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TECHNICAL AND ECONOMIC BACKGROUNDS FOR THE ORGANIZATION OF SYNTHETIC RUBBER PRODUCTION IN DEVELOPING COUNTRIES[1]

by

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SUMMARY

TECHNICAL AND ECONOMIC BACKGROUND FOR THE ORGANIZATION OF SYNTHETIC RUBBER PRODUCTION IN [illegible][1]

by

[illegible]
[illegible]
Ministry [illegible]
[illegible]
[illegible]

Raw materials base [illegible] rubber industry. Saturated hydro-carbons C_4 and C_5 [illegible] production, basic methods of producing [illegible] obtaining [illegible] for synthetic rubber production.

[illegible] its effect on the cost of production [illegible]

[illegible] production by different [illegible]

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[1] The views [illegible] this paper are those of the author [illegible] the secretariat of UNIDO. [illegible] editing.

id.6[illegible]

Other monomers (styrene, acrylonitrile, isobutylene, ethylene and propylene), their production and utilization.

Characteristics of the capital investments in the monomer production. The share of the energy base in the total volume of capital investments.

Technical and economic data on the production of synthetic rubbers – energy consumption, auxiliary materials, manpower, investments in the production of various rubbers. Optimum capacity of production.

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.

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Content

1. Current state and prospects for the development of the synthetic rubber industry.
2. Sources of raw material for the synthetic rubber industry.
3. Power consumption in the production of synthetic rubber and initial monomers.
4. Structure of capital investments in synthetic rubber plants.
5. Labour requirements for synthetic rubber plants.
6. Structure of the production costs of the main types of synthetic rubbers.
7. Conclusions.

1. Current State and Prospects for the Development of the Synthetic Rubber Industry

At present rubber as raw material gains ever increasing importance for the development of a number of heavy industry branches and in the manufacture of consumer goods.

The constant extension of the circle of rubber consumers and increase in the total volume of its consumption have caused high rates of development of the world synthetic rubber industry for the past 20 - 30 years.

The synthetic rubber industry is being developed mainly in two directions:

1. Development of high-capacity plants for the production of general purpose rubbers to meet the demands of the main consumers such as tyre industry and production of rubber-technical goods.

2. Development of the manufacture of special purpose rubbers used in relatively small amounts and permitting to obtain articles with special properties not inherent in natural rubber (oil-, ozon-, gasoline-stability, cold-resistance etc.). The application of special rubbers is an indespensable condition for the development of certain modern technical outlets.

Although the production scale of general purpose rubbers is now several times larger than that of special purpose rubbers, a constant increase in the share of the latter in the total rubber consumption and accordingly in synthetic rubber production is being observed.

High rates of development of consuming industries cause high rates of development of synthetic rubber production.

The share of the consumption of natural rubber is constantly falling. On the one hand it results from low rates of its production increment, on the other hand from the great progress in technique, technology and economics of synthetic rubber production, as well as from the creation of rubber with properties inherent in natural rubber and even better in certain respects. In the period from 1941 to 1967 natural rubber production increased by 55 [illegible], while synthetic rubber manufacture in the developed countries alone increased almost by 50 times (from 8000 t [illegible] to 37[illegible] t [illegible]) for the same period.

In the developed countries taken as a whole the specific consumption of natural rubber will decrease from 62 [illegible] in 1955 to 3[illegible] in 197[illegible].

Even a very approximate analysis shows that the world demand for rubbers in the coming decade will amount to more than 10 million tons.

Because of the limited possibilities for the growth of natural rubber production high rates of synthetic rubber production will be maintained.

The analysis of the structure of rubber consumption in developed countries shows that about 50 - 60 % of rubber is utilized for tyre manufacturing in each country.

The average rubber consumption per tyre amounts to 5 - [illegible] kg depending on the kind of automobile transport prevailing in the country (trucks or passenger cars). Available data on the automobile fleet in each country permit to evaluate rather rapidly the demand for tyres and hence for rubber. By doubling this demand for rubber one can obtain approximate data on the total rubber consumption for a certain period of time.

The demand for special purpose rubber amounts to 20 - 25 % of the total consumption.

As a number of articles can be manufactured from natural rubber only, the minimum demand for the latter is about 10 %. On the basis of these data it is possible to evaluate the total volume as well as the structure of the rubber consumption in the country.

At a certain stage in development of the economy in each country it becomes necessary to solve the problem of providing the industry with rubber.

This problem can be tackled in two ways:

1. Import of rubber.

2. Creation of a home synthetic rubber industry, meeting the requirements of the country in rubber.

3. Co-operation of several countries in the manufacture of various rubbers as well as of initial monomers to satisfy the overall demand of these countries for rubber.

The economic backgrounds of the development have determined the way this problem can be solved in individual countries.

The Soviet Union was the first country to develop a large-scale synthetic rubber industry.

In 193[illegible] the first synthetic rubber plant in the world was put on stream in the Soviet Union. Since 193[illegible] Germany has started producing synthetic rubber, and since 1942 - the United States. In the decade from 1950 to 1960 the number of countries producing synthetic rubber has increased considerably.

At present synthetic rubber is manufactured in 21 countries, a number of countries are planning to initiate production in the near future. The technical and economic backgrounds for the organization of synthetic rubber manufacture are outlined below.

2. Source of raw materials for the synthetic rubber industry

Synthetic rubber production belongs to one of the most material-consuming industries. Hydrocarbon compounds obtained in the process of crude oil production, topping of the casinghead gas and at oil treatment or stabilization plants, natural gasoline plants and refineries are used as raw material for the manufacture of synthetic rubber.

The main monomers used in the synthetic rubber industry are butadiene, styrene and isoprene, obtained from C_4 and C_5 saturated and unsaturated hydrocarbons. The principal methods for the production of butadiene and isoprene from hydrocarbon raw material are given below.

Monomers and methods of their production	Stage of development
I. Butadiene	
1. Two-stage dehydrogenation of n-butane	Commerical production
2. One-stage dehydrogenation of n-butane under vacuum (Houdry process)	"
3. One-stage oxidative dehydrogenation of n-butane in the presence of iodine and an acceptor	Research and experimental work is being conducted
4. Oxidative dehydrogenation of butylenes in the presence of various catalysts (chromium-zinc, bismuth-molybdene etc.)	"
5. Recovery of butadiene from steam cracking C_4 - fraction	Commercial production

6. Dehydrogenation of butylenes	Commercial production
IV. Isoprene	
1. Two-stage dehydrogenation of isopentane	"
2. Formaldehyde isobutylene condensation	"
3. One-stage oxidative dehydrogenation of isopentane with iodine	Research work is being conducted
4. Synthesis from propylene	Commercial production
5. Synthesis from ethylene and propylene (through isoamylene)	Research work is being conducted
6. Synthesis from acetone and acetylene	"

The methods and raw materials used for the production of monomers are determined by the structure and development scale of oil producing, oil refining, petrochemical and gas industries in various countries.

At present saturated hydrocarbons such as n-butane, isobutane, isopentane are mainly used for the production of monomers.

Due to the large-scale development of catalytic cracking in oil refining in the USA, butylenes find a wide application in the production of butadiene in that country. The production of monomers from the steam-cracking C_4-fraction is acquiring ever greater importance.

Wide-scale development of steam cracking processes results in growing utilization of petroleum feedstock. By steam cracking of it, C_4-fractions, aromatic hydrocarbons and other products can be obtained apart from ethylene and propylene.

Depending on the kind of feedstock used and the steam cracking conditions the C_4-fraction obtained can amount to 3 - 12 % by weight on the steam cracking feedstock.

Large scale butadiene production and recovery of the steam cracking C_4-fraction has been established especially in Japan and in Western Europe (Federal Republic of Germany, Great Britain, France, Italy) where due to the lack of crude oil reserves and production practically no other raw materials are available to obtain this monomer.

Steam cracking of liquid petroleum feedstock not only enlarges the raw material basis for monomer production but also substantially improves the economy of production.

In this connection it is to be noted that even in the [illegible], possessing large reserves of saturated and unsaturated hydrocarbons for the manufacture of monomers provided by the oil producing and petroleum refining industries, the share of butadiene production from the steam cracking C_4-fraction is also becoming greater.

In the USSR the butadiene production on the basis of this fraction will also increase with the development of the steam cracking process.

The average composition of the C_4-fraction (depending on the process conditions and feedstock) is given below:

butadiene	23 - 48 % by wt
n-butylenes	39 - 17 % by wt
iso-butylene	23 - 31 % by wt
n-butane isobutane	12 - 3 % by wt
others	3 - 1 % by wt

The composition of the fraction predetermines the best method of processing with simultaneous production of butadiene, butylenes and isoprene. After the recovery of butadiene the n-butylene-isobutylene fraction can be used for the synthesis of dimethyl dioxane (by formaldehyde condensation) with subsequent decomposition to isoprene. The n-butylene fraction isolated at dimethyl dioxane synthesis can be dehydrogenated to obtain butadiene.

On the basis of design and preliminary studies conducted in the USSR the production of butadiene by various methods can be illustrated by the following comparative technical and economic data.

Methods of production	Specific (capital) investments in the main production	Plant cost of production
1. two-stage n-butane dehydrogenation	1[illegible]	100
2. one-stage n-butane dehydrogenation	[illegible]	75
3. one-stage oxidative n-butane dehydrogenation	[illegible]	55
4. oxidative butylene dehydrogenation		
a) on iron-chromium catalyst	100	35
b) on bismuth-molybdenum catalyst	1[illegible]	30
5. butadiene isolation from the C_4-fraction	45	55

The above data show that it will be possible in future to improve the economy of butadiene production mainly on the basis of one-stage oxidative processes of dehydrogenation of saturated and unsaturated hydrocarbons as well as by wider utilization of the steam cracking C_4-fraction.

It applies equally to the prospects of improvement in the economy of isoprene production as seen from the comparative technical and economical data on isoprene manufacture by various methods given below.

Methods of production	Specific capital investments in the main production including semi-finished products	Plant cost of production
1 two-stage isopentane dehydrogenation	100	100
2. formaldehyde isobutylene condensation	95	[illegible]
3. One-stage oxidative isopentane dehydrogenation	90	[illegible]
4. Synthesis on the basis of propylene	100	100
5. Synthesis on the basis of acetone and acetylene	100	100

Among the other monomers methylstyrene, acrylonitrile, chloroprene, isobutylene, ethylene and propylene are used in the production of synthetic rubber.

The share of these compounds in the total monomer consumption is relatively small.

In contrast to butadiene and isoprene which are produced mainly for the synthetic rubber industry the above mentioned monomers are used in other industries on a much larger scale (production of plastics, synthetic fibres etc.).

The share of the synthetic rubber industry in the total consumption of these monomers is relatively small and no difficulties will be experienced in the supply of these monomers to the synthetic rubber industry, provided their production is organized on a large scale.

Besides that, a great quantity of auxiliary materials (catalysts, antioxidants etc.) are used in the production of synthetic rubber especially in the stage of polymerization and recovery.

In total up to 200 types of various auxiliary materials are consumed

[illegible]

[illegible] consumed [illegible] manufactured [illegible]

[illegible]

[illegible] materials [illegible] kinds [illegible]

[illegible]	[illegible]	[illegible]	
		[illegible]	[illegible] feed stock [illegible]
[illegible]	[illegible]		2.2
	materials	-	0.1
[illegible]	[illegible]		0.21
	[illegible]		[illegible]
	[illegible]	-	
[illegible]	[illegible]	-	1.65
[illegible]	[illegible]	-	1.04
	[illegible] materials	-	[illegible]
[illegible] extended	[illegible]	[illegible]	-
	[illegible]	[illegible]	-
	[illegible]	[illegible]	[illegible]
	[illegible]	-	1.17
	[illegible]	-	[illegible]
	[illegible]	-	[illegible]
	[illegible]	[illegible] 25	[illegible] 33

2. [illegible] t diene [illegible] [illegible]	1. [illegible] t diene [illegible]		
	2. [illegible]		
	[illegible]		1. [illegible]
	[illegible] P [illegible]		[illegible]
	5. Ben[illegible]		[illegible]
	[illegible]		
	[illegible]	[illegible]	[illegible]
3. [illegible] rubber ([illegible])	[illegible]	[illegible]	
	[illegible]		[illegible]
	[illegible] A		
	[illegible] terials	[illegible]	[illegible]
4. [illegible] [illegible] [illegible])	1. [illegible]	[illegible]	
	2. [illegible]		1.[illegible]
	3. [illegible]		1.[illegible]
	[illegible]		
	[illegible] terials	[illegible]	1
5. [illegible] t diene rubber ([illegible])	[illegible]	[illegible]	
	[illegible]		[illegible]
	3. [illegible]		
	[illegible]	[illegible]	[illegible]

3. [illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

The highest power consumption in the production of synthetic rubber is on the stage of manufacture of initial monomers.

Comparative data on power consumption on the stages of monomer production and polymerization are given below for the various kinds of synthetic rubbers.

Synthetic rubber	Power consumption	
	Monomer production	Polymer production
1. Butadiene-styrene rubber		2[illegible]
2. Isoprene rubber	[illegible]3	1[illegible]
3. [illegible] rubber		3[illegible]

The introduction of one-stage oxidative dehydrogenation processes in the manufacture of monomers will permit in the future to reduce considerably the power consumption at the stage of synthetic rubber production.

Monomers	Power consumption			
	two-stage dehydrogenation		one-stage oxidative dehydrogenation	
	metric tons of standard fuel (7000 kcal/kg)	%	metric tons of standard fuel (7000 kcal/kg)	%
1. Butadiene	[illegible]	100	[illegible]	1[illegible]
2. Isoprene	[illegible]	100	[illegible]	32

Power consumption in the production of various kinds of synthetic rubbers is shown below

Synthetic rubber	Power consumption metric tons of standard fuel [illegible]
1. Butadiene-styrene rubber	3.4/1.3
2. Isoprene rubber	[illegible]
3. Butadiene rubber	6.[illegible]

Note: Numerator - data for operating plants

Denominator - after introduction of new processes in the future

4. Structure of capital investments in synthetic rubber plants

Synthetic rubber plants are large production complexes generally comprising the manufacture of a number of products.

The following units form the main parts of the plants:

1. Feedstock preparation (central gas separation unit, desulfurization and isomerization units)
2. Production of monomers
3. Production of polymers
4. Production of catalysts

The complex utilization of the hydrocarbon feedstock predetermines the expediency of combining the manufacture of a number of monomers and rubbers in a single plant.

To meet the requirements of the main production units the corresponding utilities must be provided for, such as power and water supply, purification and disposal of effluents, pipe-lines, instruments and control equipment and automation, storehouses. Furthermore the synthetic rubber plants require maintenance and transport services as well.

The ratio of capital investments in the main production units and in the utilities is 1 to 1. The main production units in synthetic rubber plants are complicated technological complexes provided with complex equipment.

High-capacity compressors, refrigerators, pumps, and complex reactors are used in synthetic rubber production.

Large-size equipment is required on the stages of polymerization and recovery. The pumps must be adapted to handle high-viscosity media. Large amounts of special high-alloy steels are needed for the manufacture of the equipment. A great number of heat exchangers and columns are used in the plant. Due to the specific character of the production process automatic and inter-plant communications are to be provided for as well as the erection of special buildings, installations, loading racks etc.

The following data show the ratio of capital investments for the synthetic rubber plants in accordance with the adopted system of distribution of expenses.

1. Equipment	30 - 40 %
2. Construction work (cost of buildings, constructions) and erection work	60 - 50 %
3. Other works	6 - 10
Total	100 %

The reduction of the number of buildings and structures by placing equipment in the open air proves to be one of the principal tasks to be solved to provide reduction of the construction cost and to attain an increase in the share of the equipment cost in the total capital cost of synthetic rubber plants.

Additionally to direct capital investments in synthetic rubber plants associated expenditure on the erection of raw material and power facilities is required. This expenditure is on average [illegible] of the synthetic rubber plant construction cost.

5. Labour requirements for synthetic rubber plants

Due to the high degree of automation and mechanization of the manufacturing processes in synthetic rubber plants the requirements for man-power in these enterprises are comparatively low.

Approximate labour requirements in synthetic rubber plants of different capacity regarding objects of main production are presented in the following table.

Designation	Capacity based on rubber, thousand t	Required man-power
1. Plant producing butadiene rubber including monomer production	90	1000
2. Plant producing isoprene rubber including the monomer production	90	1050
3. As above, with enlarged equipment	120	900

6. <u>Structure of the prime cost of the main types of synthetic rubber</u>

The structure of the production cost of the main types of synthetic rubber in case of their production by most advanced processes is shown below

Expenditure items	Rubber		
	butadiene-styrene oil-extended	isoprene	butadiene
1. Raw material	16	30	13
2. Auxiliary materials	34	5	[illegible]
3. Energy supply	2[illegible]	36	36
4. Wages and shop expenses	9	12	10
5. Wear	6	9	9
6. Waste (subtracted	–	2	1
7. Administration expenses	4	4	4
8. Commercial expenses	2	2	2
Total prime cost	100	100	100

As seen from the above data the main expenditures fall to the share of raw material and power supply.

In terms of future possible introduction of new one-stage oxidation processes of initial monomer production, enlargement of the equipment and unit capacity of production, [illegible] on condition that a number of [illegible] progress in this field be taken, the [illegible] of [illegible] synthetic rubber types would [illegible] of production to approximately [illegible] compared with [illegible].

[illegible] items	[illegible]		
	Isoprene	[illegible] diene	Ethylene-propylene
1. [illegible]	[illegible]	[illegible]	[illegible]
2. [illegible] materials	[illegible]	[illegible]	4[illegible]
3. Energy supply	26	20	12
4. [illegible] expenses	3	5	3
5. [illegible] (amortization)	11	3	4
6. [illegible]	1	1	-
7. [illegible]	4	1	4
8. Commercial [illegible]	2	2	2
Total [illegible]	1[illegible]	1[illegible]	100

[illegible] Conclusions

[illegible] can be concluded [illegible] factors are dominant when the problem of organizing synthetic rubber production in developing countries is to be solved:

1. [illegible]

[illegible] of the country is determined on the basis of [illegible] for the development of tyre, [illegible].

2. [illegible] determined on the basis of [illegible] for synthetic and natural rubber [illegible] development of [illegible] level for synthetic and

natural rubbers. It should be noted that the volume of synthetic rubber export in developed countries has increased from 550 thousand tons in 1961 to 950 - 1000 thousand tons in 1967 - 1968.

3. Choice of optimum capacities for the production of synthetic rubbers and initial monomers for them.

The tendency to maximum extension of the unit capacity, and to corresponding enlargement of the basic technological equipment is gaining strength. As a result of it a considerable reduction in the specific capital investments and in the cost of production and an increase in labour productivity are achieved.
This can be illustrated by the example of the following productions:

Kind of production	Specific capital investments in the main production	Shop cost of production	Labour productivity
1. Isoprene rubber production including the monomer production			
capacity			
60 thousand t/y	100	100	100
120 thousand t/y	50	65	3.7 times as much
2. Ethylene-propylene production			
capacity			
30 thousand t/y	100	100	100
60 thousand t/y	55	55	7 times as much
3. Styrene production			
capacity			
40 thousand t/y	100	100	100
250 thousand t/y	65	75	4 times as much

Thus, not only the home demand for synthetic rubber but also the minimum economic production capacity are to be taken into account when considering the problem to create or [illegible] synthetic rubber production in the country.

4. Availability [illegible] sources in the country.

[illegible] rubber production only if the country [illegible] (oil refining and petrochemical industries) [illegible] quantity and quality.

[illegible] basis for the main feedstock [illegible] number of chemicals in the country [illegible].

5. Availability [illegible] in the country (coal, petroleum, [illegible] power station.

6. [illegible] to supply the plant with sweet water [illegible].

7. [illegible] industry and availability [illegible].

[illegible], fitters and operators.

15. 3. 72