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ECONOMIC CRITERIA FOR THE ESTABLISHMENT OF A STYRENE-BUTADIENE SYNTHETIC RUBBER FACILITY 1/

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CONTENTS

I. INTRODUCTION

1. Emulsion styrene-butadiene synthetic rubber (SBR) is by far the most widely used type of synthetic rubber across the world, and will remain so for many years to come. With one exception, viz., Firestone, the various tire companies in N. America, W. Europe and Japan use emulsion SBR as the preferred main elastomeric component for automobile tires - the largest single use of synthetic rubber.

2. The technology for the production of emulsion SBR has been fully developed commercially over a period of some 30 years, and is readily available from a number of licensors. Of the ten developing countries which built their first synthetic rubber facility since 1962, nine of those plants were emulsion SBR.

3. The present paper covers four areas with respect to the economic criteria for the establishment of an emulsion SBR facility in a developing country:

a) The various cost components such as capital cost, license fee, preproduction expenses and startup costs, and fixed and variable production costs, are presented for a typical SBR plant of capacity 35,000 metric tons per year, and a calculation is made of the necessary selling price of the products to obtain a particular economic return on investment;

b) The sensitivity of the above economics to changes in various factors such as sales buildup, plant cost, and monomer costs, is evaluated;

c) An examination is made of the effect of plant capacity over the range 20,000-100,000 metric tons per year on cost per metric ton of installed capacity and all-inclusive production costs per metric ton of the products; and

d) An examination is made of the correlation between the Gross National Product of various countries and the existence in those countries of general purpose synthetic rubber plants.

II. ECONOMICS OF A TYPICAL SBR PLANT

4. The aim in presenting in this paper the economics of a hypothetical 'typical SBR plant' is to draw to the reader's attention what factors must be taken into account in calculating the economics of a particular plant in a particular location, and to give only a general (but by no means an absolute) picture of the economics of the production of SBR.

5. In order to [illegible] a large number of assumptions [illegible] to the extent that it is possible, the basis used for the assumptions in the present working will be outlined. However, it must be emphasized at the outset that although the costs [illegible] costs', for various reasons described later in this part, actual [illegible] may be very much different from those assumed here.

The various assumptions made for the typical plant are as follows:

Plant Capacity

6. In Table 1, a listing is made of emulsion SBR plants built as the first synthetic rubber facility in various countries throughout the world since 1961. The original design capacity of the 11 plants listed varies from 15,000 to 60,000 metric tons per year, with an average of about 35,000 metric tons per year. The latter figure has, therefore, been selected as the capacity of a typical SBR plant to be built as the first synthetic rubber facility in a developing country.

Capital Cost Estimate

7. Based on late 1977 Gulf Coast, U.S.A. equipment and materials costs and labour rates, the capital cost estimate for an integrated SBR plant of capacity 35,000 metric tons per year is:

Component	Cost, '000 U.S.$
Battery limits plant	[illegible]
Offsites	2,500
Total	[illegible]

The scope of items included in this estimate is listed in Appendix I.

License Fee

8. A reasonable licensor fee for a plant of capacity 35,000 metric tons per year would be U.S. $1,300,000.

9. The technology and services provided to licensee by licensor for such fee would include the basic design of the plant (which would enable licensee's contractor to prepare the final design, procure equipment and materials and construct the plant), the know-how technology (which would enable licensee to operate the plant), review of contractor's final design, review of actual construction in the field, training of licensee's employees in the operation of a similar facility, and assistance during startup. In addition (see following section on preproduction expenses and startup costs) for those services provided by licensor's personnel in licensee's country (review of construction, startup assistance), licensee would reimburse licensor at a per diem rate of, say, U.S. $150 per man day plus travel and living expenses.

Preproduction Expenses and Startup Costs

10. Preproduction expenses and startup costs are estimated in Table II to total U.S. $1,770,000.

Total Cost of Plant

11. The total cost of the plant is the sum of capital cost, license fee, and preproduction expenses and startup costs:

Item	Cost, 000 U.S.$
Capital costs	13,200
License fee	1,300
Preproduction, startup	1,770
Total	16,270

Fixed Production Costs

12. Fixed production costs, including various overheads, as outlined in Table III, amount to U.S. $3,580,000 annually.

Variable Production Costs

13. In Table IV, the annual variable production costs are estimated to amount to U.S. $7,130,000 when the plant runs full out producing the following grade mix:

Grade	% of Mix	Annual Production, Metric Tons
1500	15	5,250
1502	15	5,250
1712	55	19,250
1778	15	5,250
Total		35,000

i.e., 30% clear product and 70% oil-extended product (37.5 parts oil per hundred parts rubber).

14. Variable production costs per metric ton of SBR 1500 and 1700 types are displayed in Table V, and amount to U.S. $236 and 191, respectively.

Return on Investment

15. Having made the above cost calculations, and assuming further, sales volumes and selling prices for the products over a period of years, it is now possible to calculate the return on investment for our typical SBR plant. Or, conversely, because a new plant built in a developing country would not ordinarily offer an attractive rate of return if the products were to be sold at prevailing world prices, we may determine the selling prices necessary within the country (i.e. assuming that the border prices would be closer to exports) to achieve a particular desired rate of return - in this case, a 15% discounted cash flow rate of return on investment.

16. The actual economic worksheet for our plant is presented in Table VI. In addition to the cost assumptions made above, it is further assumed that during the first three years of operation of the plant, sales amount to 17,500, 24,500 and 31,500 tons per year (i.e. 50, 70 and 90% of capacity) and then would run at 35,000 tons per year thereafter. Other assumptions made in working out the rate of return on investment for the plant are presented in Appendix II.

17. Based on trial and error calculations, the last of which is shown in Table VI, it transpires that in order to achieve, for our hypothetical 'typical SBR plant', a discounted cash flow (DCF) rate of return on investment of 15%, the products would have to yield net sales revenues (i.e. selling price less distribution costs) of U.S. $500 per ton for the SBR 1500 types and U.S. $400 per ton for the 1700 types, or a weighted average for both types at a 30/70 grade mix of U.S. $430 per ton.

III. SENSITIVITY OF ECONOMICS TO CHANGES IN ASSUMPTIONS

18. It is of interest to determine how the economics of our hypothetical 'typical plant' would change were any of the assumptions made above to change, or, specifically, assuming a constant DCF rate of return of 15%, how the product net sales revenues (NSR's) would have to change in order to accommodate changes in the various assumptions.

19. Such a sensitivity analysis is presented in Table VII. The required NSR's for products of the SBR 1500 and 1700 series, rounded to the nearest U.S.$5 per ton, are seen to vary about the base case by as much as +U.S. $35 and -U.S. $50 per ton; and although actual NSR's are quoted for reference purposes, the importance of the information in Table VII is rather the change in NSR's brought about by the change in a particular assumption, rather than the absolute values of the NSR's, which for a particular plant in a particular location, may be very much different.

The variants studied are as follows:

Subcases 1,2 Fast Sales Buildup, Slow Sales Buildup

20. Were the plant to run full out for 10 years at 35,000 tons per year (a most unlikely event), the required NSR's would drop by U.S. $30 per ton, while if the plant were filled out by only the sixth year (sales 20, 50, 70, 80 and 90% over first five years) rather than by the fourth, the required NSR's would increase by U.S. $35 per ton.

Subcases 3,4 Plant Costs 10% Less, 10% More

21. A change in plant costs by ± 10% results in a change in required NSR's of only ∓ U.S. $15 per ton.

Subcase 5 Integrated Plant

22. If the plant is built in conjunction with a petrochemical complex, so that the cost of the plant is reduced by some U.S. $4 million (mainly savings in offsites) to U.S. $12.31 million, the number of required personnel drops by 40 to 149 and annual fixed costs are reduced by U.S. $0.82 million to U.S. $2.76 million, the required NSR's drop by a very significant U.S. $50 per ton.

Subcases 6-9 Changes in Monomer Prices

23. A change in butadiene price of ± U.S. $20 per ton results in a change in required NSR's of only ∓ U.S. $10 per ton, while an equivalent change in styrene price results in an even smaller change in NSR's of only ∓ U.S. $5 per ton.

Subcase 9 No Tax

24. The elimination of income tax reduces required NSR's by a very significant U.S. $50 per ton.

Subcase 10 10% DCF

25. Were the desired DCF return for the plant reduced from 15 to 10%, the NSR's would be reduced by a very significant U.S. $75 per ton.

IV. EFFECT OF PLANT CAPACITY ON ECONOMICS

26. The economic considerations covered in Sections II and III above were restricted to a plant of capacity 35,000 metric tons per year, but it is also of interest to consider other plants over the range 20,000-100,000 metric tons per year. However, to keep the matter simple, we shall restrict ourselves here to examining only the effect of plant capacity on the cost per metric ton of installed plant capacity, Table VIII, and on all-inclusive production costs per metric ton of the products, Table IX.

27. Without going into details, we attempt [illegible] various costs are similar to those presented in Section V above; but again, it must be emphasized that the cost figures presented in Tables VIII and IX should be regarded only as general reference figures, subject to changed pending or actual conditions prevailing for a particular plant in a particular location. It is the relative magnitude of the figures, rather than their absolute values, which is important.

28. Perhaps to no one's surprise, it is noted from the Tables that the costs associated with a 70,000 ton plant are very much higher than those of a 35,000 ton facility, while the costs of a 70,000 ton plant are, in fact, only moderately less than those of a 35,000 ton facility and only slightly more than those of a 100,000 ton plant. In fact, the discrepancy in production costs is no doubt greater than that shown in Table IX, as the larger volume purchase and/or production of raw materials for the larger plant would certainly also result in lower variable production costs than for the smaller plants.

29. It is worthy of note that SBR plants operating in N. America, W. Europe and Japan have, on the average, a design capacity well in excess of 100,000 metric tons per year.

V. CORRELATION BETWEEN GROSS NATIONAL PRODUCT OF VARIOUS COUNTRIES AND EXISTENCE IN THOSE COUNTRIES OF SYNTHETIC RUBBER PLANTS

30. Because of the possible variation over wide ranges of the many parameters which enter into the economics of any particular SBR plant built at a particular location, and, further, because in any particular case, strategic considerations such as development of the local economy, saving of hard currency or independence from sources of supply outside the country might take precedence over usual return on investment considerations, it is rather difficult to forecast what developing countries are currently likely candidates for their first synthetic rubber facility.

31. However, there is a general correlation between the Gross National Product (GNP) of various countries and the existence in those countries of at least one general purpose synthetic rubber (emulsion SBR, solution SBR or polybutadiene) facility. Such general correlation, as evidenced in Tables X-XIII, covering Africa, the Americas, Asia and Australasia, and Europe, is, namely, that countries with one plant have a GNP of at least $10 billion, while those with two plants have a GNP of at least $20 billion.

32. Based on such general correlation, one may predict what countries (those with a GNP of at least $10 billion) are likely candidates for their first synthetic rubber plant.

Appendix I

Scope of Work Included in Capital Cost Estimate
for [illegible] 50,000 Ton/Year SBR Plant

The "Battery Limits" estimate includes:

Monomer storage (one month's supply) and blending and recycling
Extender oil [illegible] chemical storage (one month's supply) and pigment mixing
Reactor area for continuous polymerization of [illegible] and butadiene to produce latex
Recovery area for stripping unreacted monomers from the latex and recycling them for reuse
Finishing area for coagulation, drying and packaging of the final product rubber
Process refrigeration system
Brine makeup and softening

The "Offsites" estimate includes:

Monomer storage (one month's supply)
Steam boilers
Electric substation
Plant air
Instrument air system
Cooling water tower
Water softening and treatment, including deaeration
Effluent holding basins
Effluent treatment
API oil separator
Sanitary sewers
Storm water drainage
Flare system
Fire pumps and system
Control laboratory and equipment
Product warehouse
Process chemical warehouse
Administration building
Site development
Fence
Roads
Special cleaning equipment
Maintenance shop and equipment
Instrument shop and equipment
Transport equipment

Appendix 1 (cont'd)

Office equipment
Emergency generator
Firefighting equipment
Safety equipment
Nitrogen supply system

Appendix II

Assumptions Made in Working Out DCF Rate of Return Displayed in Table VI

a) A project life of 10 years.

b) No cost escalation over the period.

c) A corporate income tax rate of 45%.

d) Working capital equivalent to 3 months net sales revenue.

e) Cash flow in at the end of 10 years is the sum of recovered working capital and the salvage value of the plant, taken as 10% of the original capital cost.

f) January 1, 1974 taken as time zero, monthly discount factors used for the years 1974 through 1983, and the yearly factor taken for cash recovered at the end of project.

Table I

SBR Plants Built as the First Synthetic Rubber Facility in Various Countries Since 1961*

Country	Startup Date	Original Capacity, 000 Tons/Year
Argentina	1965	40
Australia	1961	25
Brazil	1962	60
Bulgaria	1971	15
Czechoslovakia	1963	50
India	1963	30
S. Korea	1973	25
Mexico	1967	44
Romania	1963	50
South Africa	1964	30
Turkey	1974	33

* Data source C. F. Ruebensaal

Table II

Preproduction Expenses and Startup Costs
for 35,000 Metric Ton per Year SBR Plant

Item	Cost, 000 U.S.$
Salary, wages and benefits for 6 months for 189 employees @ average U.S. $8,000 per person per year	760
Travel and living expenses for personnel trained by licensor	30
Reimbursement of per diem rate and travel and living expenses of licensor's personnel who review plant construction and provide startup assistance	300
One month's non-saleable consumption of raw materials and utilities (see Table IV)	580
Miscellaneous	100
Total	1,770

Table III

Annual Fixed Costs for
35,000 Metric Ton per Year SBR Plant

Item	Cost, 000 U.S.$
Salary, wages and benefits (189 operating, maintenance, administration and marketing employees @ average U.S. $8,000 per person per year)	1,510
Maintenance materials (1.25% of capital cost)	170
Supplies	20
Depreciation, amortization (10% of cost of plant)	1,630
Overheads (includes travel, communication, non-process utilities, local taxes, etc.)	250
Total	3,580

Table IV

Annual Variable Production Costs for
35,000 Metric Ton per Year SBR Plant Producing
30% 1500 Types and 70% 1700 Types

Raw Materials	Consumption, Metric Tons	Unit Cost, U.S.$	Cost, 000 U.S.$
Butadiene	20,350	170	3,460
Styrene	6,600	220	1,450
Extender oils	6,810	56	380
Process chemicals	-	-	1,400
Raw Materials Subtotal			6,690

Utilities	Consumption	Unit Cost, U.S.$	Cost, 000 U.S.$
Electric power	16×10^6 kWh	0.006	96
Process water	350×10^3 m^3	0.10	35
Cooling water throughput	7×10^6 m^3	0.0012	10
Steam	123×10^3 tons	1.20	148
Air	6×10^6 Nm^3	-	20
Nitrogen	10×10^3 Nm^3	-	—
Utilities Subtotal			310
Packaging Materials (for local delivery by truck)			150
Total			7,150

Table V

Variable Production Costs per Metric Ton of SBR 1500 and 1700 Types

Raw Materials	Consumption, kg		Unit Cost, U.S.$	Cost/Ton, U.S.$	
	1500 Types	1700 Types		1500 Types	1700 Types
Butadiene	723	523	0.17	122.9	88.9
Styrene	235	169	0.22	51.7	37.2
Extender oils	-	278	0.056	-	15.6
Process chemicals	-	-	-	48.7	36.2
Raw Materials Subtotal				223.3	177.9
Utilities				8.9	8.9
Packaging Materials				4.3	4.3
Total				236	191

Table VI

Calculation of DCF Rate of Return on Investment for 35,000 Metric Ton per Year SBR Plant

000 U.S.$

	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
Sales, tons		17500	24500	31500	35000	35000	35000	35000	35000	35000	35000	
Net Sales Revenue		7350	10540	13550	15050	15050	15050	15050	15050	15050	15050	
Variable Costs		3500	5010	6440	7150	7150	7150	7150	7150	7150	7150	
Fixed Costs		3580	3580	3580	3580	3580	3580	3580	3580	3580	3580	
Total Costs		7080	8590	10020	10730	10730	10730	10730	10730	10730	10730	
Profit before Tax		270	1950	3530	4320	4320	4320	4320	4320	4320	4320	
Income Tax, 45%		120	880	1590	1950	1950	1950	1950	1950	1950	1950	
Profit after Tax		150	1070	1940	2370	2370	2370	2370	2370	2370	2370	
Working Capital		1680	2440	3190	3760	3760	3760	3760	3760	3760	3760	
Cash Flow Out												
Plant, Working Capital	10,720	1680	760	750	570							
Cash Flow In												
Profit after Tax		150	1070	1940	2370	2370	2370	2370	2370	2370	2370	
Depreciation		1630	1630	1630	1630	1630	1630	1630	1630	1630	1630	
Total Flow In		1780	2700	3570	4000	4000	4000	4000	4000	4000	4000	
Net Cash Flow	(10,720)	(1680)	1940	2820	3430	4000	4000	4000	4000	4000	4000	
Discount Factor, 10%	1.000	0.926	0.842	0.765	0.694	0.631	0.574	0.522	0.474	0.431	0.391	
Discounted Cash Flow	(10,720)	(1550)	1630	2160	2380	2520	2300	2090	1900	1720	1560	

Recovered Working Capital	3760
Salvage Value, 10%	1070
Total Flow In	4830
Net Cash Flow	1070
Discount Factor, 12%	0.257
Discounted Cash Flow	275

Table VII

Sensitivity of Required Net Sales Revenues to Changes in Assumptions

Subcase	Change in Assumption	Change in NSR, U.S.$/Ton	NSR, 1500 Types	NSR, 1700 Types
-	Base case	-	500	400
1	Fast sales buildup	-30	470	370
2	Slow sales buildup	+35	535	435
3	Plant costs 10% less	-15	485	385
4	Plant costs 10% more	+15	515	415
5	Integrated plant	-50	450	350
6	Butadiene $20/ton less	-10	490	390
7	Butadiene $20/ton more	+10	510	410
8	Styrene $20/ton less	-5	495	395
9	Styrene $20/ton more	+5	505	405
10	No tax	-50	450	350
11	10% DCF Return	-45	455	355

Table VIII

Effect of SBR Plant Capacity on Cost per Metric Ton of Installed Capacity

Plant Capacity, 000 Tons/Yr.	Number of Polymerization, Finishing Lines	Capital Cost, MM U.S. $	License, Prepaid., Startup Costs MM U.S. $	Total Plant Cost, MM U.S. $	Cost per Ton Installed Capacity, U.S. $
20	1	10.5	2.6	13.1	660
35	1	13.2	3.1	16.3	470
70	2	19.2	4.7	23.9	340
100	3	24.8	6.1	30.9	310

Table IX

Effect of SBR Plant Capacity on All-inclusive Production Costs per Metric Ton of Products

Plant Capacity, 000 Tons/Yr.	Annual Fixed Costs, 000 U.S.$	Fixed Costs/ Ton, U.S.$	Variable Costs/Ton 1500 Types, U.S.$	Variable Costs/Ton 1700 Types, U.S.$	Total Costs/Ton 1500 Types, U.S.$	Total Costs/Ton 1700 Types, U.S.$
20	3,220	161	236	191	397	352
35	3,580	102	236	191	338	293
70	4,810	69	236	191	305	260
100	5,980	60	236	191	296	251

Table X

Correlation between Gross National Product and Existence of General Purpose Synthetic Rubber Plants

Africa

Country	GNP (1970), billion U.S.$	Synthetic Rubber Plants
Algeria	4	
A.R. Egypt	6	
Libya	3	
Nigeria	7	
South Africa	17	1

Table XI

Correlation between Gross National Product and Existence of General Purpose Synthetic Rubber Plants

Americas

Country	GNP (1970), billion U.S.$	Synthetic Rubber Plants
Argentina	26	1
Brazil	30	2
Colombia	7	
Mexico	32	2
Peru	5	
Venezuela	10	

Table XII

Correlation between Gross National Product and Existence of General Purpose Synthetic Rubber Plants

Asia and Australasia

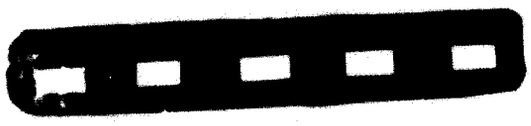
Country	GNP (1970), billion U.S.$	Synthetic Rubber Plants
Australia	31	3
P.R. China	121	2
India	65	1 + 1 under construction
Indonesia	12	
Iran	11	
Israel	5	
S. Korea	8	1
Pakistan	7	
Philippines	8	
Thailand	7	

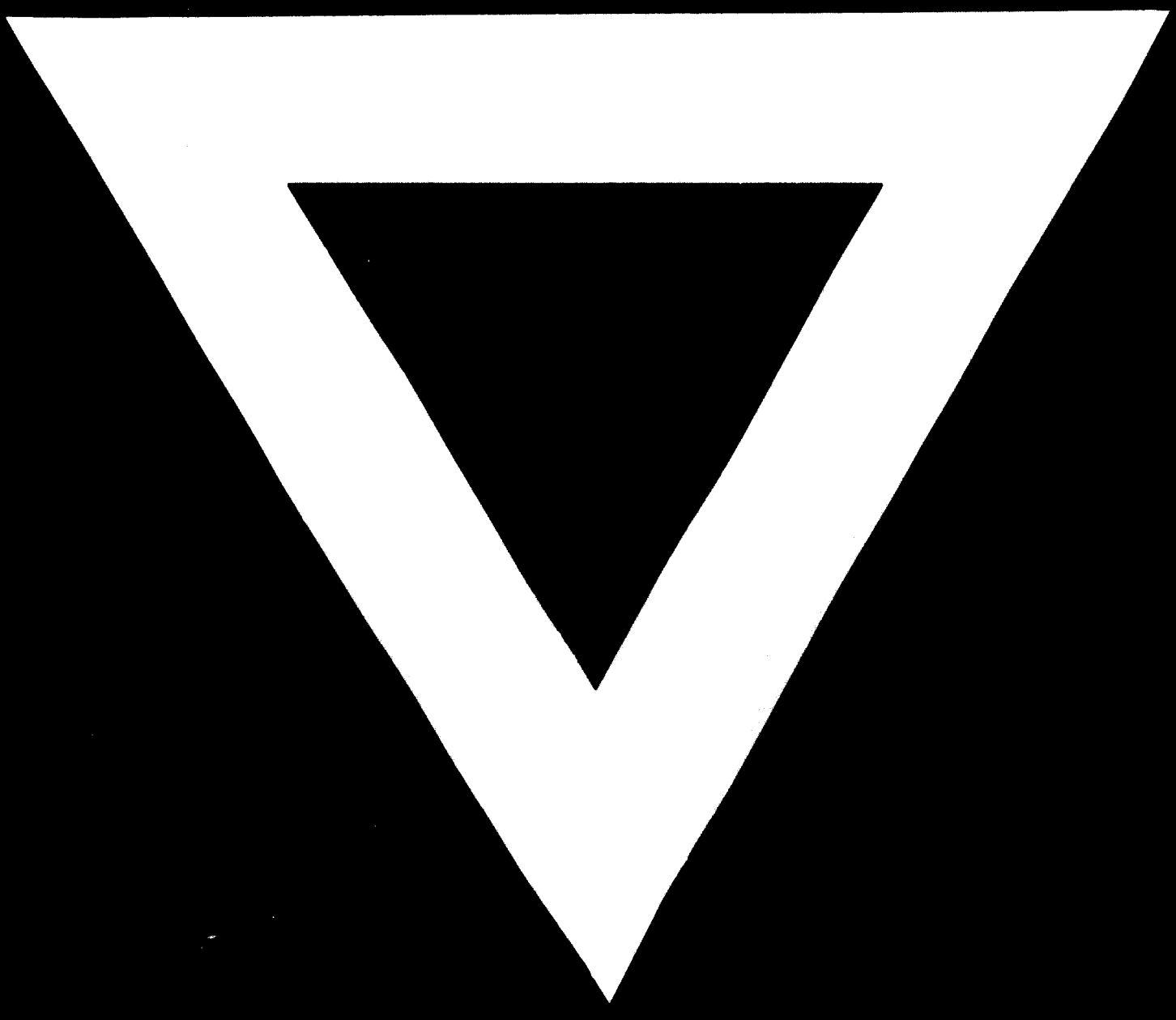
Table XIII

Correlation between Gross National Product and Existence of General Purpose Synthetic Rubber Plants

Europe

Country	GNP (1970), billion U.S.$	Synthetic Rubber Plants
Bulgaria	12	1
Czechoslovakia	33	1
Finland	11	
Hungary	16	
Romania	24	1
Turkey	13	2 under construction
Yugoslavia	13	





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