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RECENT DEVELOPMENTS IN PETROCHEMICAL AND PLASTICS TECHNOLOGY IN THE USSR[1/]

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THE DEVELOPMENT OF THE USSR PETROCHEMICAL INDUSTRY

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THE DEVELOPMENT OF THE USSR PETROCHEMICAL INDUSTRY

The presence of cheap and readily available hydrocarbon raw materials of petroleum origin, the practically unlimited demand possibilities for various types of chemical products, and the high level of national scientific and technical achievements have foreordained the Soviet Union's great successes in the important branch of the national economy represented by petrochemicals and won for the Soviet Union the second place in the world, after the United States, in volume of manufacture of chemical products from petroleum raw materials.

The great achievements of the Soviet Union in the field of the development of the petrochemical industry, and its great experience in giving technical assistance in the development of such industry to a number of Socialist and developing countries (Bulgaria, Poland, India, Ethiopia, Turkey, etc.), can be used to good effect by the developing countries.

The Soviet Union is prepared both to send individual experts to developing countries and to help in working out the complex problems of the development of a petrochemical industry in those countries.

I. The development of the raw material base and the production capacity of the petrochemical industry in the USSR

At present, natural gas is processed in many chemical plants in the Soviet Union. Over 50 per cent of the entire output of ammonia, urea and methanol is produced from natural gas.

The development of the consumption of petroleum hydrocarbon gases for chemical processing over the period 1958–1970 is shown by the following figures:

(per cent)

1958 – 100.0
1963 – 270.0
1965 – 480.0
1970 (planned) – 900.0

In 1965, 3.7 billion cubic metres of natural gas (2.9 per cent of the entire production of such gas) was used for chemical processing, while in 1970 it is planned to use 10.3 billion cubic metres of natural gas (4.4 per cent of the total production of such gas) as chemical raw material. This amount will be 2.8 times more than in 1965. The main purpose for which natural gas will be used in the future, as at present, will be the production of ammonia and methanol, while the main processing method will be conversion to give hydrogen and synthesis gas.

Ammonia produced from natural gas is twice as cheap as ammonia produced from coke and coal, and the specific capital investments required for its production by this method are 20 per cent lower.

The cost of methanol produced from natural gas is 60 per cent lower than that of methanol produced by the gasification of coal, and the specific capital investments for its production are 25 – 30 per cent lower. Acetylene produced by the thermo-oxidative pyrolysis of natural gas at the place where it is extracted from the ground is approximately 40 per cent cheaper than acetylene produced from carbide, and the specific capital investments for its production are 25 per cent lower. The main raw material for the production of acetylene will be natural gas and, to a small extent, benzene; methanol and ammonia will be produced primarily from natural gas, and synthetic alcohol will be produced from gases arising in the processing of petroleum, other by-product gases, etc.

The main consumer of the liquefied gases produced in the processing of petroleum by-product gases and the stabilization of petroleum is the petrochemical industry.

The total commercial production of liquefied gases in 1965 was almost 2.8 million tonnes - ten times more than in 1958. In the next few years, a further considerable increase in the production of liquefied petroleum gases and gaseous benzene is planned in order to satisfy to the full the requirements of both the petrochemical industry and other branches of the national economy. In 1970, the production of liquefied gas will be three times higher than the 1965 level. The major proportion of the output of hydrocarbon raw materials comes from the petroleum refining industry, which produced about 60 per cent of the total output of liquefied gases in 1967. In the past, oil refineries produced only one type of liquefied gases, namely, the butane-butylene fraction, but now they produce a wide range of the C_3-C_5 hydrocarbons needed by the petrochemical industry.

Oil refineries also supply the petrochemical industry with methane-hydrogen fractions for the production of ammonia, methanol and acetylene; ethane fractions and propane for the production of ethylene and propylene; butane and pentane for the production of divinyl and isoprene; narrow benzene fractions for the production of benzene, toluol and xylols; paraffins for the production of albumins of fatty acids and alcohols; and hydrogen sulphide for the production of sulphuric acid and sulphur.

The main raw materials for the production of practically all synthetic materials are clefin, aromatic and higher paraffin hydrocarbons.

The production of ethylene and propylene is growing at a particularly rapid rate.

The development of the consumption of ethylene and propylene is shown below, in relative percentages:

	Ethylene	Propylene
1958	100.00	100.0
1962	207.2	200.0
1963	279.0	261.7
1964	365.4	333.4
1965	390.3	416.7

The percentage breakdown of the production of ethylene from various raw materials in 1965 is as follows:

Ethylene produced by pyrolysis of hydrocarbon raw material - 96.76 per cent;

Ethylene from the coal tar chemical industry - 1.92 per cent;

Ethylene produced by the breakdown of ethyl alcohol - 1.32 per cent;

Ethylene, propylene and other monomers are the basis for the production of the most widely used types of plastics (polyethylene, polypropylene, copolymers of ethylene and propylene, polystyrol and copolymers of styrol, etc.) and the most promising types of synthetic rubber and latex (polyisoprene, polybutadiene, butyl rubber, etc.).

Extensive production capacity for the output of polyethylene has been established in Soviet oil refineries and petrochemical plants.

Capacity has also been installed for the production of polypropylene, another important plastic material based on low molecular weight olefines, which surpasses polyethylene in a number of properties.

The production of styrol has been extensively developed, and the output of this product has been considerably increased over the last seven years.

It is planned to begin quantity production, in the next year or two, of copolymers of ethylene and propylene, which have high resistance to attack by chemical media, good heat and cold resistance, and high mechanical and dielectric properties.

Isopropyl alcohol, which is taking the place of ethyl alcohol to an increasing extent in the paint industry and other fields, is now produced in quantity from propylene, phenol and acetone.

The financial saving from the use of isopropyl alcohol instead of ethyl alcohol amounts to 250,000-300,000 roubles per thousand tonnes of alcohol used. A more sophisticated method for the production of isopropyl alcohol by the direct hydration of propylene is being worked out. The production of acrylonitrile and butyl alcohols is also being developed.

In the last few years, considerable importance has been assumed by processes for the production of oxygen-containing compounds from hydrocarbon olefines (alcohols, aldehydes and acids).

It has become possible to manufacture these products thanks to the development of processes for oxosynthesis and alumino-organic synthesis, and also methods for the direct oxidation of ethylene to acetaldehyde, with subsequent condensation of the latter into butyraldehyde and 2-ethylhexanol.

Extensive production capacity has been set up in the USSR for the production of butyl and higher alcohols by the oxosynthesis method.

The establishment of oxosynthesis plants has made it possible to abandon the use of edible raw materials for the production of butyl alcohols. The plants for the production of these materials which are already in operation enable an annual saving of about 200,000 tonnes of edible raw materials to be made, and alcohols produced by oxosynthesis are in no way inferior in quality to those produced from edible raw materials.

The higher alcohols can be used successfully as flotation agents in the enrichment of non-ferrous metallic ores, and after suitable purification they can also be used as a plastifying component for polyvinyl choloride resins.

Great progress has been made in the development of the production of aromatic hydrocarbons, which are one of the first chemical products to be obtained from hydrocarbon raw material.

The coal tar chemicals industry now plays a drastically reduced role in the production of aromatic hydrocarbons, and toluol and xylols are now produced mainly from petroleum raw material:

Product	Proportion of aromatic hydrocarbons obtained from petroleum raw material (per cent)		
	1963	1966	1970
Benzene	1.0	9.0	36.8
Toluol	48.7	62.1	76.5
Xylols	74.2	84.2	93.6

Benzene is of the greatest importance in the manufacture of synthetic products from the lower aromatic hydrocarbons. Among the products manufactured from benzene are isopropyl benzene and phenol, ethyl benzene and styrol, caprolactam, chlorobenzene, nitrobenzene, dodecyl benzene, and other materials produced from these compounds, such as synthetic resins, plastics, fibres, rubber, wetting agents, dyes and many other products. By 1970, the petrochemical industry will supply about half the total national production of benzene, which is the basic raw material for the production of caprolactam used for the manufacture of synthetic fibres.

In the near future, toluol may be used in the production of phenol, divinyltoluol (to replace styrol in the production of plastics), caprolactam and dimethyl terphthalate. In addition, toluol may be widely used in demethylization processes for the production of benzene and hence in the production of a whole range of different products manufactured from benzene. Toluol can now be considered as a replacement for benzene in the synthesis of basic organic intermediate materials or as an additional source of raw material for the production of benzene itself.

Xylols have only been used in the manufacture of synthetic materials for a relatively short time. For a long time, they were only used as solvents. Para-xylol is of great importance, as it is now used in the production of the fibre "Lavsan".

The petrochemical industry will be the main basis for the further extensive reduction of the use of vegetable oil in the production of paints and varnishes.

Petroleum paraffins have assumed great importance in the manufacture of many petrochemical products in the last few years. They serve as the raw material for the production of synthetic fatty acids and higher fatty alcohols by the direct oxidation method.

The sharp increase in demand for wetting agents and surface-active products and the need for the greatest possible reduction in the use of natural fats for technical purposes have been important factors in the development of a new branch of the petrochemical industry: the industry of synthetic fat substitutes and of surface-active agents and wetting agents based on such substitutes.

The use of synthetic fat substitutes in industry has made it possible over the period 1964-1967 to free for their more normal and proper use as foodstuffs over 800,000 tonnes of edible products of vegetable and animal origin.

The importance of synthetic fatty acids to the national economy of the country lies not only in the fact that they free edible fats previously used for industrial purposes, but also in the considerable economy of labour and operating costs achieved through the lower outlay involved in the production of synthetic fatty acids, compared with the production of such acids from natural fats. This can clearly be seen from the following figures:

	Acids from natural fats	Synthetic fatty acids from solid paraffins	Synthetic fatty acids from liquid paraffins
Cost per tonne of acid, per cent	100.0	50.7	89.3
Labour costs for production of one tonne of acid, per cent	100.0	15.5	20.0

Synthetic fatty acids and products manufactured from them are widely used in industry and agriculture, in daily life, and in medicine.

In the production of toilet and commercial soaps these synthetic fatty acids take the place of edible fats and imported coconut oil, while in the petroleum industry they are used for the manufacture of high quality lubricants. Synthetic fatty acids are now widely used for the production of softeners and plasticizers for the leather industry and the plastics industry. The residual high molecular weight acids are used for the manufacture of finishing materials for the construction industry and high quality bitumen.

In the last few years, a large-scale industry for the production of primary higher fatty alcohols by the hydrogenation of synthetic fatty acids has been built up. These alcohols, in their turn, have become widely used in many branches of the national economy: for the production of plasticizers, for the flotation processing of non-ferrous metallic ores, and in light industry.

Large production capacity has been established in oil refineries and petrochemical plants for the production of synthetic wetting agents in powder and liquid form.

In order to satisfy even the basic requirements of the national economy of the country, the output of petrochemical products in 1970 will have to be 2-2.5 times greater than the 1965 level, with the following increases in the output of individual products: methanol and ethyl alcohol - over 1.3 times; butyl alcohols - 3.6 times; phenol - 1.7 times; ammonia -1.6 times; carbamide - 3.5 times; and sulphuric acid - 3.3 times.

In order to ensure the further rapid growth of the manufacture of synthetic products, it is planned to increase the output of ethylene and acetylene not less than 2.5 times by 1971.

At present, the main types of raw material for the production of monomers for use in the manufacture of synthetic rubber are:

1. Petroleum hydrocarbon raw material: n-butane, isobutane, pyrolysed butylene-butadiene fractions, pentane, etc.
2. Synthetic ethyl alcohol.
3. Hydrolysed ethyl alcohol.
4. Acetylene produced either from calcium carbide or by pyrolysis of natural gas (methane).

The use of petroleum raw material for the industrial-scale production of synthetic rubber is now developing very extensively in the following directions:

- the production of butadiene from ethyl alcohol synthesized from ethylene by the sulphuric acid process or by direct hydration;
- the production of butadiene from butane by 2-stage catalytic dehydrogenation over a powder catalyst in a fluidized bed;
- the production of isobutylene by the catalytic dehydrogenation of isobutane;
- the extraction of isobutylene from the C_4 fraction of cracking gases and the pyrolysis of petroleum with sulphuric acid;
- the production of styrol by the dehydrogenation of ethylbenzene;
- the production of isoprene from isobutylene and formaldehyde by the 2-stage method;
- the production of isoprene by the dehydrogenation of isopentane;
- the production of butadiene from pyrolysed butylene-butadiene and cracking butane-butylene fractions.

The use of petroleum raw material in the production of synthetic rubbers gives great economic advantages.

The cost of one tonne of ethyl alcohol produced from petrochemical raw material is three times lower than the cost of one tonne of ethyl alcohol obtained from edible raw materials. Since 1967, the synthetic rubber industry uses practically nothing but petroleum hydrocarbons as raw material.

The transition to the massive utilization of hydrocarbon raw material will permit the expansion of the raw material base for the production of synthetic materials, plastics, synthetic rubbers and fibres, and will be of great economic advantage to the national economy of the country.

II. The production of plastics

At the present stage in the development of science and technology, the solution of many important technical problems is impossible without the use of plastic materials.

The production of plastics in the USSR has increased rapidly. Whereas about 300,000 tonnes of plastics of all kinds were produced in 1960, 950,000 tonnes were produced in 1965, and about 1.2 million tonnes in 1967; in 1970, the production of plastics and synthetic resins will reach between 2.1 and 2.3 million tonnes, or 2.7 times the quantity produced in 1965.

Besides this increase in the volume of production, there was also a steady change in the range of plastics produced and the relative output of different types. In 1960, the share accounted for by plastics produced by polymerization was only 18 per cent, while in 1965 it was 30 per cent.

The production of the different types of plastics in 1970 in comparison with 1965 will be as follows: polyolefins, 5.5 times the quantity produced in 1965; polyvinyl chloride, 3.0 times; phenol-formaldehyde resins, 1.4 times; phenol-formaldehyde moulding powders, 1.6 times; carbamide resins, 2.3 times; moulding materials based on urea-formaldehyde resins, 1.3 times; polyester resins for glass-like plastics, 3.5 times; polystyrene and its copolymers, 4.1 times; ion-exchange resins, 2.1 times.

In the Soviet Union, some 35-40 per cent of the plastics and synthetic resins produced are used by the engineering industries.

At the present time, plastic materials are used not only as substitutes for metal, wood, glass and leather but also in steadily increasing quantities as independent, non-substitute materials.

The use of plastics and synthetic resins in various spheres of material production will ensure a significant rise in labour productivity, a sharp decrease in operating costs, and a substantial saving in capital investment.

The production of plastics requires between half and one third of the capital investment required for the production of non-ferrous metals. The cost price of one tonne of plastic is between one half and one third of the cost price of one tonne of non-ferrous metal, and in terms of one cubic metre the cost is less than one tenth.

In 1970, the consumption of plastics in engineering will be about 3-4 times the 1965 level. Moreover, as a result of the replacement of metals by plastics, more than 1 million tonnes of valuable types of steel and over 600,000 tonnes of scarce non-ferrous metals will be released, the saving in direct labour costs will be more than 2 hundred million man-hours and the saving on production costs will be over 170 million roubles.

Of all the engineering industries, the largest consumer of polymerised materials, particularly plastics and synthetic resins, in the current five year period and in the next period will continue to be the electrical engineering industry. For example, every tonne of epoxy resins used in the production of transformers will save about 1.5 tonnes of copper and 3 tonnes of rolled ferrous metal.

Plastics are being used more and more in the manufacture of chemical equipment such as vessels and pipelines, valves, filters, pumps, sealing components, etc., which must be resistant to corrosive liquids. The replacement of the lead lining of chemical apparatus by plastics will allow a saving of 4-5 tonnes of lead for every tonne of plastic.

It is hardly possible to imagine the further development of the cable industry without polymerized materials, mainly polyvinyl chloride and polyethylene. One tonne of these polymers takes the place of 2-5 tonnes of lead, while one tonne of lavsan takes the place of about 3 tonnes of cotton yarn and natural silk. Over the period of 1959-1965, the amount of lead used per tonne of electrical cable produced fell on average by 27 per cent, while the amount of cotton yarn used fell by over 30 per cent and at the same time, in contrast, the amount of polyvinyl chloride used increased almost twice and the amount of polyethylene used increased 10 times.

In the electrical equipment industry, polymerized materials are already being widely used as electrical insulating materials and construction materials.

Soviet production of resins produced by polycondensation and of plastics based on them is increasing all the time and new types of such resins and plastics are constantly being developed. Thus:

- More than 200 different types of phenol-formaldehyde resins and moulding materials based on them are being produced in industry;
- A great deal of work is being done on the replacement of the batch process for the production of urea-formaldehyde resin by continuous

production processes, and on the development of a new, original method for the continuous synthesis of carbamide resin by means of high-temperature polycondensation and the subsequent concentration of the product;

- Polyester resins are being produced industrially on a large scale for various purposes for general use, for high heat-resistance, for uses requiring high elasticity and specific impact strength, and for uses requiring high water and acid resistance;
- In 19[illegible], more than [illegible] types of epoxy resins and more than 10 types of compound based on them were produced, and new methods were developed for the epoxidation of unsaturated compounds, while new techniques were also developed for the continuous production of several types of epoxy resins;
- Among the polyamides produced by industry, the commonest are: nylon-6 produced from caprolactam; nylon-6,6 produced from hexamethylenediamine and adipic acid, nylon-6,10 produced from hexamethylenediamine and sebacic acid; and a new anti-friction construction material, kaprolon;
- A technique has been mastered for the manufacture of a new thermoplastic material, polycarbonate diflon, and preparations are being made to build a plant for its production;
- A new thermoplastic material, polyformaldehyde, is being developed; efforts are being made to raise the polymer's resistance to heat and light and plans are being made for large-scale production;
- Experimental installations are being planned for the synthesis of polyarylates - a new type of heat-resistant polyesters - and of dichloranhydrides of aromatic dicarbonic acids.

The production of synthetic polymerised resins and plastics based on them is increasing at a rapid rate even though production on an industrial scale began much later than in the case of condensation polymerised products.

I. Polyvinyl chloride

Polyvinyl chloride (PVC) is an important industrial polymer on account of its low cost, the ease with which it can be processed, its durability and its excellent physico-mechanical properties.

The technique for the production of PVC has been steadily improved and the volume of production increased.

While vinyl chloride was originally produced by dehydrogenation of dichloroethane in alcohol alkali, a system was subsequently devised for producing it by hydrochlorination of acetylene in the gaseous phase over a solid mercury catalyst. As a result there was a distinct improvement in the quality of the original monomer.

The industry produces six varieties of suspensions of polyvinyl chloride (PVC-S) and nine varieties of polyvinyl chloride, latex (PVC-L) differing in molecular weight and application.

Suspended PVC is mostly used for the preparation of high quality cable, electro-insulating and hose rubber, vinyl sheeting, film and sheet materials, gramophone records, perchlorvinyl etc; latex PVC is used for the preparation of artificial leather, hard and soft films, etc.

Glues and varnishes are made from chlorinated polyvinyl chloride resins. Chlorinated polyvinyl chloride resin is used to make varnishes and paints which are highly corrosion and weather-resistant.

III. Synthetic fibre production

The production of chemical fibres in the USSR amounted to 407,300 tonnes in 1965, 450,000 tonnes in 1966, and will attain between 780,000 and 830,000 tonnes in 1970. The output of synthetic fibres in 1970 will be 276,000 tonnes.

The proportion of viscose fibres in the total output of chemical fibres dropped to 72.3 per cent in 1965, while that of synthetic fibres rose to 19 per cent (including 16.1 per cent polyamide, 1.8 per cent polyester (dacron), 0.7 per cent polyacrylonitrile (nitron), and 0.4 per cent chlorinated polyvinyl chloride). In 1970 synthetic fibres will account for about 35 per cent of the total volume of chemical fibres produced.

There is also a greater variety of fibres. In addition to capron and polyvinyl chloride, the synthetic fibre group now includes polyester (dacron) and polyacrylonitrile (nitron).

Over the last few years techniques have been developed for producing polynose, polyvinyl alcohol (vinol) and polypropylene fibres, which have been manufactured on experimental scale.

The increased output of chemical fibres has been accompanied by improvement in their technical and economic characteristics. This has been facilitated to a considerable degree by the combining of enterprises into larger units. For example, the daily output of a modern cord plant is between 50,000 and 100,000 square metres of capron cord fabric, while the productivity of a textile thread plant is between 10,000 and 15,000 tonnes a year, and for an industrial fibre plant between 30,000 and 35,000 tonnes a year.

Continuous production processes are being introduced successfully into the synthetic fibre industry. For example, polycaproamide is now manufactured and converted into fibre as a continuous operation.

The production of nitron now includes combined polymerization and dissolution of the polymer.

A continuous process has been developed and high-efficiency equipment constructed for the manufacture of industrial capron thread with a thickness of 93.46 tex (Nos. 10 and 7) and 186.91 tex (Nos. 5 and 35).

Over the last few years a method has been developed for forming capron cord without intermediate separation and pulverization of the polymer.

Large quantities of capron thread are also used for the manufacture of V-shaped belting and conveyor belts, for sheathing sleeves and rubber hosing, and so on. As a result, the service life of conveyor belts is doubled or trebled, the parts are lighter and the permissible loads are increased.

Because of the high-quality performance of polyester fibre (dacron), the production of it is being stepped up. It is of great importance in the rubber industry. Compared with capron, dacron exhibits lower thermoplasticity and a higher elastic modulus. The manufacture of heavy-duty dacron-base conveyor belts for the mining industry has been introduced.

New plants for the production of vinol and polypropylene fibre are under construction.

In addition to its good physical and mechanical properties, vinol is also very resistant to light and atmospheric effects. It is therefore being extensively used for manufacturing canvas, upholstering materials, cables and netting.

Polypropylene will become one of the cheapest synthetic fibres available and will likewise be widely used for making cable, upholstering materials and netting. Carpets made with polypropylene, just as polyamide fibre, are highly wear-resistant and can be cleaned and washed.

Polyacrylonitrile (nitron) is similar in properties to wool and is used to make a similar variety of fabrics. Considerable savings have been obtained by using nitron to filter exhaust gases in the non-ferrous metallurgical industry. Nitron is a valuable material for manufacturing parts that operate at low temperatures, in high vacuum and under conditions where they are subject to radioactive radiation.

The use of certain synthetic fibres, for example dacron, polyphene etc., has also proved effective in medicine

Research into the production of heat-resistant fibres is progressing favourably; studies are near completion on the production of phenylon, which is heat-resistant at temperatures up to 250°C; technology is under development for polypyromilitimide fibres, which are heat-resistant at high temperatures;

materials of this kind have also been produced from polyacrylates, which are new polymers; exceptionally high resistance to agressive media (acids, alkalis and oxidants) is shown by the fluorine derivatives of ethylene, which in addition exhibit a low friction coefficient, thereby suiting them for extensive use in gasket linings for different kinds of machinery.

Until 1970 the principle industrial fibres will be the viscose and capron variety. In that year the ratio between viscose and synthetic industrial fibres will be 58:42.

Prospects for the development of the synthetic fibre industry are very good. Its high rate of development is due to the fact that the fibres can be used with great economic advantage in engineering, and it is planned to utilise dacron, amide, vinol and polypropylene fibre in this context. An increase in the production of PVC (polyvinyl chloride) by a factor of 4.5 is envisaged for the period 1966-1970. Research is under way to obtain new types of PVC and styolymers derived from it that possess higher shock-, heat- and frost-resistance.

2. Polyolefins

Due to the low cost and abundance of raw material, polyolefins occupy the lead among polymers, and before long will become the most commonly used types of plastic. Whereas the production of polyethylene was only tens of thousands of tonnes in 1964, the figure for 1970 will be hundreds of thousands of tonnes.

The most important type is low-density polyethylene (high pressure polyethylene), possessing excellent dielectric properties, pliability and elasticity. It is widely used in cable production, in electrical engineering and for the manufacture of all kinds of hardware. The first major plant for its production was started up in 1962.

We have also started industrial production of high density (low pressure) polyethylene. This type is more durable and heat-resistant than the low-density variety, but not as good in dielectric characteristics, and is mainly used as a construction material for prefabricated parts, ventilation units, piping and non-corroding equipment.

Soviet scientists have worked out a unique and highly-productive technological process for obtaining polypropylene at low pressure. The method has been used since 1967 for the production of this valuable high-grade plastic on a large scale. By 1970 its production will have risen from 10,000 tonnes a year to a considerably higher figure.

Polypropylene, which can be much more easily synthesized at low pressure than polyethylene, is more durable and heat-resistant (up to 150–160°C). The disadvantage of it is a certain brittleness at temperatures below 0°C. Polypropylene is used for fibres, fabrics, floating cables, etc.

5. Polystyrene

Once the method of continuous block polymerisation in columns and the suspension method had been introduced, we began producing pure, high-grade polystyrene.

This plastic has excellent dielectric characteristics and water-repellence, and is one of the main materials used for making electric insulators, and also consumer goods.

A technique has been developed for producing a variety of styrene derivatives, but only the copolymers alpha-methylstyrene and styrene have acquired practical importance.

The combining of polystyrene plastics and rubber by the graft polymisation technique makes it possible to produce a wide variety of materials with good chemical, mechanical and dielectric properties.

It has been possible to manufacture a shock-resistance material [illegible] based on styrene, nitril rubber and acrylonitrile.

In addition, several large plants for the production of vinyl acetate and products made from it are either in operation in the USSR or under construction; a large number of materials and parts based on polymethylmethacrylate containing styrene (styracryl) and other monomer and polymer additives are now being manufactured; the ever-increasing consumption of fluoroplast-4 (polytetrafluoroethylene) and fluoroplast-3 (polychlorotrifluoroethylene) has acted as an incentive for a manifold increase in their output.

IV. Synthetic rubber

The Soviet Union is the home of the synthetic rubber industry.

The following figures show the dynamics of growth in synthetic rubber production:

Years	Growth in synthetic rubber production(%)
1961	100.0
1964	134.0
1967	192.0
1968	211.0
1969	269.0
1970	338.0

From the above figures it will be seen that the average annual increase in the production of synthetic rubber during the period 1961-1967 was 15 per cent, while the rates of growth will be considerably higher during the years 1968-1970.

At present, the basic monomers in the synthetic rubber industry are butadiene isoprene, isobutylene, ethylene and propylene.

The following approximate increase in production capacity (in percentages, compared with 1966) are planned for 1970:

Divinyl	-	162
Isoprene	-	270
Isobutylene	-	180
Ethylene	-	250
Propylene	-	120

The new industrial process of obtaining butadiene by two-stage catalytic dehydrogenation of n-butane presents greater technical and economic advantages than the production method based on ethyl alcohol.

The new methods of producing divinyl are based not only on the dehydrogenation of n-butane but also on butylene-divinyl pyrolysis

The comparative figures (in percentages) for the production of divinyl from alcohol and by the method of n-butane dehydrogenation and butylene-divinyl pyrolysis respectively, are as follows: 1965, 67 and 33; 1970, 43 and 57.

Extensive research is being successfully carried out to devise still more effective methods for the production of divinyl: one-stage dehydrogenation of n-butane in a fluidized bed of a powdered catalyst and one-stage oxydizing dehydrogenation of n-butane in the presence of iodine and an acceptor.

Isoprene has become very important as an industrial monomer for the synthesis of rubber as a substitute for the natural product. At present, only two methods are used on an industrial scale in the USSR to produce isoprene: synthesis from isobutylene and formaldehyde and catalytic dehydrogenation of isopentane.

The main line of development in the future will be the second process.

Production of isoprene rubber was begun in 1964 at synthetic rubber plants in the towns of Togliatti and Volzhsk, while in the same year the factory at Efremovo began to produce rubber from divinyl. These plants have the highest production capacity in the whole world.

The main trend in the development of the Soviet synthetic rubber industry is to build up the capacity to produce high quality rubbers from isoprene, divinyl and other substances. The changes planned in the pattern of production and in the range of synthetic rubbers and latexes are shown in table No. 1.

TABLE 1

	YEAR		
	1960	1965	1970
Rubbers for general purposes, total	88	88.1	73.2
Comprising:			
Sodium butadiene rubber	51	18.8	4.1
Divinylstyrene and divinylmethylstyrene rubber	37	65.8	40.0
Divinyl rubber	-	0.7	11.8
Isoprene rubber	-	2.8	18.3
Rubbers for special purposes, total	9.4	8.5	20.3
Comprising:			
Butyl rubber	-	0.1	3.5
Chloroprene rubber	8.0	6.2	12.3
Nitrile rubber	0.7	1.5	3.1
Other special rubbers	0.7	0.7	1.4
Synthetic latexes, total	2.6	3.4	5.5

The figures show that by 1970 the specific gravity of special-purpose rubbers and synthetic latexes will have considerably increased.

By 1970 the specific gravity of isoprene and divinyl rubber will be almost 30 per cent as against 3.5 per cent in 1965.

It is anticipated that by 1970, production of synthetic rubber and latexes will be 2.2 times greater than in 1965, and the production figures for isoprene and divinyl will be 15 and 42 times higher respectively.

Increasing use of rubbers of the stereoregular type (isoprene and butadiene) in the tire industry will make it possible to reduce imports of natural rubber and result in considerable savings by increasing the life of tires by 20 to 30 per cent. It is estimated that expenditure on the construction of isoprene- and divinyl synthetic rubber plants can be recovered in two to three years.

The synthesis of stereoregular rubbers from isoprene and butadiene thus affords a means of solving one technical problem - how to make elastomers that are not only not inferior to natural rubber but even surpass it in certain characteristics.

The introduction of special-purpose synthetic rubbers such as butadiene-nitrile, chloroprene, siloxane and flourine-containing rubber has made it possible to improve the design and perfect the production processes of articles for the new technology and to create a number of fundamentally new technical rubber articles for modern engineering uses.

By 1970, it is estimated that there will be as many as 28 different types of synthetic rubber and as many as 200 different varieties (brands).

Extensive scientific research and experimental work will be necessary to create synthetic rubbers with fundamentally new technical properties ("the ideal elastomers of the future").

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