegible] capacity. The upper parts of refrigerator waggons are made from low weight construction units consisting of a foam core covered with aluminium and glass reinforced polyester.[3]

The applications of plastics for equipping the interior of passenger coaches are manifold. Facings for walls and ceilings are laminates made from phenolic resins or aminoplasts or are spanned foils of plasticized PVC. The latter is also the basic material for floorings and upholstery of cushioned seats. Finally moulded pieces of phenolic resins or aminoplasts or injection moulded parts should be mentioned (e.g. door handels, reading lamps, window cranks, ashtray supports, lettering plates, lavatory installations, etc.)

Plastics are extensively used in the automobile industry too. A modern car contains far more than 300 single parts made of almost every sort and type of plastics.[4] Their total weight amounts to 38 kg per car.[4] About 5 kg of PVC per car are used for the upholstery of cushioned seats, for floor mats, for sound absorbing coverings, and for cable insulations.[5] Instrument panels, masking grids, apparatus casings, handles and control knobs are made of styrene copolymers and terpolymers (ABS) whereas reservoirs for water for the windscreen wiper and for the brake fluid are produced from polyethylene.[5] At present fuel tanks of high density polyethylene are tested in order to gain experience of their advantages and disadvantages.[6]

Generally seen two different ways in the production of carriage bodies and parts can be distinguished: the hand lay-up moulding of glass reinforced polyester resins or the thermoforming of impact resistant styrene terpolymers (ABS) or polypropylene.[7] [8] In both cases savings in weight are very considerable ([illegible] and more). For the manufacture of such parts from glass reinforced polyesters cheap moulds of wood, clay, gypsum or glass reinforced polyester are sufficient thus saving tool costs of approximately 75 % in comparison to deep-drawing moulds used for the forming of sheet iron plates. This is of special interest in regard to cost-prices if only small series productions are considered.5/ Moreover, the use of glass reinforced polyester allows to integrate a greater number of constructional units so that assembly is substantially rationalized and less expensive.5/ Besides the above mentioned advantages of low weight and low mould costs carriage bodies and parts, e.g. rigid roofs, fenders, truck cabins, etc. made of plastics, offer a considerable reduction of noise due to their improved shock absorption and excellent corrosion resistance. Damages by breakage which can be expected in cases of relatively vehement collisions only can easily be repaired with polyester resin and glass fabrics. The above described technique is preferably employed for specially constructed carriage bodies for sports cars, ambulances, caravans, buses, delivery trucks, etc.

Plastics are of particular interest for the construction of tank lorries. A 20 m^3 transport tank of glass reinforced polyester weighs over 2 tons less than a steel tank of the same size which makes possible to increase the effective loading capacity by 10 % retaining the same motor and undercarriage.5/ By coating plastic tanks with rigid foam of polystyrene or PVC the temperature of the content can be kept stable against changes of the outside temperature. This is especially important for the transportation of milk and wine.9/ 10/ In such cases the used plastic foam has to satisfy very high requirements regarding resistance to vibration. Furthermore, vibrations as a consequence of driving on uneven roads must not cause abrasion or crumbling of the plastic foam. Hence polyvinyl chloride or polyethylene foams of higher volume weights are preferred for such purposes.

Among watercraft smaller boats are manufactured almost exclusively from glass reinforced polyesters the body respectively the upper part made in one piece. Shell shaped constructional parts make the usual ribs dispensable and by incorporation of closed-cell rigid foams the stiffness as well as the seaworthiness of watercrafts is increased to such an extent that even under severe conditions they can be successfully used as lifeboats. Boats of more than 20 m length have already been built and are in operation; first drafts for 60-m-long boats have been worked out.[13] For smaller loads boat bodies are made of deep-drawn styrene terpolymers (ABS).[14] Collapsible boats are produced from polypropylene.[15]

Various equipment for larger ships (e.g. lifeboats, rafts, life jackets, fenders and buoys) is manufactured from closed-cell rigid foams of PVC or polystyrene thus obtaining a high carrying capacity which is not impaired even if the outside skin is damaged. Plastics are also used for indoor equipment in a similar way as has been outlined in the sections dealing with building construction or with railway carriages. Main emphasis is given to flame resistant and selfextinguishing types of plastics.

It is obvious that particularly low weight materials as plastics are of special interest to the aircraft industry therefore thousands of single parts are produced from plastics. The most suitable materials satisfying the specific requirements have to be selected regardless of whether home industry is able to provide them or not. Sandwich constructions based on glass reinforced plastics are successfully used, e.g. for the construction of helicopter rotor blades.[16] Because of the high strain of these parts and with respect to the high safety requirements polyesters are replaced by epoxy resins which adhere to glass fibres even better. In order to avoid local defects a winding process with endless glass fibre strands is applied. Sometimes small aircraft contain extraordinarily great amounts of plastics so that one could easily speak of all-plastic airplanes.[17]

Among the means of transportation special constructions made of plastics are very important. Machines, machine parts, and tools are packed in a corrosion-proof way with the help of shrink foils, casting resins, or by spinning them with vinylchloride polymers.[18] One-way fruit cases made of polystyrene foam have the advantage of particularly low weight.[19] Pallets made of glass reinforced polyester can bear a cargo which weighs 40 times their own weight.[20] Bottle cases made of polyolefins or of impact resistant polystyrene are distinguished by high resistivity against shock.[21] Shrink foils of polyethylene are used for wrapping bulky goods together with the pallet.[22] To transport petroleum products by water hose-like containers made of plastic coated fabrics have been developed which float up and can be towed by a tug-boat.[23]

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3. Tabular Synopsis of Applications of the Most Important Plastics

A brief survey shall now sum up the various fields of applications making use of the following abbreviations:

A .... Agriculture
Cl .... Clothing
F .... Footwear
B .... Building Construction
E .... Equipment of rooms including furniture
H .... Household
R .... Refrigeration
Ee .... Electrical Engineering
G .... Gluing and improving of wood
V .... Varnishes and coating materials
P .... Packaging
C .... Containers
T .... Transportation
Ta .... Auxiliary means of transportation

3.1. Applications of polyvinyl chloride

3.1.1. Rigid PVC

Sheets	: B,E,Ee,C
Pipes	: A,B,Ee
Profiles	: B,E,Ee
Hollow articles	. P,C
Deep-drawn pieces*	: B,H,P
Foams	: B,R,C,T
Coatings	: G,P

3.1.2. Plasticized PVC

Coverings	:	B,H,T
Foils	:	A,Cl,B,E,H,G,P
Flexible tubings	:	A,H,Ee
Profiles	:	B,E
Coatings, sheathing	:	Cl,F,B,E,H,Ee,G,P,T
Solutions and dispersions	:	V

3.2. Applications of polyolefins (polyethylene, polypropylene)

Pipes	:	A,B,Ee
Foils	:	A,Cl,B,H,P,Ta
Injection moulded parts	:	A,Cl,S,E,H,Ee,P,T
Hollow articles	:	A,K,P,C
Fabrics	:	F,P,Ta
Coatings, sheathings	:	A,S,Ee,P

3.3. Applications of homo- and copolymers of styrene

Monomer styrene	:	G
Dispersions	:	B,V
Pipes	:	B
Injection moulded parts	:	Cl,B,E,H,Ee,P,T,Ta
De· drawn pieces	:	E,P,Ta
Foams	:	A,B,R,F,C,T,Ta

3.4. Applications of phenol-formaldehyde resins

Liquid resins and solutions	:	G,V,P
Foams	:	B,R,C,T
Moulded parts	:	Cl,B,E,H,Ee,P,T
Laminates	:	B,E,H,Ee
Coatings	:	G,P

3.5. Applications of urea-formaldehyde- and melamin-formaldehyde resins

Liquid resins and solutions	:	G,V,P
Foams	:	A,B
Moulded parts	:	Cl,B,E,H,Ee,P
Laminates	:	B,E,H,P
Coatings	:	G,P

3.6. Applications of unsaturated polyesters

Liquid resins and solutions	:	G,V,
Sheets (glass reinforced)	:	B,E,R,Ee,T
Moulded parts (glass reinforced)	:	A,B,Ee,C,T,Ta

4. Summary and conclusions

Everything mentioned in this report has clearly shown that plastics cover a very broad field of applications and can, therefore, contribute to a substantial increase in the standard of living of the inhabitants of developing coutries. In a critical analysis of that problem however, certain decisive facts should not be left out of consideration.

The plastic industry is usually subdivided into the plastic producing and the plastic processing industry. The first one produces the plastics mainly from low molecular petrochemical substances whereas the processing industry manufactures semiproducts as well as finished articles from the plastics.

Between the chemical industry and the plastic producing industry there exist strong links because e.g. the supply of the necessary raw and auxiliary materials has to be secured as well as have the by-products of the synthesis of plastics to be utilized profitably. The simplified scheme given in the introduction of this report shows the outlines of such links. If the synthesis of plastics is made from the most simple basic materials the plastic producing industry due to the high costs for the plants requires high capital investments even if at big plants the number of employees, and as a consequence the amount of wages paid, is relatively small. In the plastic processing industry if fully automatic plants are disregarded the situation is reversed: moderate capital investments are confronted with relatively high amounts of wages. Whereas the production of plastics has actually to be run on a large scale in order to remain competitive at all, small and medium sized processing factories are quite able to compete.

In view of such circumstances and in order to secure adequate sales the best solution for a developing country would be to begin with the setting up of a plastic processing industry working with imported plastics. A plastic producing industry should be established only if the preconditions for secured sales are fulfilled.

Another solution would be to produce certain plastics in the respective country itself from imported raw materials and to deliver them to the processing industry of the country. Thus phenolic resins could be made of phenol and formaldehyde and finally unsaturated polyesters from glycol, maleic acid, phtalic acid and monomer styrene.

If, however, a plastic industry which was as much as possible self-sufficient should be established based on crude oil or natural gas it seems to be most appropriate to start with the synthesis of polyolefins because apart from the olefin which is polymerized only small quantities of addition agents are needed. Hence, the polymers which come into condideration are polyethylene of low or medium density and polypropylene.

The establishment of a self-sufficient producing industry for PVC is much more difficult because the supply of chlorine requires an alkali chloride electrolysis yielding considerable amounts of sodium hydroxide and because on an average 200 to 250 kg of plasticizers per ton of PVC are needed for the processing. Further chemical plants would be necessary for the manufacture of those plasticizers from domestic raw materials.

The production of styrene polymers is even more difficult because besides the homopolymer certain quantities of copolymers with butadiene and/or acrylonitrile are also always required. These monomers have to be synthesized from olefins obtained from petrochemical raw materials and ammonia by means of various multistage processes.

The self-sufficient production of phenolic and urea resins as well as of unsaturated polyesters meets with similar difficulties regarding the production of the different monomers.

The solution to all these economical problems could be considerably facilitated if European and American concerns were to co-operate and reach mutual agreements making possible the exchange of products e.g. polyolefins or polyvinyl chloride for other raw materials like plasticizers, phenol, carbamide, maleic acid etc. Thus a technically and economically sound production could be established in the respective developing country without prohibitive financial burdens and uneconomical manufacturing processes both resulting from an excessive splitting of the manufacturing schedules.

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