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THE TRENDS AND ACHIEVEMENTS OF THE TYRE AND RUBBER GOODS INDUSTRIES IN REPLACING NATURAL BY SYNTHETIC RUBBER 1/

by

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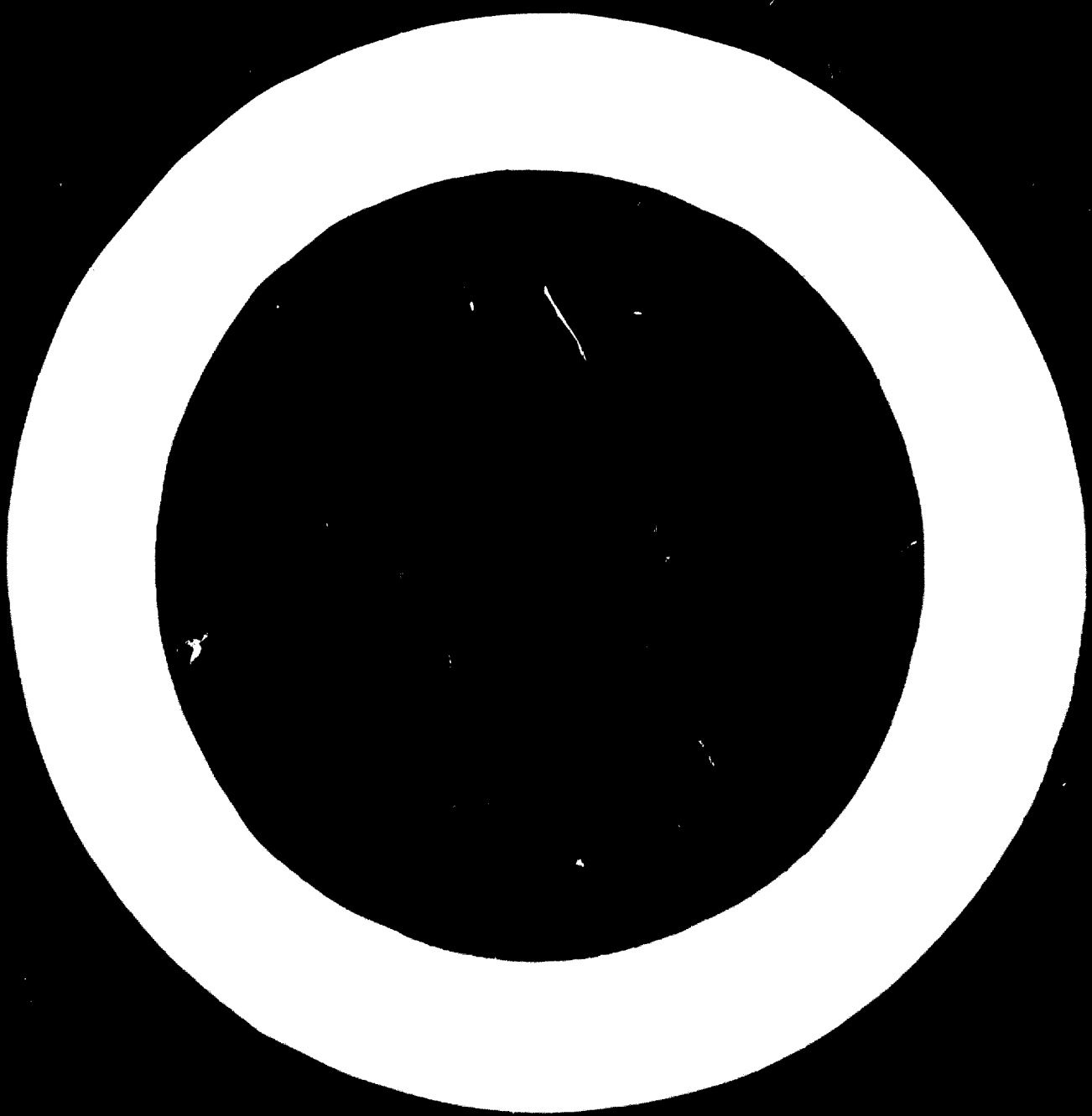

CONTENTS

I. INTRODUCTION

1. The rubber industry is one of the world major industries and is growing in size and diversifying at a rapid rate. In this paper, published statistics are analysed to indicate growth rates of the tyre and non-tyre industries and used to predict likely conversion rates from natural to synthetic rubbers. Each industry is analysed to predict the growth in types of synthetic polymer. Some attempt is made to predict the likely trends of the future.

II. ACHIEVEMENTS

2. Considering the world-wide consumption figures for the rubber industry as produced in the August 1971 edition of the Rubber Statistical Bulletin, Figure 1 demonstrates the consumption rates for both natural rubber and synthetic rubber. Until the end of 1962 natural rubber was used as the major polymer in the rubber industry being 53.13% of the total polymer. It was surpassed during 1963 by synthetic rubber. Since that time synthetic rubber has made rapid progress in the industry with the development and introduction of new polymers and expansion of existing plant capacities until, in 1970, natural rubber has been reduced to 39.28% of the total polymer used in the rubber industry.

3. It is not possible to obtain a representative picture of the rubber industry, world-wide, by looking at a particular country since each manufactures a different range of products in different ratios. Territorial conditions, governmental regulations and tariffs can alter the ratio of natural to synthetic rubber consumption. The state of economic development of a country can also influence the consumption and ratio of synthetic and natural rubber. Table 1. below, gives some statistical data for selected countries which vary in their state of economic development and in kilogrammes/per capita use of rubber.

TABLE 1.

Country	GNP per capita £	1970 rubber tonnage consumed	Kg. rubber per capita	Estimated ratio of truck to car tyres
Australia	(1) 1210	85,927	6.72	1:5
Brazil	(2) 121 (a)	122,093	1.32	1:2.5
India	(3) 31.8 (b)	118,279	0.22	1:1
Japan	(4) 790	779,000	7.53	1:2.5
South Africa	(5) 310	64,387	3.01	1:3
U.K.	(6) 793	461,800	8.29	1:5
U.S.A.	(7) 1292	2,516,918	12.58	1:7
U.S.S.R.	(8) 501.5 (b)	1,124,500 (c)	4.61 (c)	4:1 (c)

Note: a. Gross domestic product per capita
b. National income per capita
c. Estimated figure

4. Plotting the gross national product per capita versus the consumption of rubber per capita gives a reasonably straight line relationship as shown in Fig.2, with the exception of Australia. The latter could be explained by the extensive natural and agricultural resources and the low level of population for the size of the country. Both would tend to exaggerate the gross national product per capita. The position of Australia could also indicate that there is a great potential for expansion of the rubber industry in Australia particularly as the importation of rubber goods ex the U.K. amounted to £4,890,000 in 1968 (9).

5. For the purpose of subsequent discussion it is proposed to classify countries into three categories -

a) The highly developed countries which have a high GNP and a high rubber consumption per capita an example of which is the U.S.A.

b) The countries with a low level of economic development, e.g. India and Brazil.

c) Countries which fall between these two extremes, e.g. U.K. and Japan.

6. Reliable statistics for the rubber industries in the U.S.A., U.K., Japan, Brazil, and India are available. These will therefore be used for further analysis. This list of countries contains examples where governmental restrictions influence the usage of synthetic rubber. It also covers countries where there are large differences in the ratio of truck to car tyre production. The truck tyre contains the higher proportion of natural rubber.

7. Figure 3 gives the consumption of synthetic expressed as a percentage of the total rubber used.[10] Several points worthy of note are apparent from this graph. As would be expected from the state of economic development U.S.A. leads the field in the percentage consumption of synthetic rubber with an estimated 77.51% synthetic rubber consumption for 1971. The Japanese rate of conversion to synthetic rubber has been faster than the U.K. but in both cases the estimated percentage usage for 1971 appears to be lower than for 1970. India is at a significantly lower level of percentage synthetic rubber usage than the other countries. This could be partially explained by the fact, as shown in Table 1, that the ratio of truck to car tyres is 1:1. Brazil is in an interesting situation in that there has been a steady increase in the percentage of synthetic rubber used since 1960, and it uses a higher level of synthetic material than its state of economic development or ratio of truck to car tyres would indicate. This will be dealt with in more detail later in the paper.

8. The percentage of synthetic rubber usage can be further separated into the tyre and non-tyre industries from facts available [10] for U.S.A., U.K., Japan and Brazil. The result of this analysis for the period 1960 to 1971 is shown in Figure 4.
From this it can be seen that the non-tyre industry uses a higher percentage of synthetic rubber than does the tyre industry.
This is most obvious for U.S.A. and Brazil. In the case of U.K. and Japan it is only over the last two or three years that the non-tyre industries have overtaken the tyre industry in percentage synthetic rubber usage No relationship between the type of product produced in the non-tyre industry and the percentage of synthetic used could be found as the industry has such a wide variety of sub-industries with widely varying products having specialised requirements. In the tyre industry, as already pointed out, there exists a relationship between the two major products: truck and car tyres; the latter being high in synthetic and the former high in natural content. For a radial ply car tyre approximately 60% of the rubber is synthetic, for the cross ply car tyre approximately 80%.
The corresponding figures for large truck tyres would be 15-20% for the radial, and 20-25% for the cross ply. Figure 4 shows that in the U.S.A., with a high level of car tyre production, the synthetic percentage is above the other countries. U.K. with its ratio of truck to car tyres is apparently slightly lower in synthetic usage than it should be. This could be partially explained by the impact of the radial ply tyre in the U.K.
Japan and in particular Brazil, are somewhat higher in synthetic usage than their ratios of truck to car tyre would suggest.

9. To look a little closer into the reasons behind these apparent deviations in the percentage of synthetic rubber consumed it is necessary to take each country separately and compare the figures with local conditions.
Each country, while manufacturing certain types of synthetic rubber may need to import other types. It is possible that if there is an excess of local synthetic rubber production some may be exported. The difference between the quantity of synthetic rubber produced and that exported will be called "retained production".
Figure 5 shows the situation in the U.S.A. It can be seen that the synthetic rubber industry

is self-sufficient and also that there is a relationship between the percentage of synthetic used and the production rate. Figure 6 demonstrates the same plot for the U.K. The U.K. industry is not self-sufficient in polymer production and it imports substantial quantities of synthetic rubber and exports significant quantities of its own locally produced materials. Again there is a relationship between the percentage consumed and the quantity produced. Japan on the other hand, as illustrated in Figure 7, imported synthetic rubber for all of the 60's and only in 1970/71 is there an indication of the Japanese industry being self-sufficient. Japan also exports large quantities of rubber and it is estimated that for 1971 some 35% of its locally produced material will be exported. Figure 8 demonstrates the situation in Brazil where production of local synthetic rubber commenced in 1961. Initially all the synthetic rubber consumed had to be imported and synthetics only occupied a low percentage of the total rubber consumed. The synthetic production industry rapidly increased its output and reduced the quantity of rubber being imported. Here the situation was favourable to a rapid increase in the percentage of synthetic rubber consumed because of several factors:

the government allocated the locally produced synthetic rubber to the industries to minimise importations; only small quantities of Malaysian natural rubber could be imported for special strategic applications; the rest of the natural rubber requirements had to be fulfilled by Brazilian nationally produced rubber which was inferior in quality to the Malaysian product and double the price; synthetic rubbers were roughly a third of the price of the Brazilian nationally produced rubber. All these points spurred the rubber industry into using as high a quantity of synthetic rubber as possible, consistent with acceptable product performance. These factors explain why the Brazilian industry uses a high percentage of synthetic rubber relative to its state of economic development.

A similar situation of governmental allocation of locally produced synthetic rubber occurred in India, and this is shown in Figure 9. As local production increased, imports decreased and synthetic usage increased.

10. Figure 10 illustrates the percentage consumption of synthetic rubber [10] used over the period 1960-1971 for the whole world. Also plotted on this graph is the tonnage of synthetic rubber produced and consumed which indicates a slight production surplus each year.

The percentage consumption of synthetic rubbers increased rapidly in the early 60's at a rate of more than two percent per annum, but in the late 60's this had dropped to about one per cent per annum.

11. Turning now to the types of synthetic rubber used in the tyre and non-tyre industry, the figures quoted for U.S.A.[10] give an indication as to where the expansion in synthetic rubber has taken place.
Table II below gives the breakdown for 1960 and 1970.

TABLE II

TYPE OF SYNTHETIC RUBBER USED IN U.S.A.

	1960				1970			
	Tyre quantity (tonnes)	%	Non-tyre quantity (tonnes)	%	Tyre quantity (tonnes)	%	Non-tyre quantity (tonnes)	%
Styrene type	630945	92.516	287963	69.459	792362	65.491	443491	60.034
Butyl	46353	6.797	16281	3.927	68767	5.684	25061	3.392
Acrylonitrile type	441	0.064	32225	7.773	98	0.008	60464	8.185
Stereo regular	-	-	-	-	344437	28.468	65130	8.816
Others	4246	0.623	78110	18.841	4224	0.349	144594	19.537
TOTAL	681985		414579		1209888		738740	

12. In 1960 the styrene based polymers were the major synthetic polymers in use in the tyre industry, but by 1970 the stereo regular polyisoprene, polybutadiene and ethylene-propylene polymers had become significant. The main contender of the stereo regular types was polybutadiene, followed by polyisoprene. Only minor quantities of ethylene-propylene polymer were used. It is interesting to note here that when polybutadiene polymers were first introduced it was claimed that they were replacments for natural rubber, whereas, in fact they have tended to replace the synthetic SBR's to a large extent with less influence on the natural rubber field. In the non-tyre industries the stereo regular polymers have again made inroads in areas previously dominated by the styrene polymers, but the ethylene-

propylene polymers have perhaps also found applications which were new to the industry. New applications could also account for the increase in the percentage of acrylonitrile and other speciality rubbers such as the polychloroprenes and fluorinated elastomers.

13. The conclusion which can be drawn from the statistics prepared so far is that synthetic rubbers are increasing in consumption at a greater rate than natural rubber, partly because they can be used in applications where it was not possible to use natural rubber and partly because they have replaced natural rubber. By virtue of the fact that the technology and research associated with the synthetic rubber production industry is so advanced, it is relatively easy to produce a new polymer or to modify an existing one to meet the requirements of a particular application.

III. TRENDS IN SERVICE CONDITIONS

14. The rubber industry is being asked to produce products which are being used for increasingly arduous operating conditions. This applies not only to the tyre industry but also to the non-tyre sector. As examples:

- Belting has always operated under severe conditions carrying materials, which can be highly abrasive such as quarry stone and coal, from point to point. New applications include moving footpaths in air terminals and transfer of hot embers - of the order of 400-500°C - from a furnace to a dump.
- Hose is used in a wide range of severities from garden to sand blasting equipment.
- Roller covers need to resist the chemical attack of acids, oils and solvents.
- Tank lining materials must resist the chemical attack of many liquids.

New applications are being found with synthetic polymer for example floating tanks for storage and discharge of north sea gas and oil.

- Seals are being applied to a variety of conditions for example sewage pipes requiring resistance to ageing, moisture and bacterial attack, aviation seals requiring resistance to ozone, high and low temperatures and aviation fluids.
- Skirting for hovercraft requiring high fatigue resistance, the loose end of the skirt oscillating at sound barrier speeds.

- Car tyres require the greatest wet-skid resistance, the best abrasion resistance (particularly with the advent of more abrasive road surfaces such as the Shell Calcined Bauxite in epoxy resin), greater uniformity for the more sensitive modern car, and higher speed capability with increasing motorway constructions.
- Truck tyres have to contend with ever-increasing load-carrying capacities, higher speeds and require greater uniformity, better road-hold and higher abrasion resistance.
- Aircraft tyres are required for heavier aircraft, higher landing and take-off speeds, low temperatures from high altitude flying and, in the case of the vertical take-off and landing military aircraft, high temperatures from the jet exhausts.
- Earthmover tyres need to accept heavier vehicles, higher speeds, more arduous 'road' surfaces and high ambient temperatures of operation.

15. The tyre industry will have to contend with many exotic forms of transport such as the developments in rail/train transport as mentioned in the 1970 I.R.I. Foundation Lecture given by G.F. Marton [11] in which a pneumatic tyre may be used to enable trains to negotiate higher gradients.

16. As can be seen by this brief coverage of applications the rubber industry will have to contend with ever increasing arduous conditions wherever its products are applied.

IV. ASSESSMENT OF SYNTHETIC POLYMERS

17. In this section of the paper some of the major polymers are briefly discussed in relation to their advantages and disadvantages compared to natural rubber and some indication of their applications is given.

18. SBR's of the emulsion or solution types, being the major synthetic polymer used in the industry, should be considered first.
SBR's are somewhat more difficult to handle, have better abrasion, lower permeability, better road traction, are less resilient, have a higher heat build-up, suffer from "marching modulus" but are more economical to use than natural rubber. As shown earlier in the

paper these have made rapid inroads into all areas of rubber products and new applications are being found each year.

19. Polybutadienes have excellent abrasion resistance under high severity conditions, poor wet skid resistance, poor tear strength, low heat build-up, difficult processability, high permeability, good acceptance of high oil and black levels, and have made rapid gains in the tyre field.

20. Polyisoprenes are in the category of a true natural rubber replacement. Considering the Ziegler catalysed polymers these could be used as a direct replacement for natural rubber with only small differences in properties, but in general these materials are expensive possibly due to the shortage of highly pure monomer which the Ziegler catalyst requires. Once this problem has been overcome there is no reason why they should not be produced at an economic price. The alkyl lithium catalysed polymers fall short in terms of green strength and general tensile properties when compared with natural rubber, but, being more economical to produce than the Ziegler material are widely used in the tyre and non-tyre industries. In certain applications these polymers have the advantage of purity and freedom from foreign matter over natural rubber.

21. Ethylene Propylene polymers have the capability of being highly loaded with oil and black to produce very cheap compounds with good static resistance to ageing and are finding many applications in the non-tyre industry such as weatherstrips and hose. In the tyre field they have many disadvantages which preclude their use in large quantities. They are likely to only be used in sidewall application.

22. Butyl has been used for many years and this is likely to continue because of its excellent heat and weathering resistance. Halogenation of the butyl may extend its penetration into inner linings for tyres.

23. Acrylonitriles have the advantage of being highly resistant to swelling fluids and find many applications in the non-tyre industry where these properties are required.

24. Polychloroprenes find similar applications as acrylonitriles, being excellent in resistance to certain organic swelling fluids and ageing. They are widely used in the Aviation industry, in print rollers, and in special grades of belting.

25. Speciality polymers such as the fluorinated polymers, the polysulphides, and the silicones, are only used in the non-tyre industry where the service conditions require the special properties of these polymers.

V. THE INFLUENCE OF ASSOCIATED CHEMICAL INDUSTRIES

26. Use of natural or synthetic polymers cannot be considered in isolation without reference to the carbon black or chemical industries. Most polymers need to be compounded together with other materials to enable the rubber manufacturer to make full use of the desirable properties of a particular polymer. Over recent years significant advances have been made in carbon black developments, e.g. high structure blacks and blacks with high tint values. In the chemical industry improved curative systems, e.g. EV systems, better retardation of cure; cure systems which are more resistant to heat degradation e.g. the resin cure system for butyl; better protective systems such as the paraphenylene diamines which enable rubber to resist weathering to a far higher degree, have been introduced.
All these advances have enabled the rubber manufacturer to use polymers under conditions which had previously been considered to be impracticable. Many development materials are being brought onto the market each year which enable further conversion to synthetic rubbers or extends the application of both synthetic and natural rubber.

VI. TRENDS

27. From the statistics available[10] the growth rate per annum of the rubber industry can be calculated using the consumption of rubber expressed as a percentage increase over the previous year. Results of such calculations are given in Table III.

TABLE III

Year	Rubber consumption metric tonnes	% Growth
1960	3,947,500	-
1961	4,140,000	4.88
1962	4,495,000	8.57
1963	4,702,500	4.62
1964	5,115,000	8.77
1965	5,495,000	7.43
1966	5,950,000	8.28
1967	5,947,500	-0.04
1968	6,830,000	14.84
1969	7,435,000	8.86
1970	7,617,500	2.45

28. These calculations give an average rate of growth per annum for 1960-65 of 6.85%, for 1965-70 of 6.88%, and for the whole period 6.87 %. Using this figure of 6.87% p.a. the forecast of rubber consumed in 1980 would be 14.75 million metric tonnes per annum and gives a picture as shown in Figure 11.

29. Using the same method of calculation for the breakdown of natural and synthetic rubber gives the growth rate per annum as shown in Table IV.

TABLE IV

Growth Rate per Annum for Natural and Synthetic Rubber

Year	NR		SR	
	Consumption	% Growth	Consumption	% Growth
1960	2097500	-	1850000	-
1961	2162500	3.5	1975000	6.5
1962	2257500	4.5	2237500	13.0
1963	2265000	0.5	2437500	9.0
1964	2290000	0.75	2825500	16.5
1965	2422500	6.0	3072500	9.0
1966	2590000	7.0	3360000	9.5
1967	2500000	-3.3	3447500	2.5
1968	2847500	13.5	3982500	15.5
1969	2982500	5.0	4455000	12.0
1970	2992500	0.5	4625000	3.5

30. This gives an average percentage growth rate per annum over the whole period 1960-70 of 3.80% for natural rubber, and 9.70% for synthetic rubber. Using these figures and those obtained in the forecast for the total industry the consumption of natural and synthetic rubber can be calculated. For 1980 nearly 11 million metric tonnes of synthetic and 3.75 million metric tonnes of natural will be consumed. The growth of consumption is illustrated in Figure 12 for both classes of polymer. From this it can be calculated that by 1980 synthetic rubbers will constitute approximately 75% of the total rubber produced in the world.

31. Table V gives the percentage growth rate of the tyre and non-tyre industries for U.S.A., U.K., Japan, and Brazil, calculated on the consumption of rubber used.

TABLE V

% Growth Rate for Tyre and Non-tyre Industries

Year	U.S.A.		U.K.		Japan		Brazil	
	Tyre	Non-tyre	Tyre	Non-tyre	Tyre	Non-tyre	Tyre	Non-tyre
1961	-3.75	1.52	-1.83	-3.94	22.03	9.30	-3.93	6.02
1962	11.37	14.04	3.54	3.07	13.29	13.23	12.90	27.16
1963	1.34	4.75	3.05	7.52	15.91	1.35	-2.50	9.77
1964	10.87	7.54	9.60	12.21	12.64	15.24	2.68	9.07
1965	9.03	1.85	6.39	3.65	2.20	2.65	-11.52	-14.87
1966	8.08	6.87	3.36	3.97	11.62	20.47	24.44	35.71
1967	-6.11	-1.05	-0.50	1.15	23.05	13.24	8.16	8.83
1968	21.17	10.14	12.83	10.04	19.60	14.26	15.59	35.92
1969	7.18	3.33	2.59	6.62	17.09	13.11	-1.76	-3.33
1970	-8.36	-0.14	1.48	5.06	13.51	10.95	14.12	16.61
Average per annum								
	5.08	4.89	4.05	4.94	15.09	11.38	5.82	13.09

32. This table indicates the average percentage growth rate of the Tyre and Non-tyre industries. For the U.S.A. and the U.K. there is little difference between the two industries, but for the other countries there are significant differences.

VII. CONCLUSIONS AND AREAS OF DEVELOPMENT

33. From the information presented it is apparent that synthetic rubber is increasing in percentage consumption over the natural product, and this trend is expected to continue since as newer synthetic polymers are developed further applications will be opened up. However, it is considered that even with this growth in synthetic rubber consumption there will always be a place for natural rubber.

34. Modifications to the natural product are possible and the advent of such modifications as network bound antioxidants [12] and improved curing systems to resist high temperature [13]

may improve the position of natural rubber over that predicted.
Further work aimed along these lines are necessary if natural rubber is to take a bigger share of the rubber industry market.

35. Trends and developments in the synthetic rubber field may further increase its share of this market. Such items as thermolastic rubbers, transpolypentenamer and Alfin catalysed SBR or IBR may significantly alter the role of synthetic rubbers and lead to new areas of development for rubbers which can replace the natural variety.

36. Refinements in synthetic polyisoprene manufacture are perhaps the area which is most likely to bite into natural rubber usage, particularly if it offers cost savings at a stable price level.

VIII. ACKNOWLEDGEMENTS

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World Consumption of Natural and Synthetic Rubbers

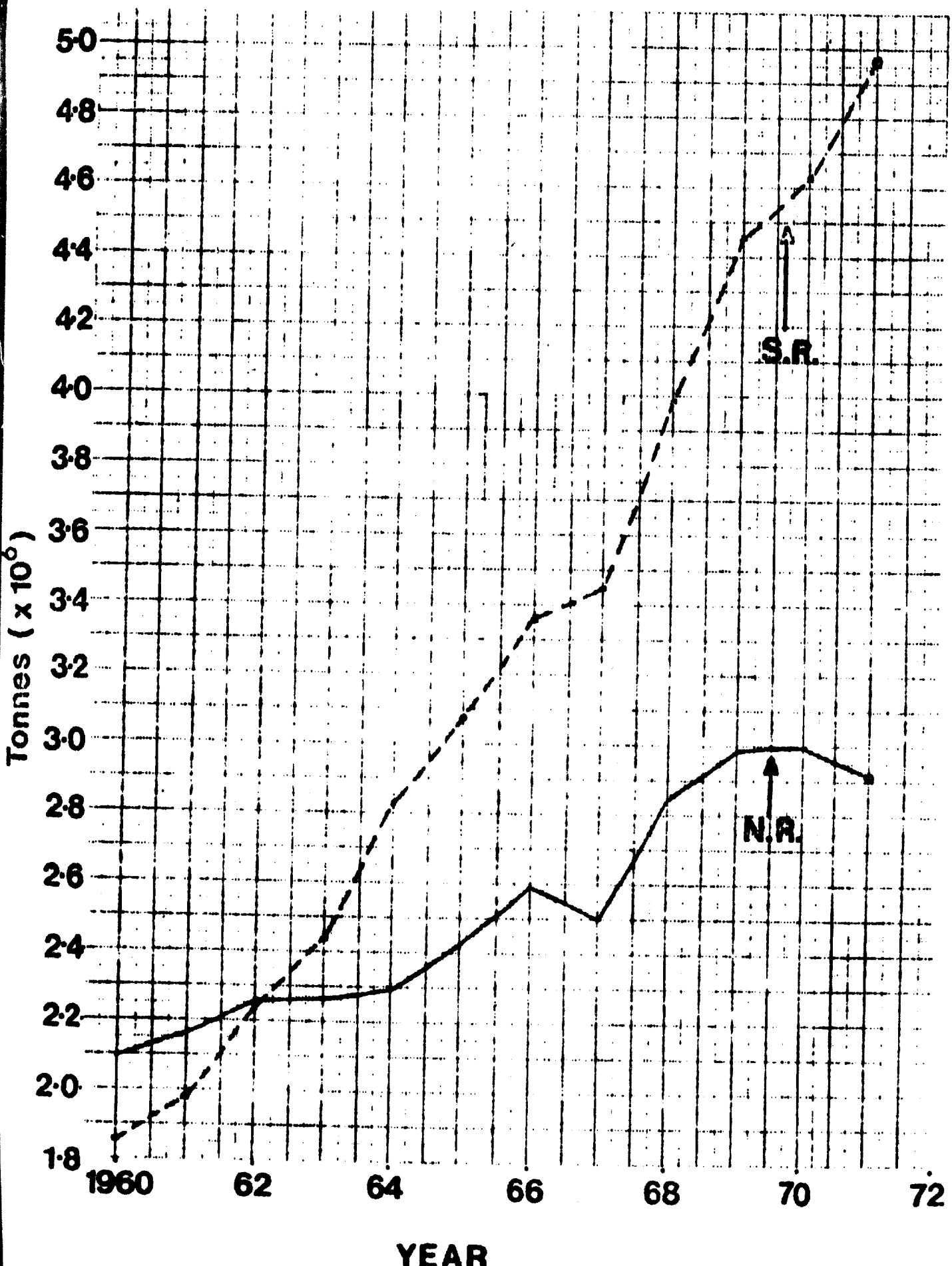


Fig.1

State of Economic Development for Selected Countries

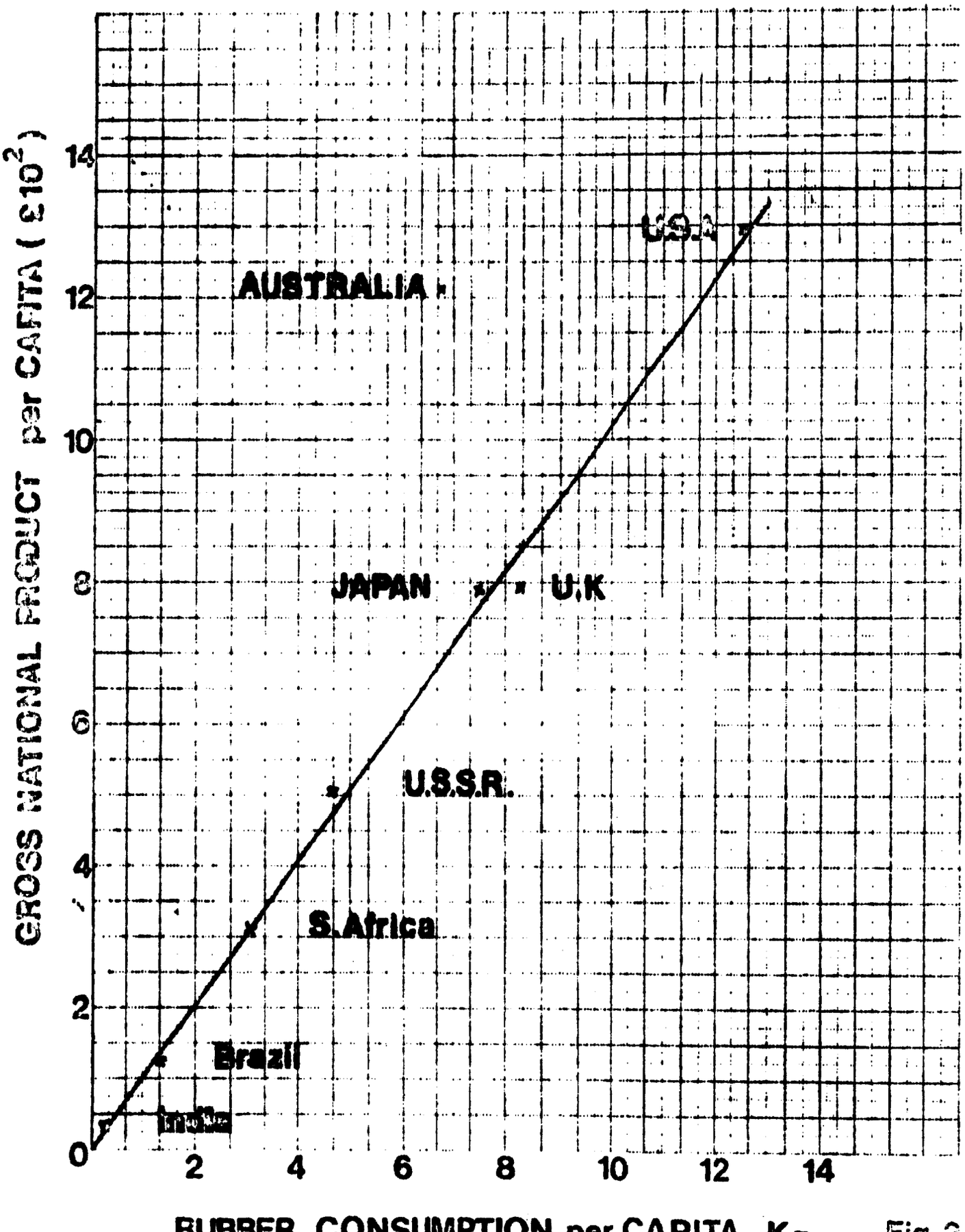


Fig.2

Percentage Consumption of Synthetic Rubber

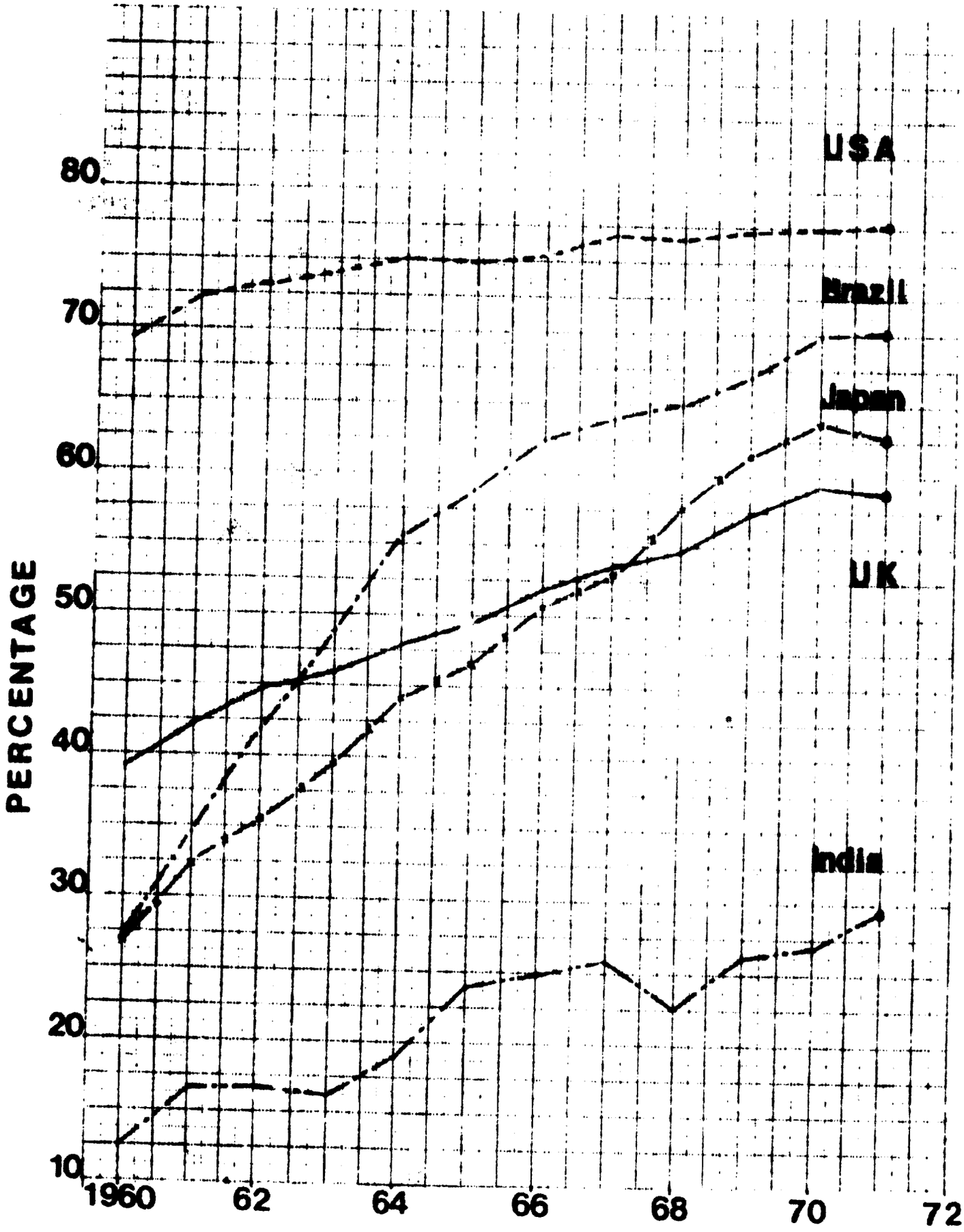


Fig. 3

Percentage Synthetic Rubber used in Tyre & Non Tyre Industries

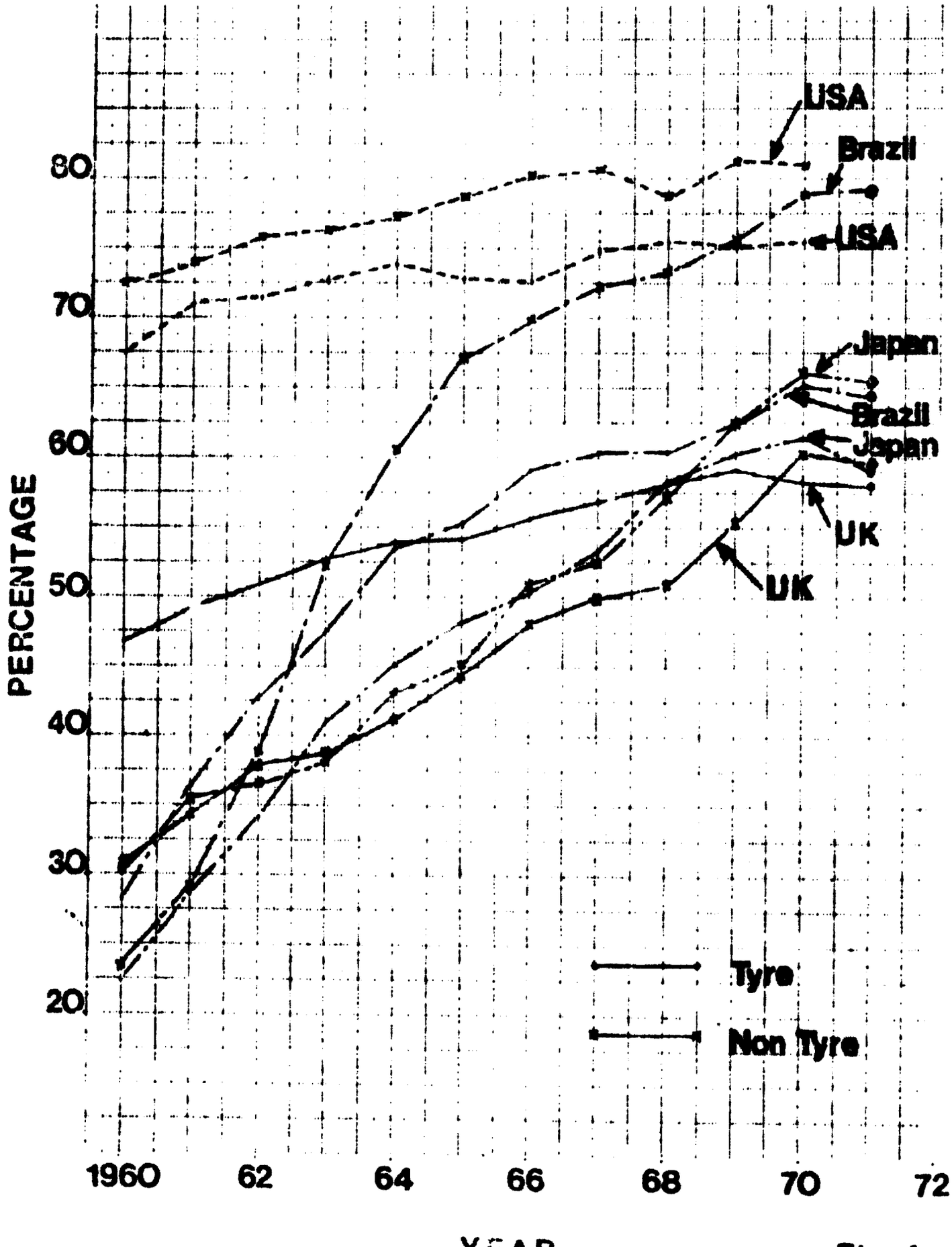


Fig. 4

Usage of Synthetic Rubber

U.S.A

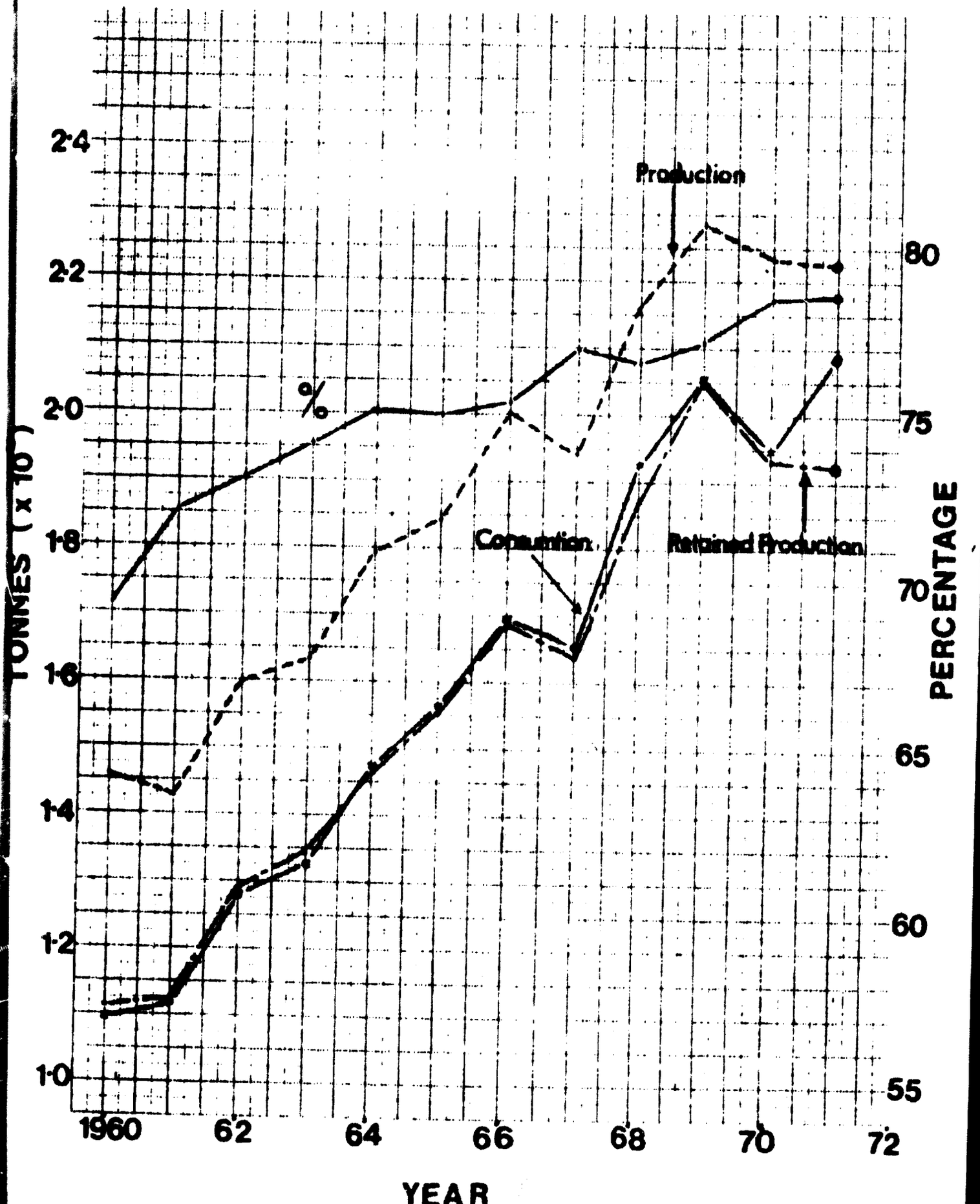


Fig.5

Usage of Synthetic Rubber

U.K

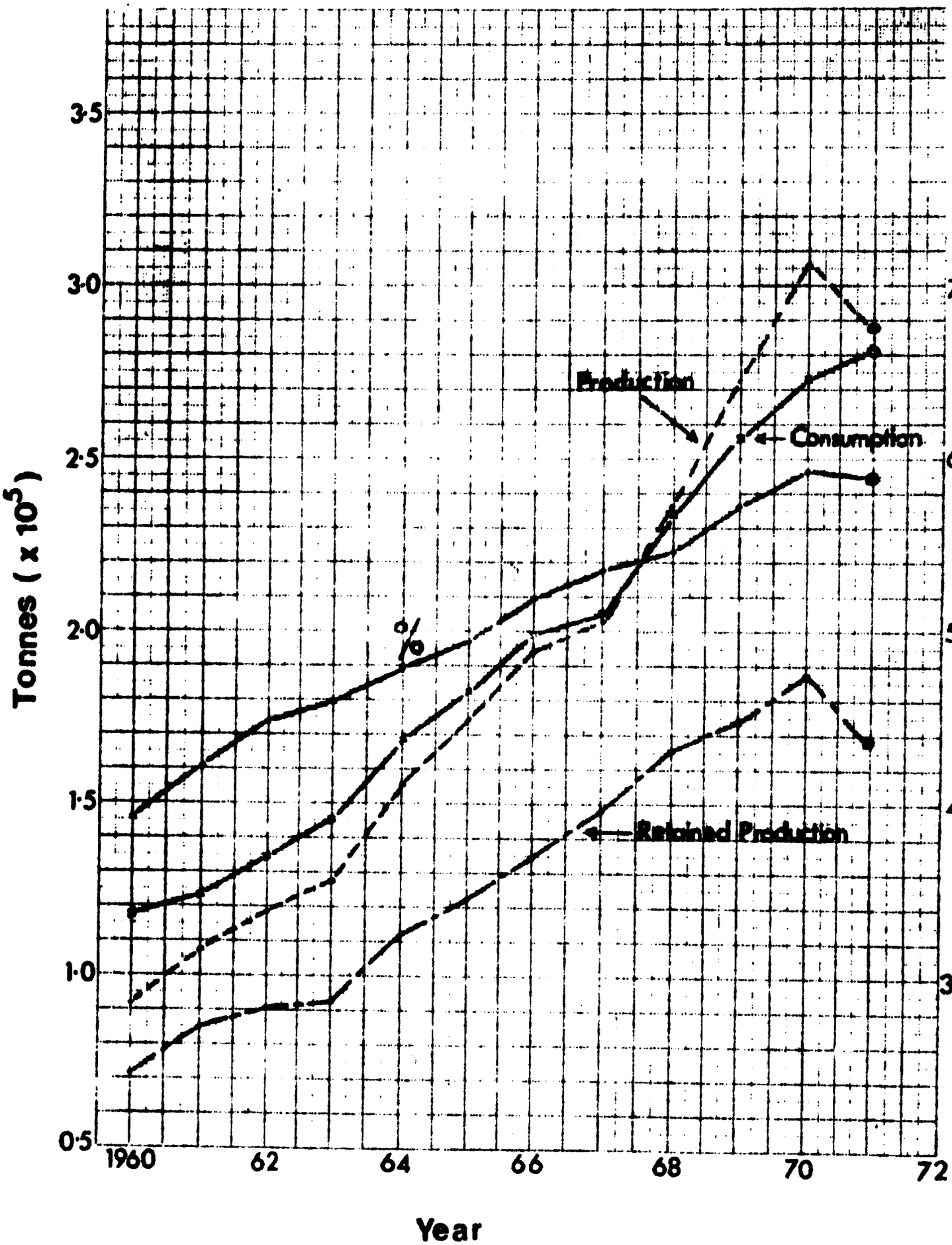


Fig.6

Usage of Synthetic Rubber

JAPAN

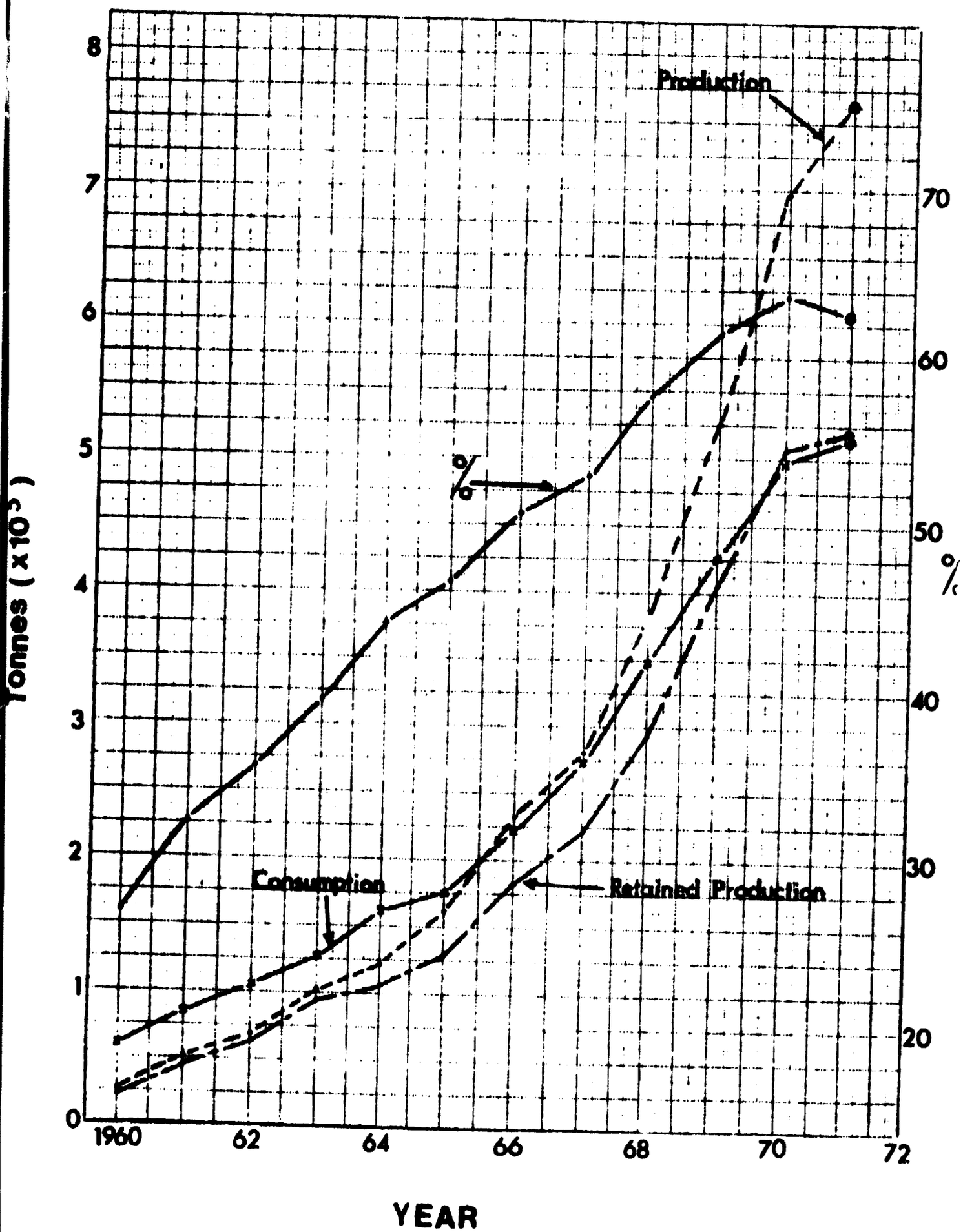


Fig. 7

Usage of Synthetic Rubber

BRAZIL

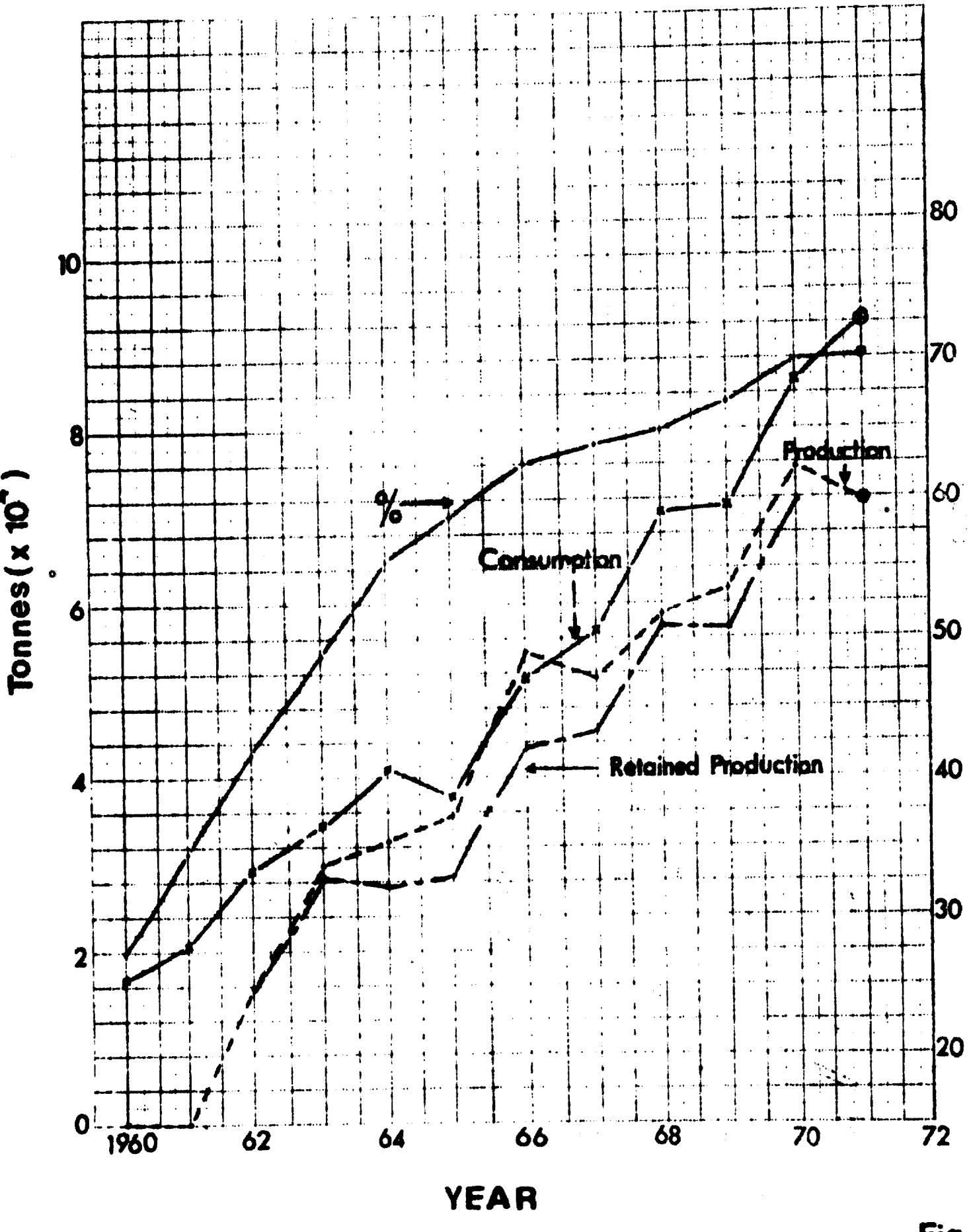


Fig.

Usage of Synthetic Rubber

INDIA

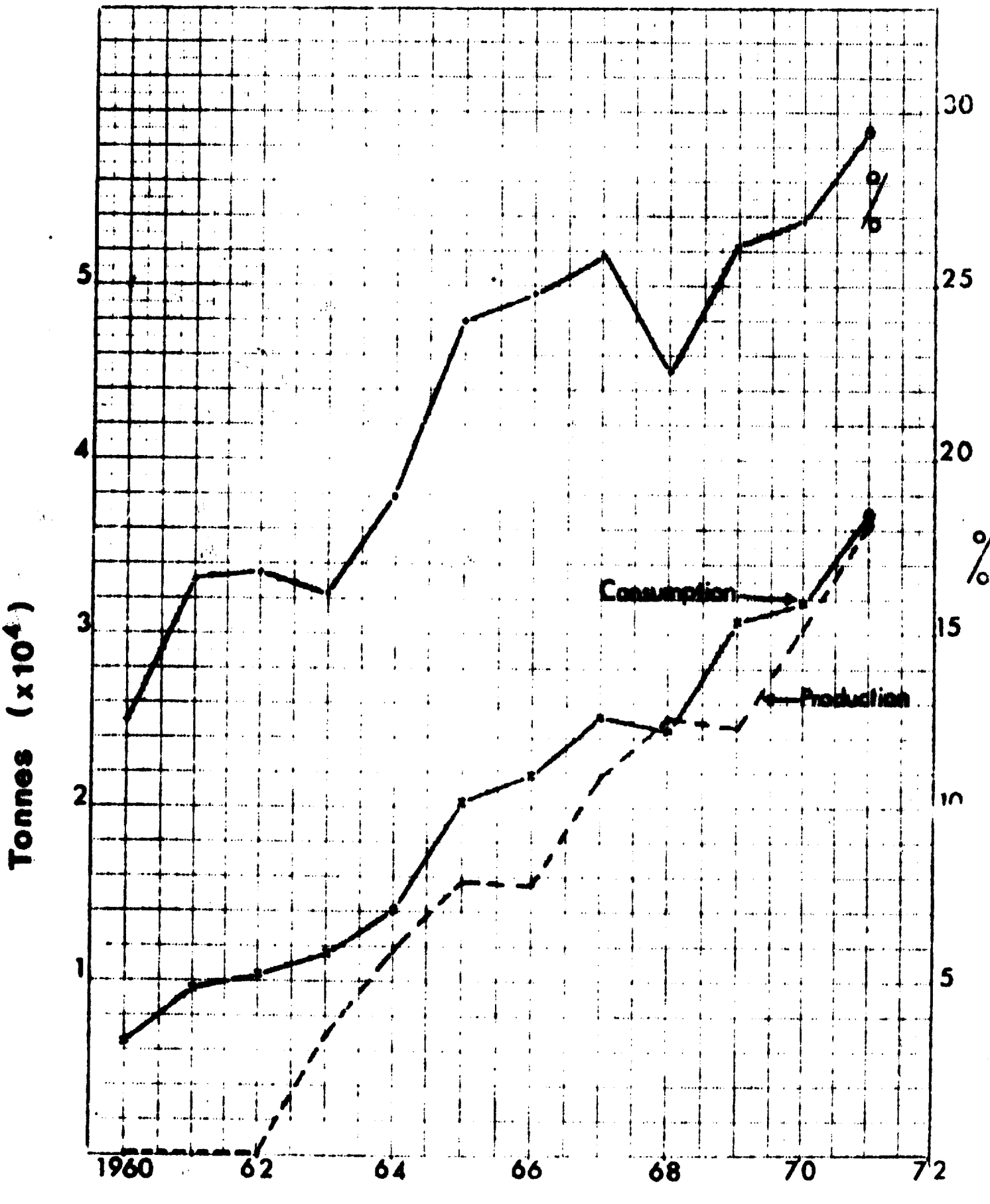


Fig. 9

Usage & Production of Synthetic Rubber - World Wide

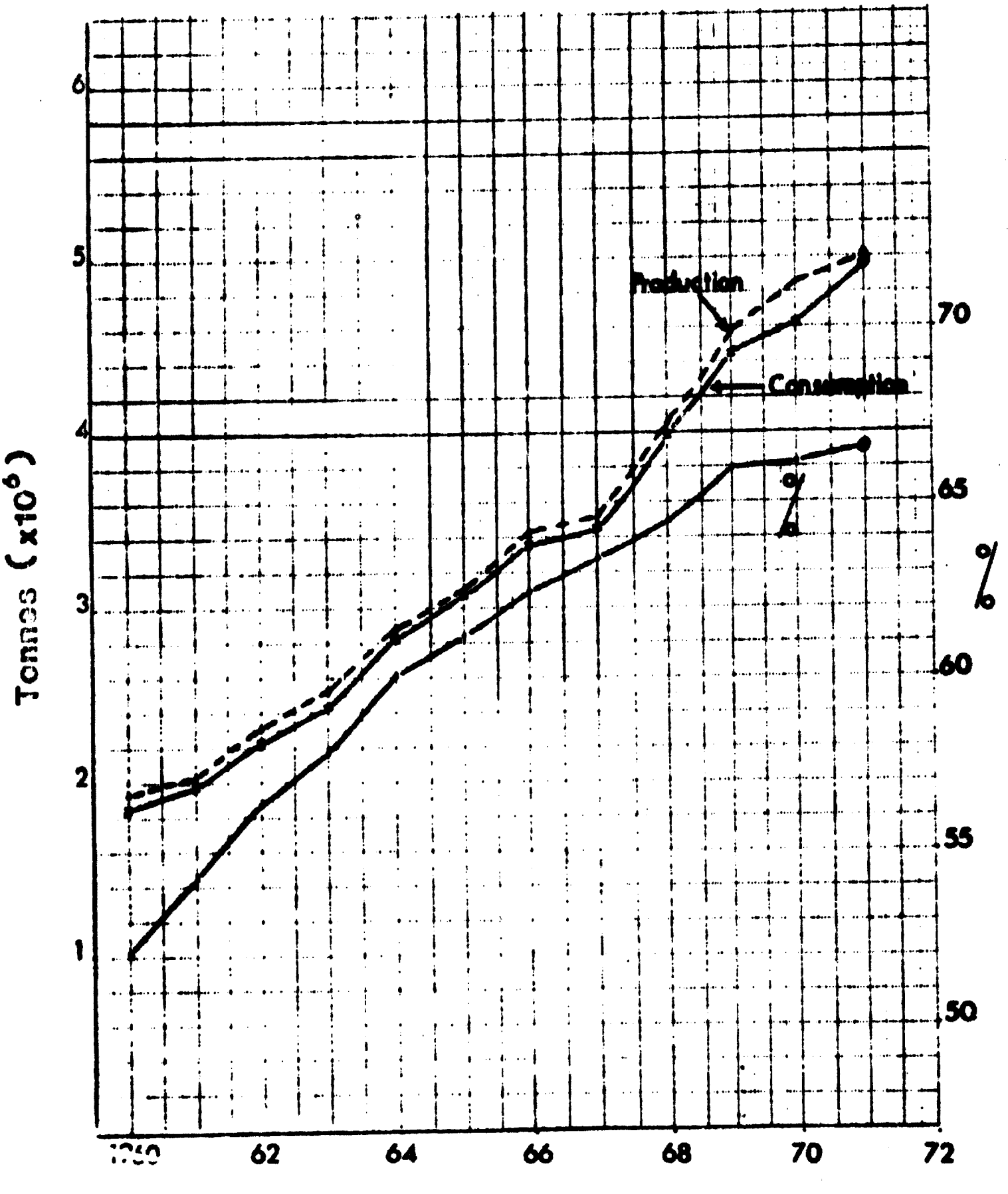


Fig. 10

Predicted Growth Rate in Rubber Consumption

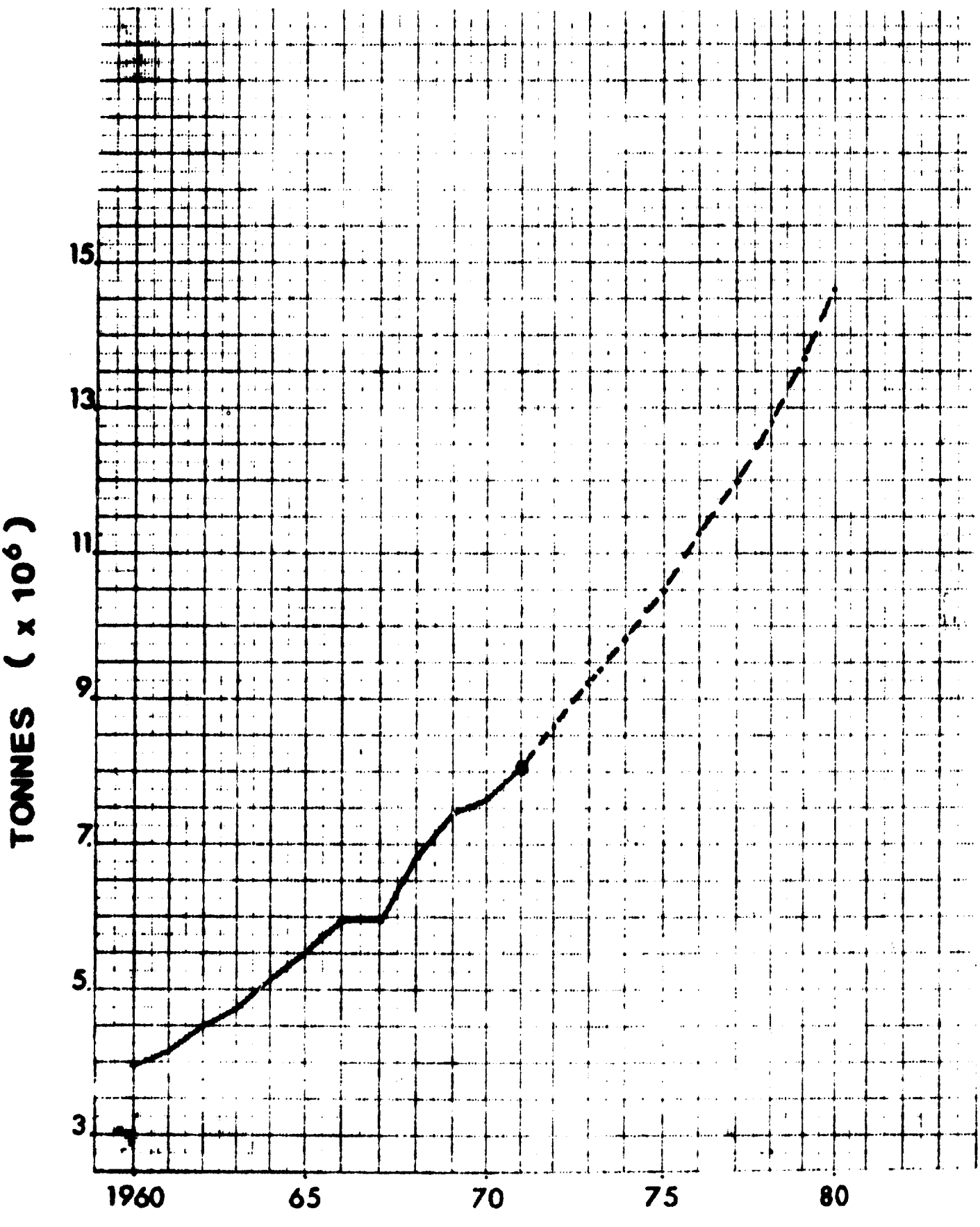


Fig. 11

Predicted Growth Rate in NR & SR Consumption

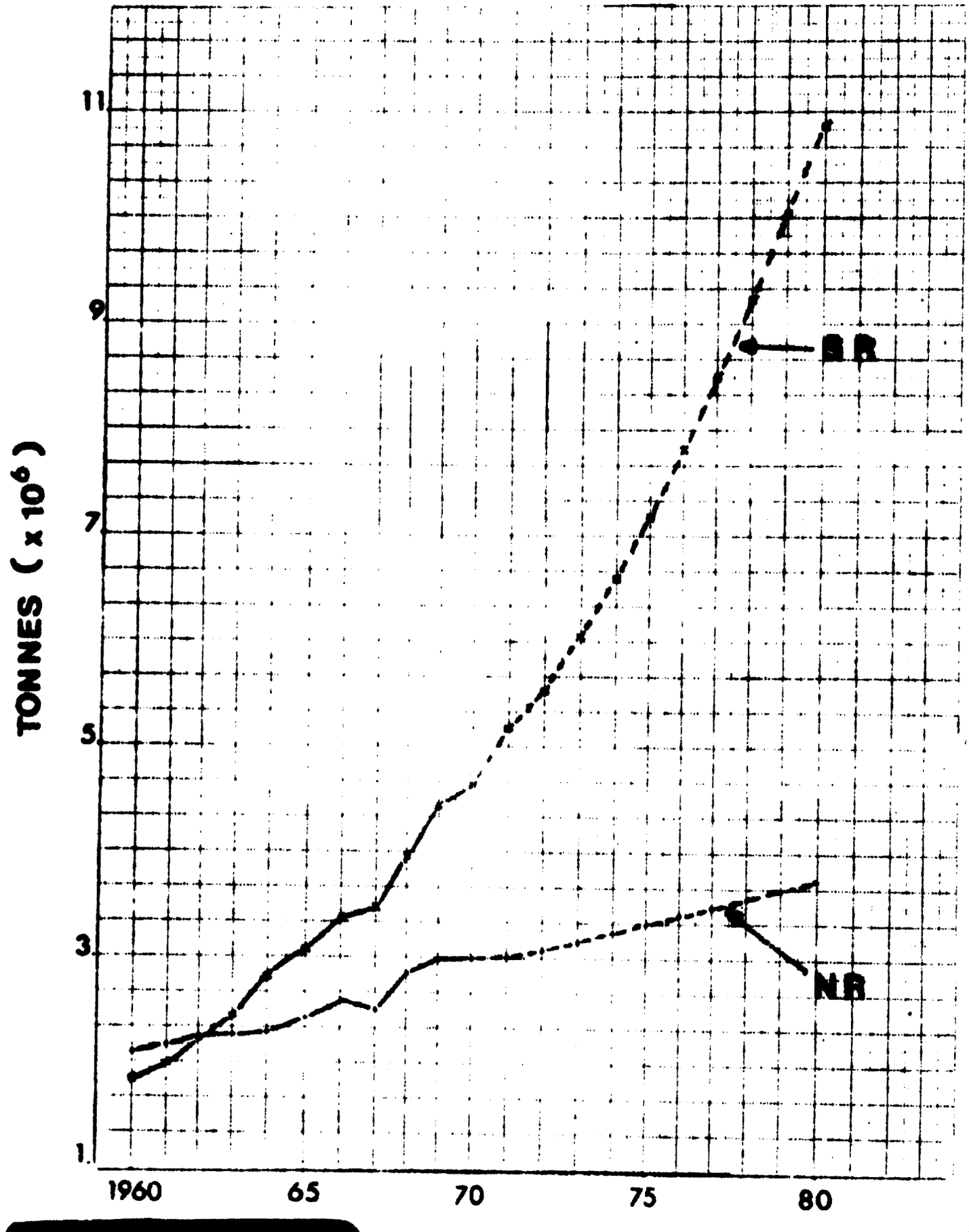
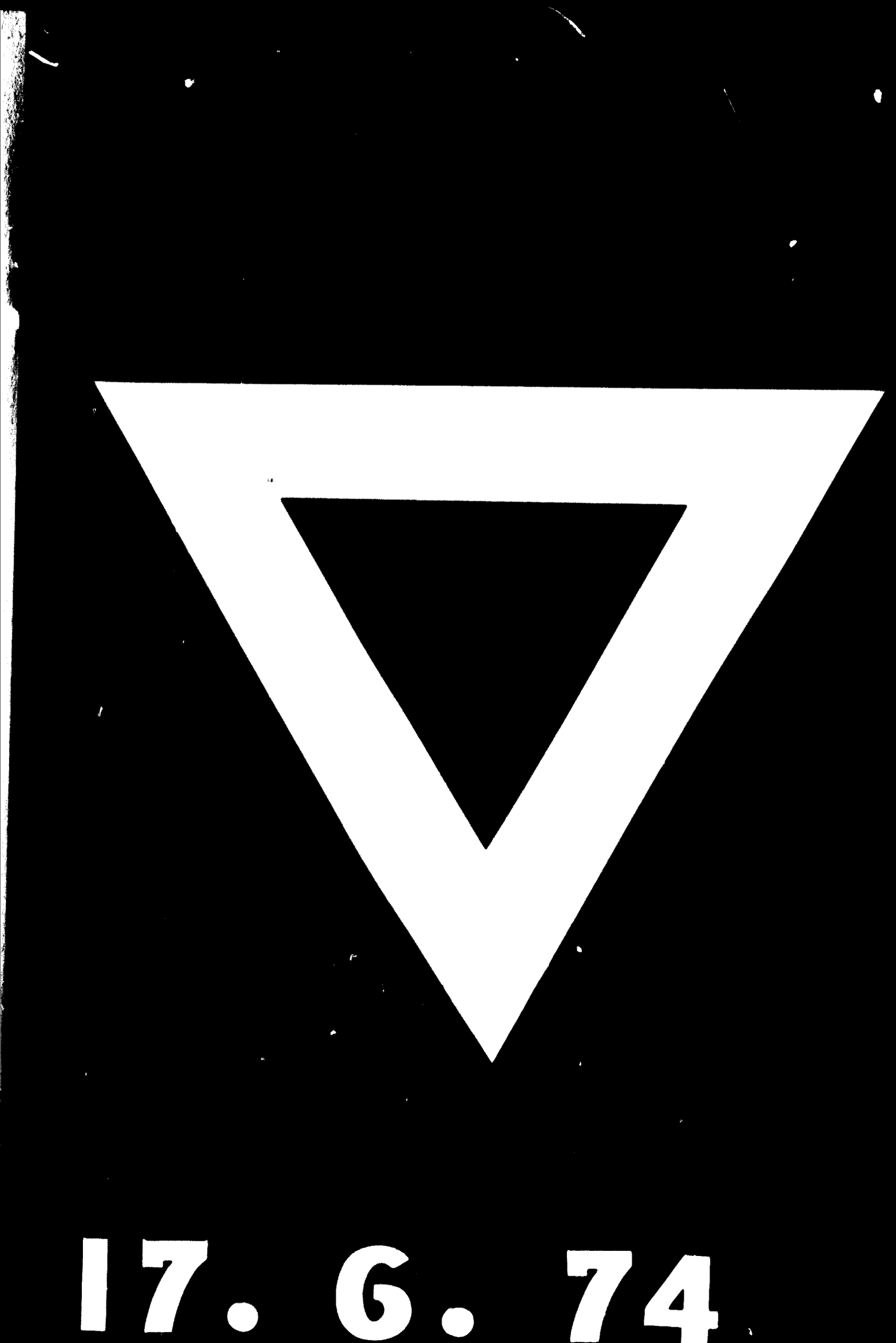


Fig. 12



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