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23 July 1969

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International Petrochemical Symposium on the
Development of the Petrochemical Industries in
Developing Countries

Baku, USSR, ~~20~~ - 31 October 1969
21

PET.SYMP. A/5

PETROCHEMICAL DEVELOPMENT
IN NORTH AMERICA[1]

by

M.S. Duncan
F. Kaupp J. Buchet
Union Carbide
United States of America

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The chemical industry with which you are concerned here in Baku is one which is so heavily influenced by a raw material base, advanced technology, and economics of scale that it has evolved as one of the most international of all businesses. This is characterized both in the high degree of chemicals activity in the export-import market and in the pattern of extensive investment by chemical companies outside their home countries.

Looking first at exports, it is interesting to compare exports of chemicals for the United States and some of the major industrial countries of Western Europe with their exports of all products.

	Exports of All Products as % of GNP	Exports of Chemicals as % of Domestic Chemical Production
Benelux	35	56
Netherlands	32	61
W. Germany	18	34
Italy	13	11
France	11	18
United Kingdom	13	19
[illegible]	4	12

You will note that only Italy exports a higher ratio of other products than of chemicals. In most countries the rate of chemicals exports is 2 to 3 times that of their general product mix. It is clear that the chemical industry has grown where there exists a combination of accessibility to raw materials, process technology, and large home markets to support economical scale operations. These countries then are to a great extent supplying the world's needs by exports. There is, however, a growing trend for companies possessing technology in which they have large research and development investments to extend the utilization of the technology by investing in facilities outside their home countries where a combination of available raw materials and available markets offers profit opportunities. Thus, European, [illegible], and Japanese companies have today approximately $2.5 billion invested in the chemical process industry in the United States. This involves 161 companies of which [illegible] are [illegible] 'foreign' owned. Conversely, U.S. chemical

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PET.SYMP. A/5

SUMMARY

PETROCHEMICAL DEVELOPMENT IN NORTH AMERICA[1]

by

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New York
United States of America

Originally the North American synthetic organic chemical industry was based on coal tars and distillates for aromatics and on wood distillates and fermentation for aliphatic [illegible]

Acetylene was available from calcium carbide and the advent of cracking in the oil refining industry made olefins available so that in the years before World War II there was a change over to these materials as the starting point for aliphatic chemicals. Immediately after the war supplies from refineries began to be supplemented by cracking natural gas and, as the industry grew up alongside the oil refining industry, the chemical and oil companies began to integrate their operations to make the

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most efficient use of the gas and liquid streams available.

The present paper attempts to outline the growth and the changes which will take place in the North American petrochemical industry up to 1980. [illegible] is mainly the US industry since the Canadian and Mexican facilities are [illegible] small part of the total. The survey is confined to existing products of [illegible] importance since there does not appear [illegible] be anything new in the labora[illegible] which will become a billion-pound/year product by 1980.

The [illegible] is likely to be on larger plants and process improvements [illegible] continuing efforts to keep costs down.

At present, North America has about 7% of world population and about 40% [illegible] petrochemical activity. Although growth rates are expected to [illegible] the 7 - 9% range, the North American share of the total is expected to [illegible] other countries expand existing and install new facilities. Growth rates will be somewhat variable with the highest figures being found in the plastics [illegible] fields [illegible] virtually no petrochemical will actually decrease in out[illegible] during the period under review.

companies have $ 8 - 9 billion in direct investments outside the U.S. It is our observation that usually at least 2 of the 3 factors, that is, raw material, technology, and market have to be inherent in a location for it to attract investment. Lacking this, the location is likely to be viewed as an export market. Europe had the market and the capability of originating technology. The general lack of indigenous petroleum raw materials was compensated for by providing accessibility first through its excellent ports and systems of waterways and more recently through an expansive and rapidly growing network of pipelines. Some of the more rapidly developing countries of South America, on the other hand, have indigenous raw materials and an attractive market growing out of the erection of LAFTA, so in this case it is the technology that flows in from outside to complete the essential trinity. There may be rare cases where the raw material base alone is so favourable that investment will be attracted based on imported technology and export markets, but our experience is that such investments are very hard to justify.

This pattern of development of the vital chemical industry is, of course, of concern to developing nations around the world, so let's look now at North America and see what the next two decades hold in store. This will in essence be one piece of a picture puzzle which, when fitted together with the pieces presented by speakers from other regions, will hopefully result in a complete enough picture to assist the developing nations in projecting and planning their respective roles in this truly international business.

During the period 1965-1985, all industrial production in North America is forecast to grow at a rate of about 5 percent per year. In contrast with this total industrial growth, the chemical industry should grow at a rate of 7 to 8 percent per year while the plastics segment of the chemical industry is forecast to grow somewhat faster, 8 to 10 percent per year.

In 1968, chemical industry sales of North America (including domestic and export) were roughly $ 50 billion with about two-thirds of the products which constitute this total dollar value showing current growth rates in the 7 to 9 percent per year range. Almost all the petrochemicals are in this 7 to 9 percent growth category. For the period ahead, the growth prospects for the petrochemical industry remain above average compared to total industrial production in North Amercia. In other words, it is, and is expected to remain, one of the more dynamic industries.

While North America represents only about 7 % of world population, it presently accounts for about 40 percent of world petrochemical capacity. The U.S. accounts for more than 90 percent of the North America total. It is anticipated that in spite of continuing growth cited above, these high percentage shares of world market will drop as markets and local production expand in other developing parts of the world. This pattern of continued growth in the U.S. but reduced percentage share of world total is clearly evident in world trade statistics. U.S. exports of all chemicals have risen from about 1.3 billion in 1956 to 3.3 billion in 1967. Over the same period, however, U.S. share of world exports has declined from about 25 percent to approximately 18 percent as shown in the following statistics.

U.S. Share of World Exports in Chemicals
(SITC 5)

	Billion Dollars		U.S. Percent Share Total	
	Total World Exports	U.S.	Exports	Imports
1956	5.22	1.27	24.3	7.1
1966	13.68	2.68	19.6	6.2
1967	14.90	2.80	18.8	5.8

Source: United Nations - Monthly Bulletin of Statistics - Special Table E.

By 1975 if present trends continue, one would anticipate U.S. exports to represent about 15 percent of world total exports, but an absolute increase in dollars. These estimates may be changed somewhat by political responses which can be made outside the control of individual producers but do reflect the trend in changes expected over the next five-year period. Incidentally, it is interesting to note in this connection that current official estimates of the U.S. Department of Commerce project over the next five years an average annual increase of 6.[illegible] percent in chemicals exports and 10.[illegible] % in chemicals imports.

The future approach to exports and overseas investments by U.S. companies will be determined by developments both in your countries and in ours. By developments in your countries I refer to such things as (a) the investment climate that you create with respect to security of invested capital, tax and legal matters, regulations regarding equity ownership, remittance of earnings, etc. and (b) your progress in welding together common markets or free trade areas of sufficient size to support an economical scale of operations. We will not speculate on these matters today since they fall more properly in your domain. It does seem appropriate to this discussion, however, for me to mention a few unresolved internal factors in the U.S. that will have a bearing on the future course of business.

1. The U.S. industry will be shifting to heavier raw material feedstocks in the near future because enough LPG is not available at economic prices. Under present conditions, the price of crude oil in the United States is controlled through the Government's control of petroleum imports. The net effect is that crude oil costs are about 50% higher (or roughly $ 1.25 per barrel) inside the United States than in markets elsewhere. Thus, raw material costs are roughly 0.3 - 0.4 U.S. cents per pound higher than for producers who have access to feedstocks at world market price. If we consider that several important products sell for only 3 - 10 cents per pound, this represents a distinct cost advantage to non-U.S. producers. Industry and government are discussing this problem. What the outcome will be is not yet known, but it is quite likely that a means will be found to give the U.S. chemical industry increasing access to foreign feedstock.
2. Various tax incentives are offered by most other countries to stimulate exports. GATT permits the rebate of indirect taxes on exports and the imposition of border taxes on imports equivalent to internal indirect taxes. European countries are widely adopting the "total value added" tax system which is an indirect tax qualifying for border adjustment. The U.S. largely uses a direct tax system which cannot be adjusted at the border. Much study is under way in both government and industry organizations in the U.S. to find ways to [illegible] this disadvantage to U.S. industry. The solution has not yet been found but we believe that ultimately this inequity will be eliminated.
3. Chemical industry wages are higher in the United States than elsewhere. It has been estimated that the average European employee's wages are

about half and the average Japanese employee's wages about a fourth those of his American counterpart. This gap has been closing gradually and the rate at which and the degree to which it closes will have a strong impact on the competitiveness of U.S. companies in world trade. This in turn is closely related to the major effort under way in the U.S. today to retard inflation, and we are optimistic that this will be achieved.

4. Export control regulations and licensing requirements of the U.S. Government that tend in some cases to inhibit exports are under intensive review and we believe will eventually be modified

5. U.S. Government controls on foreign investment have been imposed to halt the decline in the U.S. balance of payments. These were intended to be temporary, and we are assuming that they will eventually be removed.

6. U.S. credit facilities in support of export sales are not competitive with those of many other nations which subsidize their exporters by providing larger amounts of credit for longer periods of time and at lower interest rates than are available to U.S. exporters. Mr. Maurice Stans, U.S. Secretary of Commerce, is on record with the statement that the U.S. must "be competitive with other countries and if that means subsidizing interest rates, then we should find a way to do it". We are assuming a way will be found.

7. The U.S. chemical industry was somewhat disadvantaged by the recent Kennedy Round of tariff negotiations in that tariffs on chemicals imported into the U.S. will be reduced 50 percent whereas most other countries will reduce their tariffs on chemicals only 20 percent. U.S. chemical industry spokesmen are, of course, urging the Government to initiate steps to rectify this situation, but steps to be taken have not yet been determined.

These are some of the more important internal variables with which the U.S. chemical industry executive must cope in planning for the future and which in turn will also have an impact on other nations having a business interface with the U.S. in trade or investment.

There are also, of course, other external factors affecting the course of the U.S. chemical industry. One of the most important of these is the changing character of our competition. In Europe, mergers of recent years have created a number of multinational giants to challenge the biggest American companies in size. In this category are Montecatini Edison and the new Rhone-Poulenc complex joining ICI, Badische, Bayer Hoechst, Shell, ENI, etc. and the trend is continuing. All of these companies are big enough to challenge the well-established U.S. based multinational companies such as Union Carbide, Monsanto, duPont, and Dow.

Simultaneously, the scale of individual operations is also becoming fully competitive. For example, in 1966 the first 250,000 ton naphtha cracker was brought onstream in Europe by British Petroleum. In 1969 there are no less than 21 crackers in this 250,000 ton category onstream or under construction of which three are in the range of 500,000 tons to rival the largest in the U.S. Likewise plant size in Japan has for the most part achieved world competitive scale.

The interplay of these strong international competitive factors with the rapidly changing situation in the developing nations and resolution of the internal factors in the U.S. cited above make long-range forecasting a risky business. We have taken the bull by the horns, however, (I hope that is a translatable idiom) and prepared such a forecast for the major petrochemicals. It is too detailed to present from this podium but is included with the folio of information being distributed to you in connection with this meeting. We hope you will find it interesting and useful. So, in summary, we see three basic factors affecting the development of a complex, worldwide chemical industry, i.e., accessibility to raw materials, technology, and materials, technology, and markets large enough to support economical scale. These factors, in combination with policy decisions that will be made in the years ahead by your countries and ours, will determine the marketing and investment strategies of the big multinational companies in the business and will have to be a major consideration in the plans and strategies of the developing nations as well.

We are greatly pleased to be numbered among the contributors to this distinguished world gathering and will be happy to meet with any of you individually if there are topics you would like to discuss.

North America had a synthetic organic chemical industry prior to the mid-1920's. The basic hydrocarbon source was the aromatics in coal tars and distillates. Thus, the few aliphatic chemicals of commerce were derived almost exclusively via wood distillation and fermentation.

Acetylene chemistry flourished with the introduction of cellulose acetate as an apparel fiber. Acetylene was based on calcium carbide, and it was the search for a way to secure the reactive chemical from oil or gas that led to knowledge that hydrocarbon fractions of natural and refinery gases could be utilized for a host of aliphatic chemicals. Propylene was recovered, ethylene oxidized to yield the glycol, and propane was converted to acetone. Much of the fundamental work was privately financed, though some was supported at the Mellon Institute.

The cracked gases available from the catalytic cracking units and the gas fields of the United States sufficed. In the post World War II period, however, there was a build-up of facilities along the Gulf Coast because of its abundant natural gas supplies. This is also oil country, and the chemical companies found they had petroleum refiners as neighbors. And in many instances they became either partners or competitors.

The integration of petroleum refining and petrochemical operations has allowed producers to make efficient use of gas and liquid streams that would otherwise have a much lower fuel value. Technology now exists to use the heavier fractions of the crude for chemical purposes, so that the "chemical refinery" is very much on the horizon. There is good reason to believe that it will be with us before too many years have passed. However, a 30,000 barrel per day chemical refinery is small compared to 100,000 barrel per day petroleum refineries.

If, in fact, U.S. natural gas production is approaching a plateau, the shortfall in ethane and other natural gas liquids will soon become a reality. The maximum recovery of liquids from gas in 1980 might be limited to no more than 70 billion pounds. The demand for propane and butane as fuels will probably exceed that figure. We must draw the conclusion that crude oil fractions will have to provide most of the feedstock for olefins.

During the next few minutes an attempt will be made to look at the petrochemical industry in North America as it is now and as it could be in 1980.

Because the United States has by far the dominant portion of this industry, references to Canadian or Mexican facilities will be included only where they have a significant effect on the North American picture. Indeed, the juxtaposition of the two types of industries will illustrate the different problems facing a highly populated and industrialized country and those that are at a different stage in their development.

We have ignored new products in our assessment because it is an almost impossible task to quantify what is still unknown, and the petrochemicals already big are expected to grow in their importance through 1975-1980. There doesn't seem to be anything still in the laboratory that could qualify as a billion-pound/year product by 1980.

It is worth adding that the petrochemical industry is putting much more emphasis on rationalization than on exploratory research. We agree with BP Chemicals' J. [illegible] Hunter who opined last year that the concentration would be "more on the planned expansion of existing products, particularly on new processes and process improvement, and less on the development of new products, though it will seek new outlets for its products".

The U.S. chemical industry operates within the context of a nation with a population exceeding 200 million people and with an economy that is currently generating close to $1,000 billion worth of goods and services annually. This immense internal market has been the basis for the large-volume plants that have been built over the past few years.

An ethylene plant planned for the early 1970's would almost certainly be scaled to deliver 1 billion pounds or more of product annually. The same probably holds true for vinyl chloride monomer units. Some believe that in the middle 1970's ethylene plants will produce 2-3 billion pounds. A recent study by Lummus on ethylene illustrates scale-up economies. The return on investment in a billion-pound/year plant requires adding less than 1 cent to ethylene production costs. While in a 300-million-lb./year plant this same ethylene would have to be priced 0.7¢/lb. more just to secure the same percentage return on investment. About the same penalty must be paid by the smaller plant in higher operating costs. In other words, scale alone can account for a 1½¢/lb. difference in cost, provided the feedstock is the same in both instances.

Methanol is another case in point: a 10-million-gal. (67-million-lb.) plant was not unheard of a few years ago, but advances in synthesis-gas generation, including the use of the centrifugal compressor, have increased capacity by an order of magnitude. Even at the recent price of 25¢/gal., the smaller and older units provide little or no margin. In late 19[illegible], when capacity hits 1.[illegible] billion gallons in a single [illegible] — compared to only half that total earlier this year — a price cut and a shake-out of the industry appears almost unavoidable. The guess is that annual capacity totalling 4[illegible] million gallons will have to be retired.

Frontier plants tend to be large too. Sinclair's Houston works makes more para-xylene ([illegible] million lbs./year) and more ortho-xylene (200 million lbs.) than is consumed in any country other than West Germany and the United States.

The biggest styrene plant has yet to come. [illegible] and Monsanto both have [illegible]00-million-lbs./year units at Texas City. But in late 1971, Dow Chemical, which already has a [illegible]50-million-lb. unit at Freeport, will come in with a billion-pound facility at Oyster Creek, Texas.

When a Gulf Oil subsidiary, in 1953, built the world's first cumene-phenol-acetone complex in Montreal East, the size was established at 63 million lbs. cumene, and the actual output of phenol was but 1[illegible] million lbs. In 1970, Gulf will have a [illegible] million lbs./year cumene plant in place at Port Arthur, Texas, to match a like-size unit at Philadelphia.

Even this is not the ultimate: Monsanto is adding 400 million lbs. to its Alvin, [illegible] cumene plant and Union Carbide could make 600 million lbs./year in Puerto Rico by 197[illegible]. Thus the cumene output of 1.5 billion lbs. existing in 19[illegible] is expected to expand rapidly in the next few years.

Because naphtha is almost never the feedstock for ethylene plants in the U.S., the supply of propylene from these plants falls considerably short of domestic requirements. Petroleum refineries make up the difference: in 19[illegible] they diverted about a fifth of their propylene to petrochemical production. As long as the refiner doesn't need all of his C_3 olefin for an alkylation unit, he can make up whatever shortfall there is. But propylene demand is outstripping the supply of co-product from ethylene plants to such a degree that by the end of the next decade the difference could be as much as 13 billion pounds.

Since refinery propylene in 1980 may total less than 23 billion lbs. and alkylation could possibly be of even greater import to the nation's gasoline supplies, it is doubtful whether more than half the refinery's propylene output will be available for sale.

The possibility of an annual shortage in 1980 of nearly 5 billion lbs. of propylene, which would constitute 12 percent of demand, is bound to encourage U.S. chemical producers to substitute heavier feedstocks for the ethane employed so extensively today in half of most ethylene plants. In any event, 2 ¢/lb. propylene should be a thing of the past in a few years; most propylene customers being satisfied if they can purchase their feedstock at 3 ¢/lb. or a little more.

Naphtha will not be the prop for the petrochemical industry if domestic crude is to be the prime source for hydrocarbons.

Of the 15 - 16 million bbl processed daily in 1980, about 9 million bbl will have to go into gasoline and jet fuels. With sufficient hydrocracking, hydrotreating, reforming and pyrolysis equipment installed, refiners can undoubtedly obtain the necessary distillate to fuel the nation's motor vehicles and aircraft.

Supplementing straight run gasoline, naphthas and kerosene with cracked stocks will certainly price the middle part of the barrel beyond what the petrochemical industry can afford to pay for it. The alternative is thermal cracking of the heavier gas oils.

Ethylene is one of the important chemical intermediates. In the U.S. in 1[illegible], about [illegible] billion pounds of ethylene will be consumed in synthesizing polyethylene, ethyl alcohol, oxide, styrene, vinyl chloride and many other products that were once derived from acetylene or didn't exist commercially until ethylene became readily available as raw material.

A growth rate of 11% over the last 15 years would seem to be a difficult one to maintain, but even if the more modest 8% figure were used, we still come up with an estimate of 35 billion lbs. for 1980. Another [illegible] billion at least must be added to take in Canadian production possibilities ten years hence.

Low-density polyethylene producers show no sign of slackening their pace.

Able to build plants in the 300-million-lb. year class and to take 3 ¢/lb. reductions over the years, they have been able to carve out markets that have historically belonged to non-plastic materials.

U.S. output this year could be in the vicinity of 3.5 billion pounds. Because the 10 [illegible] growth rate is expected to continue, it should boost this resin to the 10-billion-lb. level by 1980 or a year later.

Polymerization plants for high-density polyethylene tend to be smaller in size, in part because so many companies divide up the 1.4-billion pound North American market that existed in 19[illegible]. Phillips Petroleum's [illegible], Texas plant is the largest at 16[illegible] million pounds. [illegible] competitive situation will continue to exist until a clear dominance of [illegible] producer is established.

The current consumption of high-density resin should double over the next ten years, reaching a total poundage of perhaps 2.[illegible] billion pounds in 1980. Two new companies -- Chemplex and Gulf -- have also fielded entries. Phillips has gone to Puerto Rico to utilize the low-cost ethylene on that island and most of the other producers are adding incrementally to existing plants to hold their market share.

Next to polyethylene, the biggest outlet for ethylene is ethylene oxide. Production of this product has now reached an annual rate of 2.[illegible] billion pounds. We think that the demand for the glycol, ethanolamines and other oxide derivatives will push production to just under 5 billion pounds in 19[illegible].

We realize that the demand for glycol anti-freeze in motor vehicles will increase only moderately. We see the upsurge in demand for polyester fibers as a compensating factor. It creates a substantial requirement for the ethylene glycol used in making the polyester.

You are probably aware that the older chlorohydrin process is being phased out. The newer plants use direct oxidation -- and they are very large units. Dow Chemical is building a 400-million lb. facility at Plaquemine, Louisiana. Pittsburgh Plate Glass installed equipment in Puerto Rico that can make 300 million pounds of oxide. Celanese has sized its Bayport, Texas unit at 300 million pounds and Union Carbide now looks to an additional 7[illegible] million pounds of oxide capacity at either Texas City or Puerto Rico.

Ethylene will probably supplant acetylene in vinyl chloride manufacture. The combination of 3 - 3½ ¢/lb. ethylene, the oxychlorination processes and large plants have made at least 500 million lbs. of existing vinyl chloride capacity obsolete. B.F. Goodrich has a billion pounds per year plant operating

Calvert City, Kentucky. Dow has just come in with a 800 million pounds per year monomer unit at Oyster Creek, Texas and PPG Industries is adding [illegible] million pounds to its Puerto Rico plant by early 1971. North American demand should [illegible] billion pounds this year.

The same shift from acetylene to ethylene has occurred in Canada where Gulf Oil is now operating 20-million pound plant at Varennes, Quebec. Dow-[illegible] has cracked ethylene dichloride at Sarnia since they began operations.

The future of synthetic -- that is, ethylene-based ethanol is not easy to predict. Its' major function has for many years been as the precursor for acetaldehyde; Union Carbide, Eastman and others operating plants expressly for that purpose. The advent of a direct route to acetaldehyde from ethylene has robbed ethanol of much of its growth potential - unless by some political miracle the synthetic ethyl alcohol was permitted in potable spirits.

But about acetaldehyde, for an intermediate that is not generally an article of commerce, it bulks large in the U.S. petrochemical picture. Production this year should be approximately 1.5 billion pounds. Present indications, however, suggest that domestic consumption will have difficulty reaching 2.0 billion pounds by 1980.

The reasons are basically those of competition from other processes. The oxo route to butyraldehyde, butanol and 2-ethylhexanol has been the preferred one because lower-cost propylene is employed instead of ethylene. And both acetic acid and anhydride can be produced directly by the oxidation of liquified petroleum gases.

Acetic acid and acetic anhydride were established as large-volume organics on the basis of their utilization in cellulosics and vinyl acetates. Demand for cellulose acetate fibers in North America is no longer on a five percent incline, the advance of nylon, polyesters and acrylics have had a levelling effect on the cellulosics.

A still more inhibiting effect of the newer synthetics is evident in the low market growth of the cellulosic ester plastics. Because about 90 percent of the acetic anhydride produced in the U.S. (and all of the Canadian output) goes directly into manufacture of the cellulosics, the likelihood of acetic anhydride reaching the 2-billion-lb. level before 1980 is slim.

Acrylic acid and its esters have vied with vinyl acetate as the monomer for paint latices. Indeed, annual demand for these acrylates reached [illegible] million pounds last year. Price of the acid has been coming down as larger plants are built. Union Carbide operates a facility at Taft, Louisiana that can make 200 million pounds of acrylic acid and acrylate esters. Rohm and Haas has a plant of equivalent size at Deer Park, Texas.

We think that the requirements for acrylates will continue to expand 10 percent annually over the next decade, putting North American consumption in 1980 in excess of 750 million pounds.

Propylene could set a faster pace than ethylene in the upcoming period — provided competition from the refiners' alkylation units doesn't drive up the price too far. Domestic consumption is [illegible] nearly [illegible] billion pounds per year, and our analysis of propylene derivatives suggests that a 10 percent annual growth rate is quite reasonable to expect for the 1970's. If this holds true, propylene demand could be in the neighborhood of 25 billion pounds in 1980.

Acrylonitrile and polypropylene producers between them take a third of the total propylene supply, and their share should increase to perhaps 40% before this decade is over. Propylene oxide, cumene and oxo alcohols will continue to be outlets of major importance.

Polypropylene will become a billion-pound product this year, an almost unbelievable status considering the short history of this thermoplastic. It hasn't been an overly profitable area for companies to work in. Dow withdrew from the field recently, and all new reactors being installed in the U.S. are by the eight existing producers. Production in Canada will not begin until next year when Imperial Oil Ltd., an Enjay affiliate, puts a unit on stream in Sarnia, Ontario.

We consider this polyolefin is still going through the steep portion of its maturity curve. In fact, its use could quadruple in the next decade.

This supposition is based on the premise that polypropylene will not only have application as a molding resin (both the filled and unfilled varieties) but also as an industrial fibre. The monofilament is off to a good start and multifilaments are finding increasing outlets in carpeting, and fibrillated polypropylene yarn is expected to further broaden markets.

The North American consumer's acceptance of acrylic and modacrylic fibers and the belated growth of acrylonitrile-butadiene-styrene (ABS) as an engineering plastic have contributed to making acrylonitrile a billion pounds per year commodity as of last year. Most of the U.S. fiber producers - and that includes Monsanto, duPont, Cyanamid and B.F. Goodrich - have chosen to go basic in acrylonitrile and to also sell to the merchant market. Monsanto, for instance, operates a 375-million pound per year unit at Alvin, Texas and together with its Texas City plant boasts a combined output of 500 million pounds. The company is also looking ahead to the day when acrylonitrile will replace most of the adipic acid used to make adiponitrile, the nylon 6,6 intermediate.

Other merchant suppliers of acrylonitrile are cropping up. Commonwealth Oil plans a 100-million pound per year plant in Puerto Rico and Imperial Oil has a small facility at Sarnia, Ontario.

ABS and SAN resins have been pushing into the automotive and piping fields with good success. It is questionable, however, whether they can maintain a 15% growth rate because of increasing competition from polypropylene. Moreover, the acrylonitrile content of these copolymers is trending downward.

The acrylonitrile required by producers of nitrile rubbers will augment the total consumption, but it should total no more than 3.3 billion pounds in 1980.

Another consumer of propylene is the oxide. Propylene oxide producers will make a billion pounds of product in 1969, mostly for conversation to the glycol and to the polyethers for urethanes. With both propylene glycol and polyether consumption on the rise, the chances are that annual oxide production will triple by the end of the next ten years.

Chlorohydrin plants supply most of this oxide, with several units in the 100-200 million pounds per year range. Dow Chemical has several more chlorohydrin units that will eventually be switched from making ethylene oxide to making propylene oxide. Once these conversions are made, there could be a swing to a direct oxidation process such as the one being employed by Oxirane Chemical.

Isopropanol ranks as a commodity chemical of large proportions: nobody in the U.S. makes less than 225 million pounds per year of the alcohol in a single facility. At Enjay's Baton Rouge works, the annual output is close to 600 million pounds.

Producers have normally converted half or more of the IPA to acetone, the percentage depending on the availability of byproduct acetone from cumene-phenol-acetone process.

If, however, the forecast on phenol capacity growth holds, the amount of IPA going into acetone production will fall from the 900 million pounds per year level to a quantity more like 500 million lbs. in 1980. Extra isopropyl alcohol capacity will still be needed in the '70s because of its use in isopropyl acetate and other esters, in protective coating formulations, deicing systems and pharmaceuticals. Our guess is that the current 1.3-billion pound annual demand rate will climb to 2.5 or 2.6 billion lbs. before the coming decade is out.

As for acetone's prospects, they are considered good despite possible restrictions by air pollution control authorities on the use of such acetone derivates as methyl isobutyl ketone (MIBK) and mesityl oxide. Fully a quarter of the acetone consumed ends up as methyl methacrylate via the acetone cyanohydrin precursor. This acrylic plastic has very good potential in the construction field.

The solvent market, which is generally held by the converters of IPA to acetone, bulks as large today for acetone producers as does that for the cyanohydrin. But California's Rule 66, which limits the use of branched ketones in paint and resin formulations to control air pollution, may spread to other States. Acetone is low enough in cost (roughly 6¢/lb.) and so versatile that its position seems assured. Last year, demand was over 1.2 billion lbs.; it should climb to 2.5 billion lbs. by 1980.

North America adopted the oxo process with alacrity and a dozen oxo chemical plants are in operation in the U.S.; Gulf Oil has a 250-million pound unit under construction at Philadelphia and two companies (BASF and Gulf Oil of Canada) are establishing oxo units in the Montreal area.

Propylene is the key raw material since it not only is fed directly to those units making butanols and 2-ethylhexanol, but also is a precursor for the heptene (propylene + butylene) used for isooctyl alcohol and for the nonene in isodecyl alcohol.

Ethylene is an alternative in that the long-established aldol condensation process can convert acetaldehyde to the butyraldehyde and then to

2-ethylhexanol or butanols. This option is always open if the price relationship between the two olefins shift in favor of ethylene.

Phthalate plasticizers represent the major outlet for the C_8, C_{10} alcohols. Production of the di-(2-ethyl hexanol) phthalate should triple within ten years from the present 400-million pound level. A similar forecast is made for diisodecyl phthalate. n-Butanol sales, related to the efficacy of this alcohol as a solvent and its convertibility to butyl acetate, will also climb well beyond the 575-million lb. mark they are at now.

Petrochemical glycerine is produced in five plants, the largest being the 125-million lb. Shell facility at Houston and the Dow unit (120 million lb.) at Freeport, Texas. It may be some time before new capacity is added. The petrochemical firms must contend with the sizable, albeit declining, supply of natural glycerine made by the soap companies. And the fall off in demand from cellophane, tobacco and explosives manufacturers has offset market gains achieved through the use of glycerine in polyurethane polyols.

The present annual consumption is at the 380 million pound level. It may have difficulty reaching 500 million pounds by 1980. Such an outlook has prompted one producer, FMC Corporation, at Bayport, Texas, to switch output to peracetic acid.

Butadiene's standing linked with that of the synthetic rubbers. Styrene-butadiene copolymer (SBR) is still the workhorse material of the rubber molders and extruders, and the strongest performer to date among the stereospecific elastomers is polybutadiene.

With butadiene rubbers serving as the base, demand for the diolefin in the U.S. is running about 1.6 billion pounds per annum at present. However, the non-rubber uses - high-impact polystyrene and ABS plastics, for example - have been expanding the fastest. In ten years they could take 25 percent of the total butadiene for sale.

Such a forecast implies that SBR will no longer hold its commanding position outside the tire industry ten years from now. SBR production in 1969 should be about 2.5 billion lbs. In 1980 it could be well below 2.0 billion.

Neoprene annual consumption has continued to expand at almost 4 percent despite the vintage of this elastomer. Industrial molders are currently buying about 350 million pounds per year and should consume about [illegible] million in 1980, assuming a 3% growth rate through the next decade.

The past few years have been characterized by new competitors to duPont's position in the North American market and the build-up of overseas capacity. Once a major export item, neoprene will have to be absorbed more and more by industry at home.

Another transformation has been the switch from acetylene to butadiene as the base for neoprene. Petro-Tex Chemical starts with butadiene for its Houston unit and duPont is reportedly going that way in the future.

The elastomer producers will have more use for ethylene and propylene as well as for the diolefins. The stereo-specific polyisoprene made by Goodyear at Beaumont, Texas, depends on a monomer which is derived from the propylene dimer, 2-methyl-pentene. And there are four companies making ethylene-propylene rubber (EPR).

Unless one or the other of these two rubbers makes it as a tire material of significance, the annual demand for the olefin feedstocks will not total 2 billion pounds, even by 1980. Consumption of the chemically - stable EPR is fast approaching the 200 million pounds per year level. It is doing well in non-tire applications, but the properties have not been developed for building tires. The pattern for polyisoprene is not too different. Current usage is close to 200 million pounds per year and the forecast for 1980 is for U.S. consumption in the neighborhood of 750 million pounds. In the case of the polyisoprene, however, the additional monomer required will more likely be derived from isoamylene than from the propylene dimer.

On the premise that about 1.6 billion pounds of EPR and polyisoprene will be produced in 1980, the propylene consumption will be less than 700 million pounds and ethylene demand but half that amount.

The reforming of straight-run naphthas may not suffice as the 70's prime source of aromatics. As in Europe, Japan and Canada, some of the benzene, toluene and xylenes may have to be extracted from cracked gasoline produced in consumption with olefins in plants based on heavier distillates.

Before the build-up of these ethylene plants abroad, the U.S. was a major exporter of benzene. In 1967, for instance, foreign shipments totalled 330,000 tons. The toluene dealkylation units are the industry's safety valve.

When the benzene supply is long and the price in the 21 ¢/gal/range (i.e. below 3 ¢/lb.), the dealkylation facilities are usually shut down and toluene returned to the refinery's motor gasoline pool. As benzene demand expands, and this has been at about 1[illegible] per year, the price tends to firm up at, say, 23 - 25 ¢/gal. (f.o.b. Gulf Coast). At this level the dealkylation units can be profitably operated, even if toluene has to be imported for this purpose.

The 11.7% annual growth rate in the consumption of styrene will probably not be maintained during the 1970's but with the monomer now being made in billion-pound per year plants, its appeal to thermoplastic and elastomer producers should have considerable lasting value.

Present annual capacity in North America is well over 5 billion pounds, taking into account the 335 million pound total represented by two Canadian units as well as the 4,665 million pound total of fourteen plants in the United States. Even if some plants are shut down when Foster Grant goes to 700 million pounds per year at Baton Rouge and Dow to 1 billion at Oyster Creek, Texas, capacity in the U.S. alone should exceed 6 billion pounds.

Gulf Coast and Puerto Rican producers of cyclohexane have been able to export up to 40 percent of their output by dint of plant size and tidewater location. Fifteen plants, ranging in sizes up to 350 million pounds per year (53 million gallons) shipped well over [illegible] million gallons off-shore in 1968, whereas domestic needs were in the order of 300 million gallons.

Since cyclohexane is the preferred starting material for both nylon 6/6 and nylon 6 (caprolactam), its demand should parallel the requirements of the textile industry for nylon. In 1972, therefore, U.S. nylon customers could be taking 500 million gallons of cyclohexane. On the other hand, there has been no rush to add to capacity. To begin with, there is about 50 million gallons per year on standby, and the export business will likely fade as large European units come on stream.

The U.S. has ranked as the world's major producer of paraxylene ever since polyester fibers and films became part of the textile scene. This year p-xylene output should exceed 1,350 million pounds, of which well over 100 million will be exported. All of this aromatic was, of course, consumed in the production of terephthalic acid or its dimethyl ester. Amoco makes both the acid and DMT at Decatur, Alabama and Joliet, Illinois and Mobil concentrates on the acid only at Beaumont, Texas.

Because terephthalic acid is a more logical monomeric material than DMT - provided the necessary purity can be achieved - it should prevail over the long term. DuPont however, has been reluctant to scrap its two DMT plants in Tennessee and Fiber Industries, the Celanese/ICI joint venture, still buys DMT from Hercules. (Hercules also supplies Millhaven Fiber's polyester plant in Canada, an the marriage of Celanese and ICI interests). On the other hand, Monsanto is relying on terephthalic acid for its entire polyester production. Introduction of the belted-bias tire with the polyester carcass adds further strength to a fiber market that is already in a sharp upward swing. Para-xylene requirements could double within four years and promise to be well over 4 billion pounds in 1980.

The separation of the para isomer from mixed xylenes is, without exception, an exercise carried out by the petroleum refiners. Amoco has just duplicated at Decatur, Ala. the continuous crystallization plant which at Texas City yields almost 300 million pounds of para-xylene annually. Chevron (at Pascagoula, Mississippi) and Sinclair (at Houston) have units of about the same size to recover the para isomer. Commonwealth and Hercules plan to expand their jointly owned plant at Penuelas, to 250 million pounds.

Chevron, Sinclair and Commonwealth take the process a step forward, separating the ortho and meta isomers. In each case there is a captive outlet for at least the ortho-xylene. Chevron operates its own phthalic anhydride plants using an o-xylene feedstock. Commonwealth delivers to Puerto Rico Chemical (and eventually, Oxochem) at Penuelas. Sinclair will ship a portion of its Houston output to the Koppers phthalic anhydride plant in the Chicago area.

Not all phthalic anhydride units can accept ortho-xylene as a feedstock, so that the 1969 consumption of ortho should be below 250 million pounds. This is likely to change, however, within a couple of years. Instead of exporting 300 million pounds, as they will probably do this year, the U.S. producers will concentrate on a domestic market which could reach 750 million pounds in 1975 and [illegible] billion pounds in 19[illegible].

But the installed capacity to recover ortho-xylene is so great - the sixteen plants can between them, produce 1.4 billion pounds and export business is almost a necessity if the units are to run at rates reasonably close to capacity.

The popularity of ortho-xylene as a feedstock for phthalic anhydride has put a crimp on the expansion of the petrochemical naphthalene industry. The U.S. has four such producers - Ashland, Collier - Tidewater, Monsanto and Sun Oil - as well as the companies who process coal tar. Together these naphthalene suppliers are currently shipping close to 700 million pounds a year to phthalic producers and other U.S. customers. Additional naphthalene is exported.

The 450 million pounds of coal tar naphthalene cannot be readily expanded in any event. And an economically sized petroleum-based plant must add a 100 million pounds of naphthalene to the market in a single year if it is to be profitable.

Phthalic anhydride itself will ride more and more on the coattails of polyvinyl chloride. Plasticizers took almost half the 750-million pounds of anhydride consumed domestically in 1968. With alkyd resin producers, the other major outlet for phthalic anhydride, barely managing to keep up the sales level in the face of the assault from water-reducible latex emulsions and acrylic lacquers, the percentage of the market going to plasticizers will continue to increase.

TABLE I

Ethane and LPG Supply and Demand for Olefin Feedstock and Fuel Use
(Millions of Pounds)

Demand	1967	1970	1980	1985
Olefin Feedstock	24,350	30,050	50,600	86,000
Fuel Use	40,050	44,550	69,550	70,500
	64,400	74,600	120,150	156,500
Supply				
From Plants	43,400	48,000	61,250	70,000
From Refineries	21,000	26,600	58,900	86,500
Total	64,400	74,600	120,150	156,500

TABLE II

Effect of Plant Capacity on Production Costs
Figures in $/ton
All Co-Products at Premium Values

Capacity in '000 ton/year	136	318	454
Feedstock	67.2	67.2	67.2
Operating Costs	46.3	35.7	33.6
less Co-Product credits	79.0	79.0	79.0
Production Costs	34.5	23.9	21.8
Return on investment	34.8	22.5	20.1
Total Production Costs	69.3	46.4	41.9

TABLE III

	Millions of Dollars	
	Current [illegible] Continued to 1975	[illegible] Needed [illegible] 1975
	Most Likely Range	Most Likely Range
1975 Exports	2900 - 3000	3100 - 3200
1975 Imports	1300 - 1400	1200 - 1300
Most Likely Net Trade Balance	1600	1900

TABLE IV

Year	Projected Imports Controls Removed	Imports Under Present Quota	Increase in Imports due to Decontrol	Increase in Imports as Percent of U.S. Oil Production
	(Thousand Barrels Per Day)			
1975	500	170	330	2
1980	860	240	620	5

TABLE V

Distribution of Refinery Streams
U.S. Total

(Thousands of Barrels Daily)

	1967	1970	1980	1985	Growth Rate % Per Yr
Gasoline and Jet Fuels	5,923	6,515	[illegible],925	10,407	3.2
Aromatic Feed	214	272	604	900	8.3
L.P. Gases	331	403	7[illegible]	1,095	6.9
Middle Distillates	2,565	2,590	2,643	2,673	0.2
Residual and Other Products	1,840	1,9[illegible]	2,210	2,359	1.4
Total	10,873	11,70[illegible]	15,170	17,433	2.6

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Chart I

Size of Methanol Plants

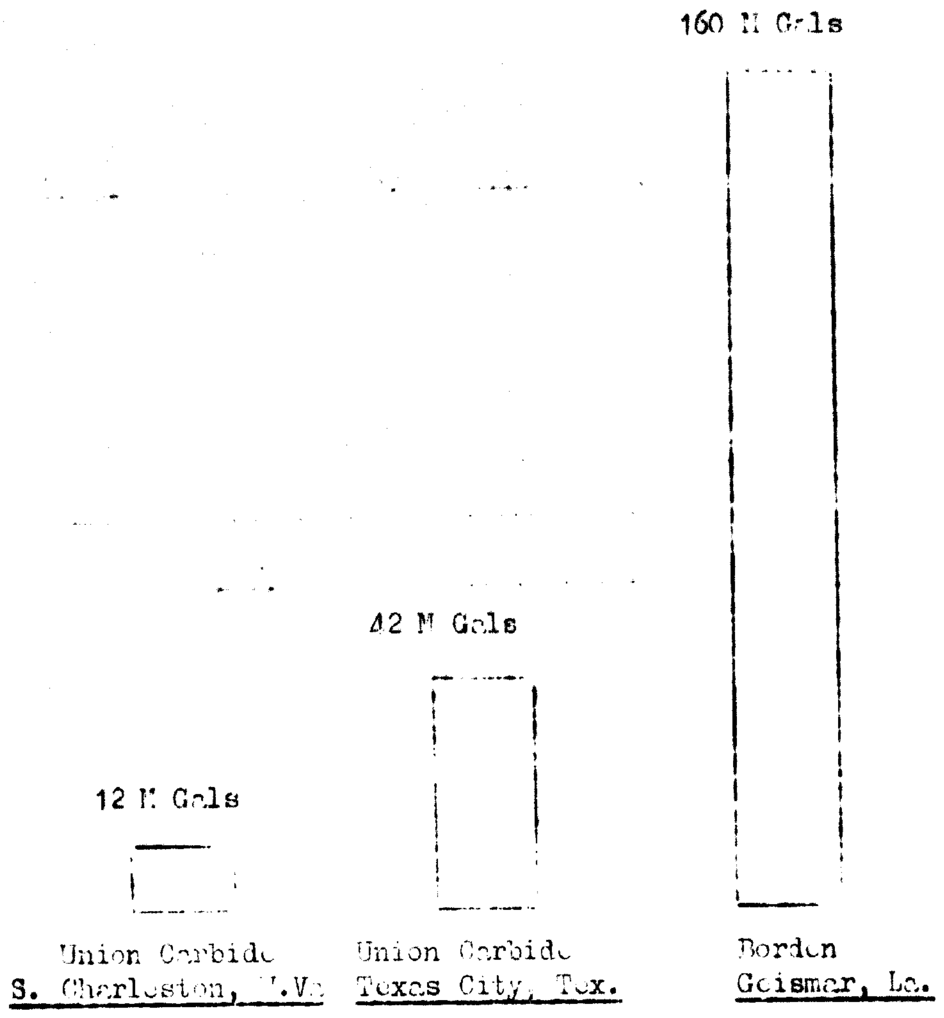


Chart II

United States Raw Material Requirements for Ethylene Production

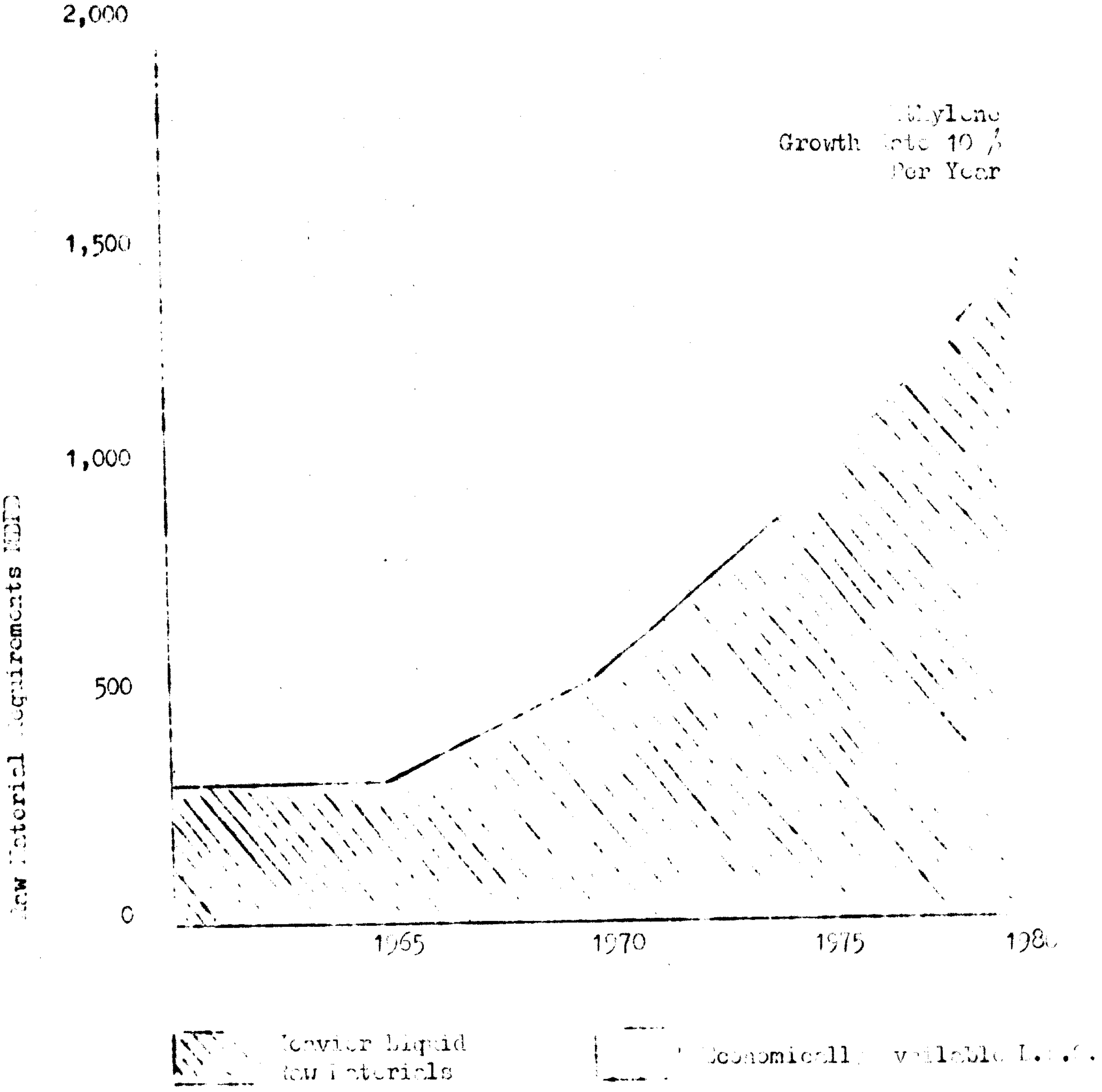


Chart III

U.S. Ethylene Consumption

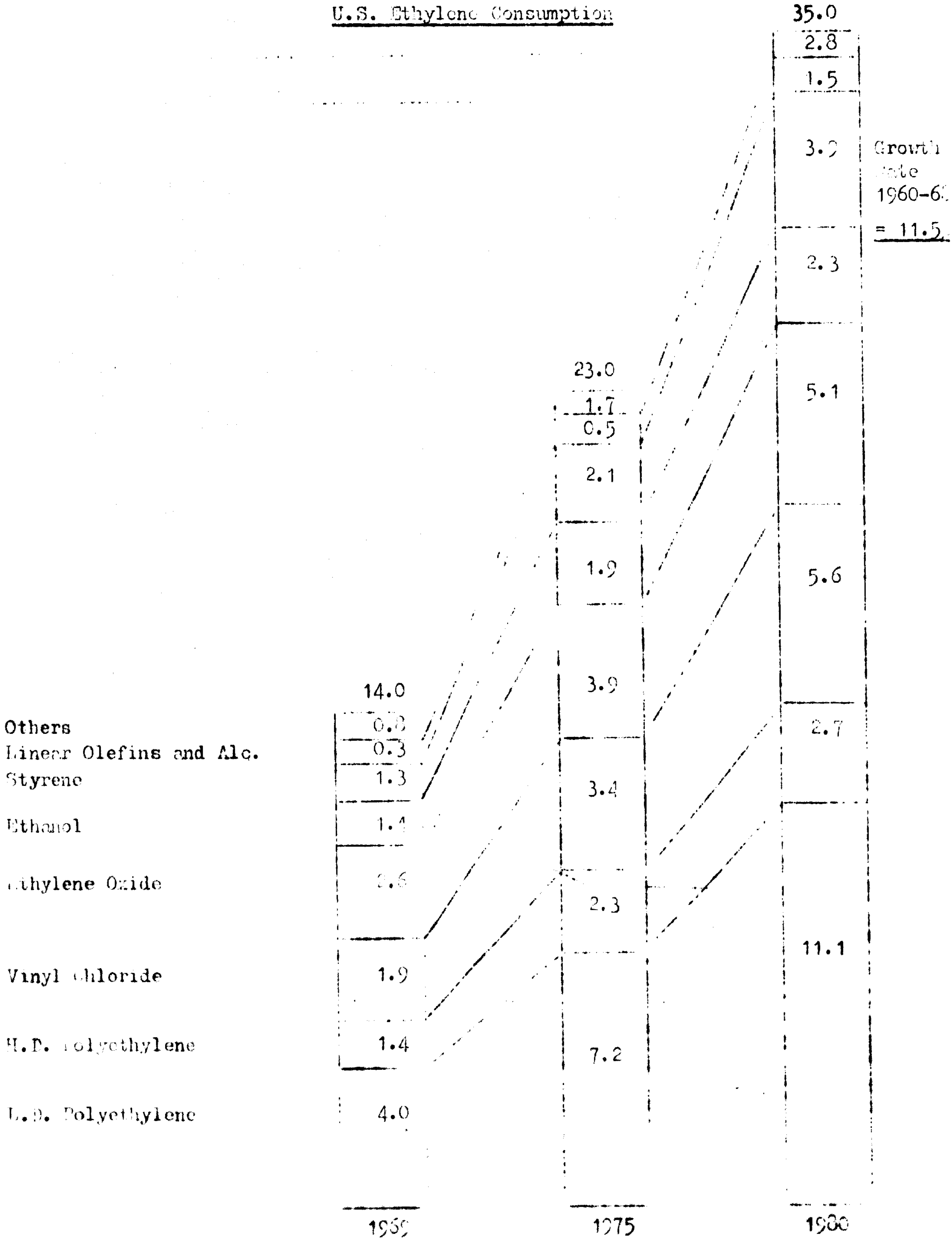


Chart IV

Low Density Polyethylene Production

(Billions lbs.)

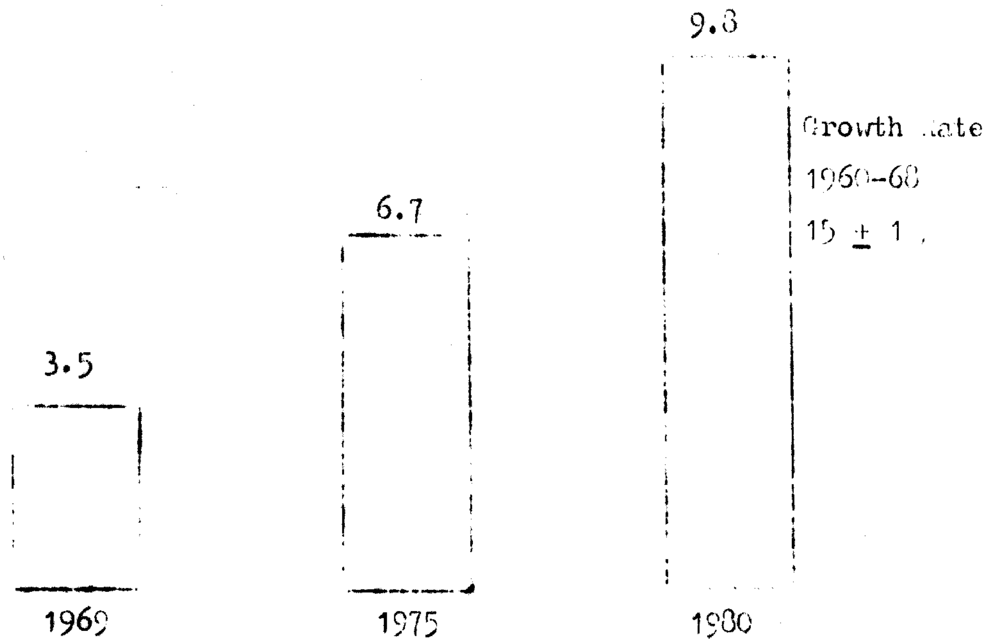


Chart V

High Density Polyethylene Production

(Billions lbs.)

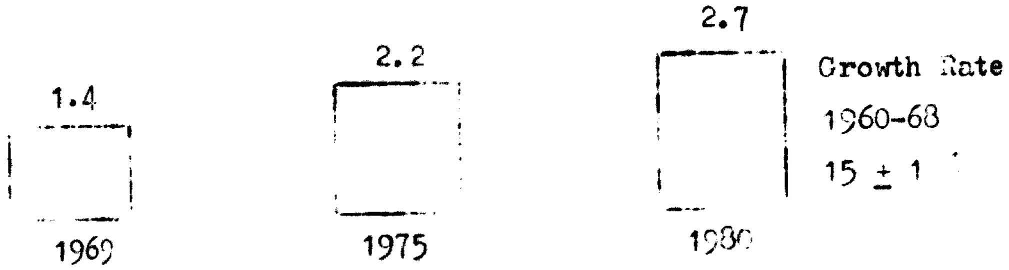


Chart VI

Ethylene Oxide Production

(Billions lbs.)

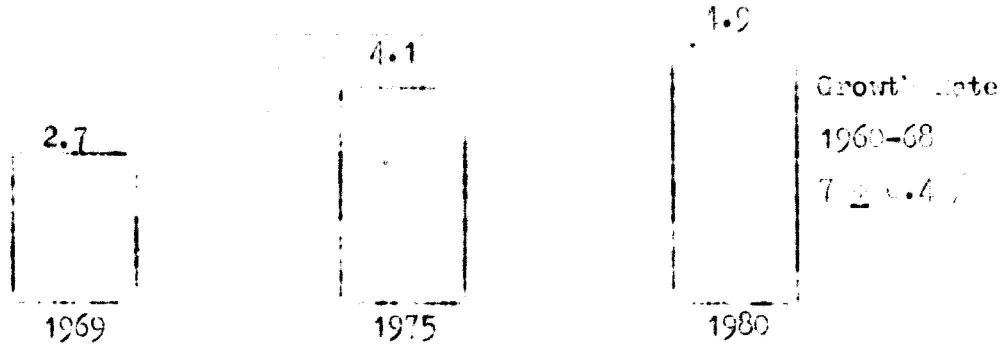


Chart VII

Vinyl Chloride Production

(Billions lbs.)

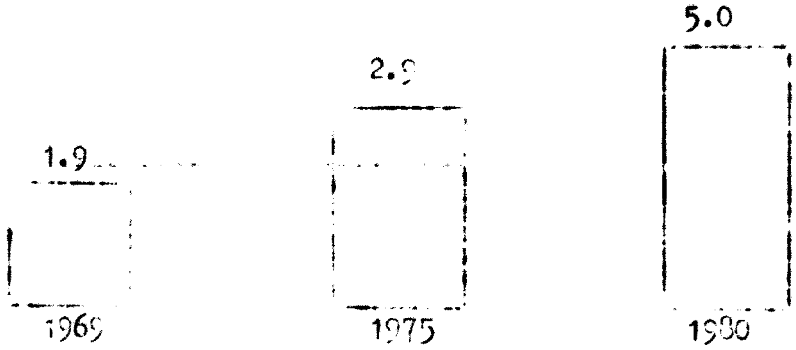
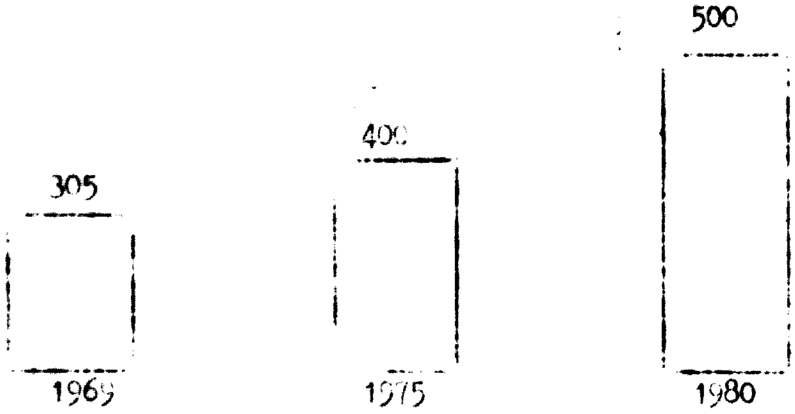


Chart VIII

Ethanol Production

(Million Gals.)



Growth Rate
1960-68
1.5 ± 5 %

Chart II

Propylene Consumption

(Billion lbs.)

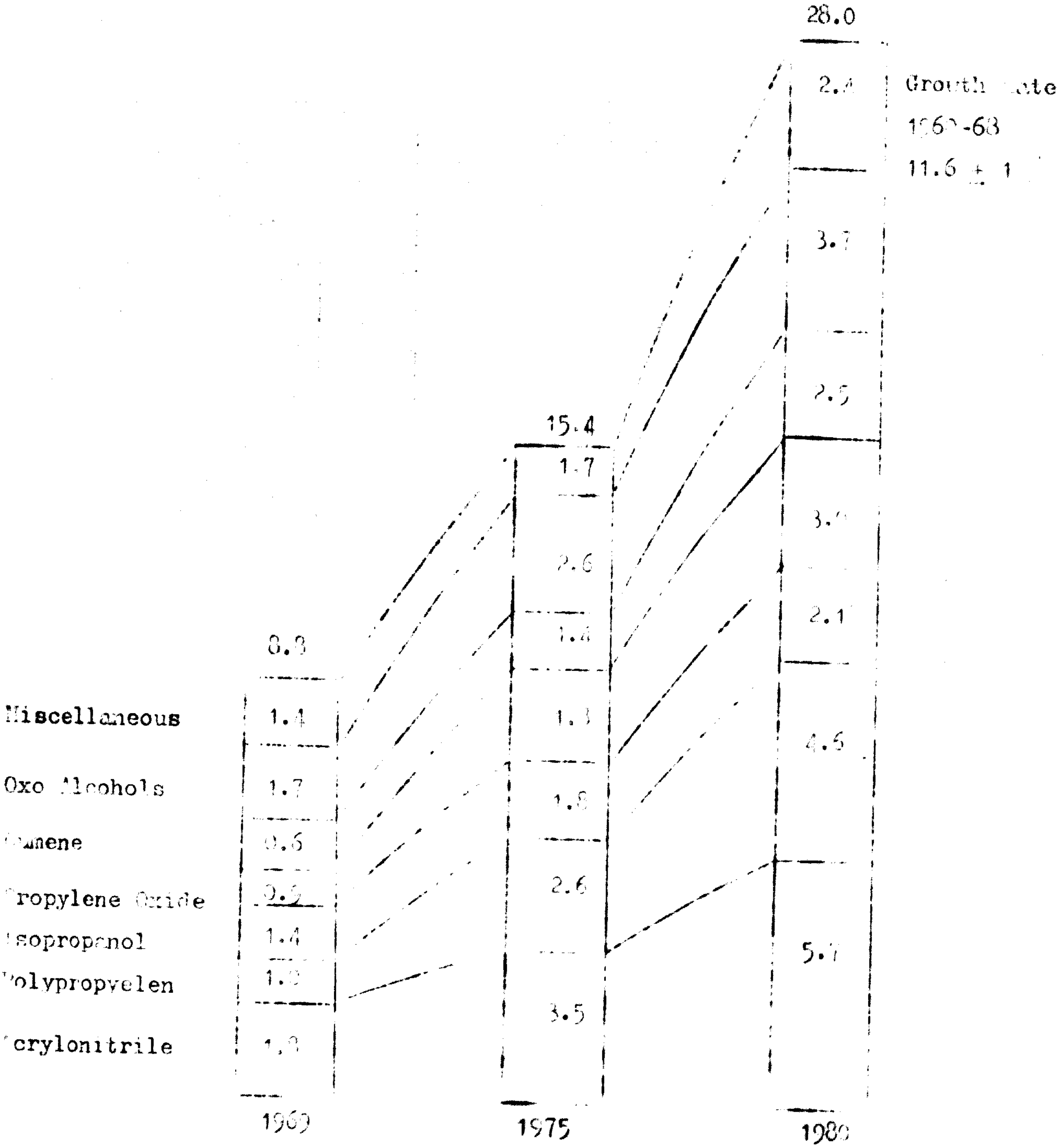
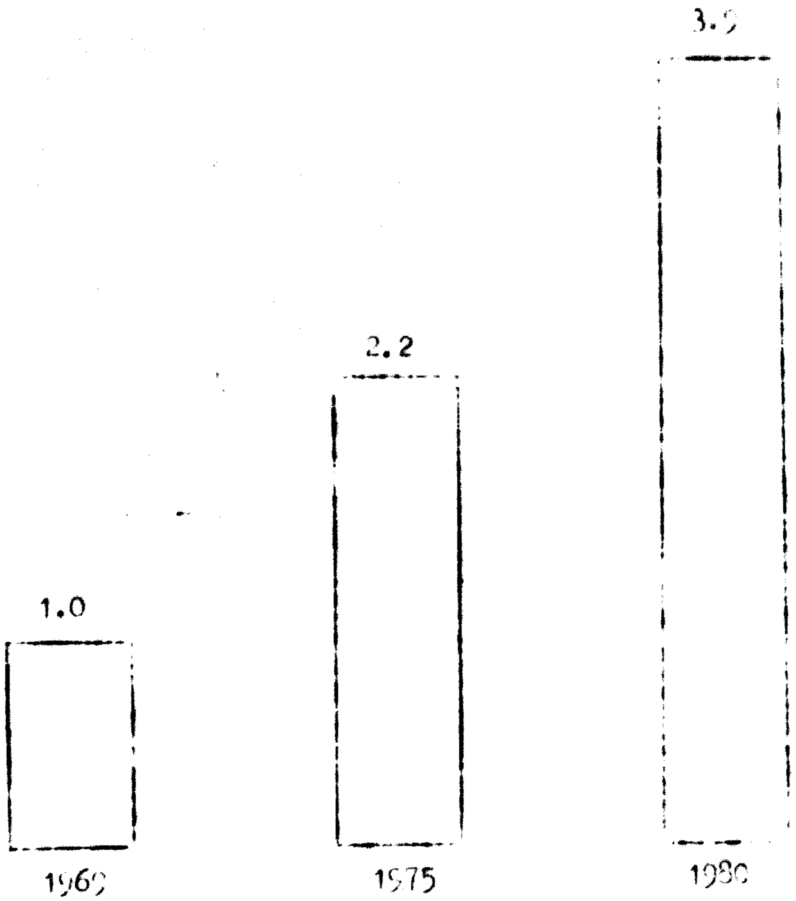


Chart [illegible]

Polypropylene Market

(Billions lbs.)



Growth Rate
1960-68
50

Chart 1

Acrylonitrile Demand

(Billions lbs.)

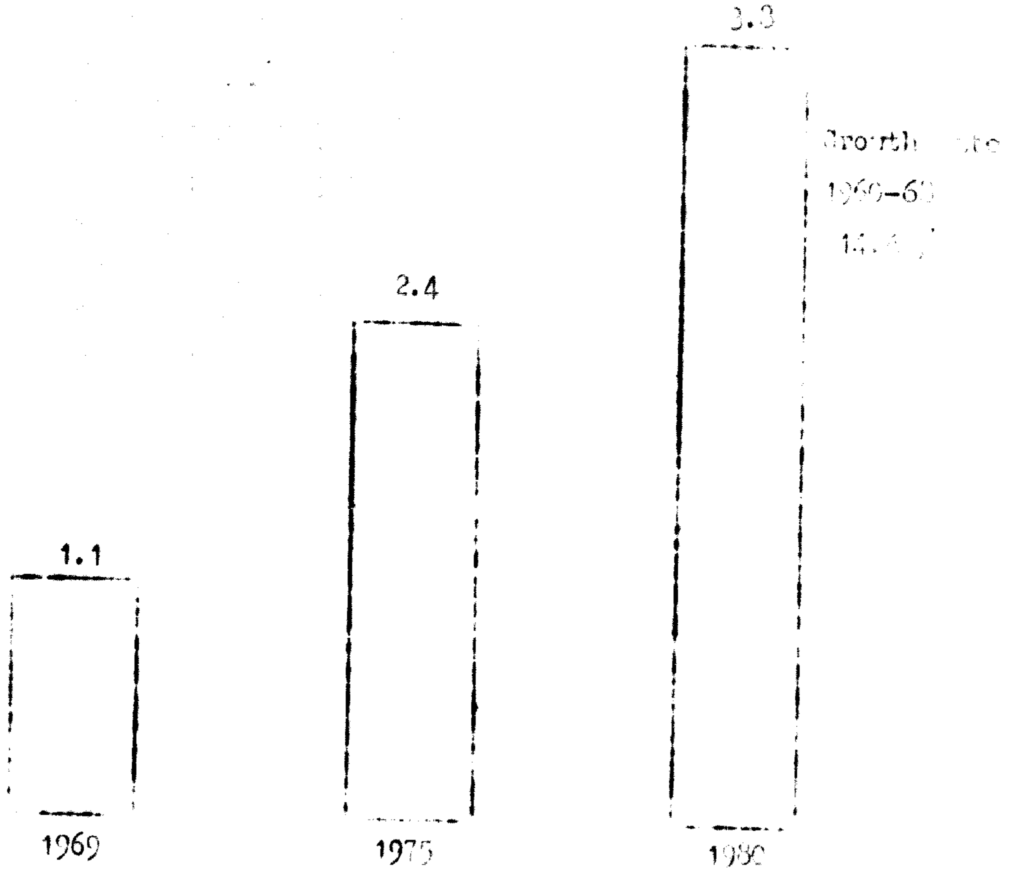
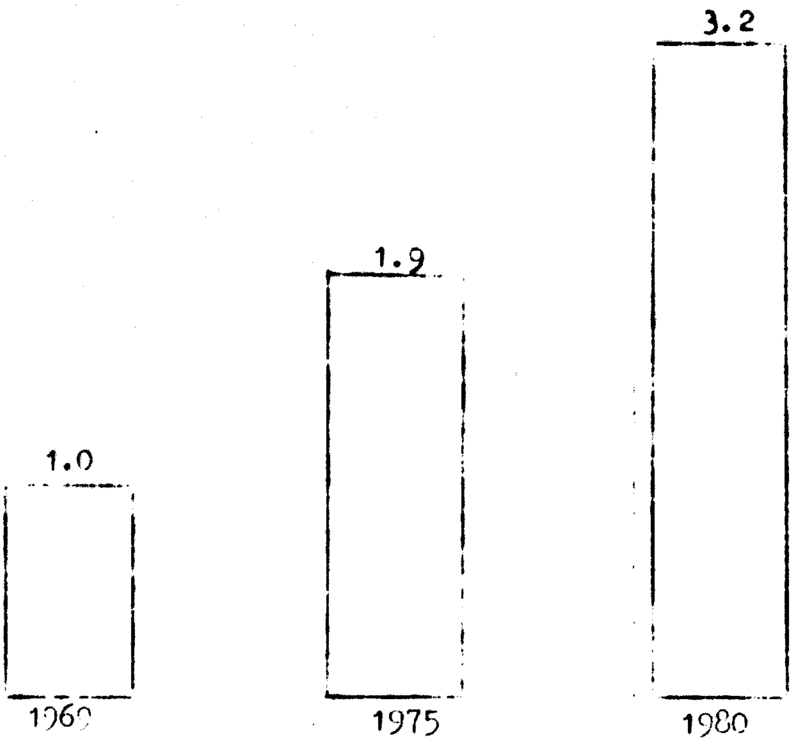


Chart XII

Propylene Oxide Demand

(Billions lbs.)



Growth Rate
1960-68
10 ± 2 %

Chart XIII

Isopropanol Demand

(Billions lbs.)

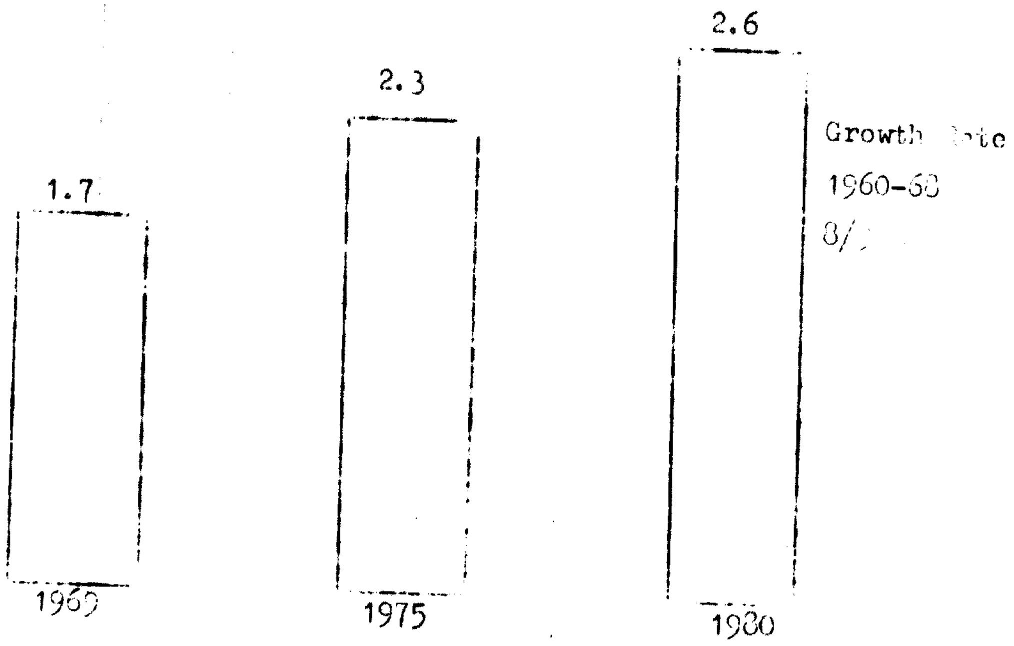


Chart XIV

Cumene Demand

(Billions lbs.)

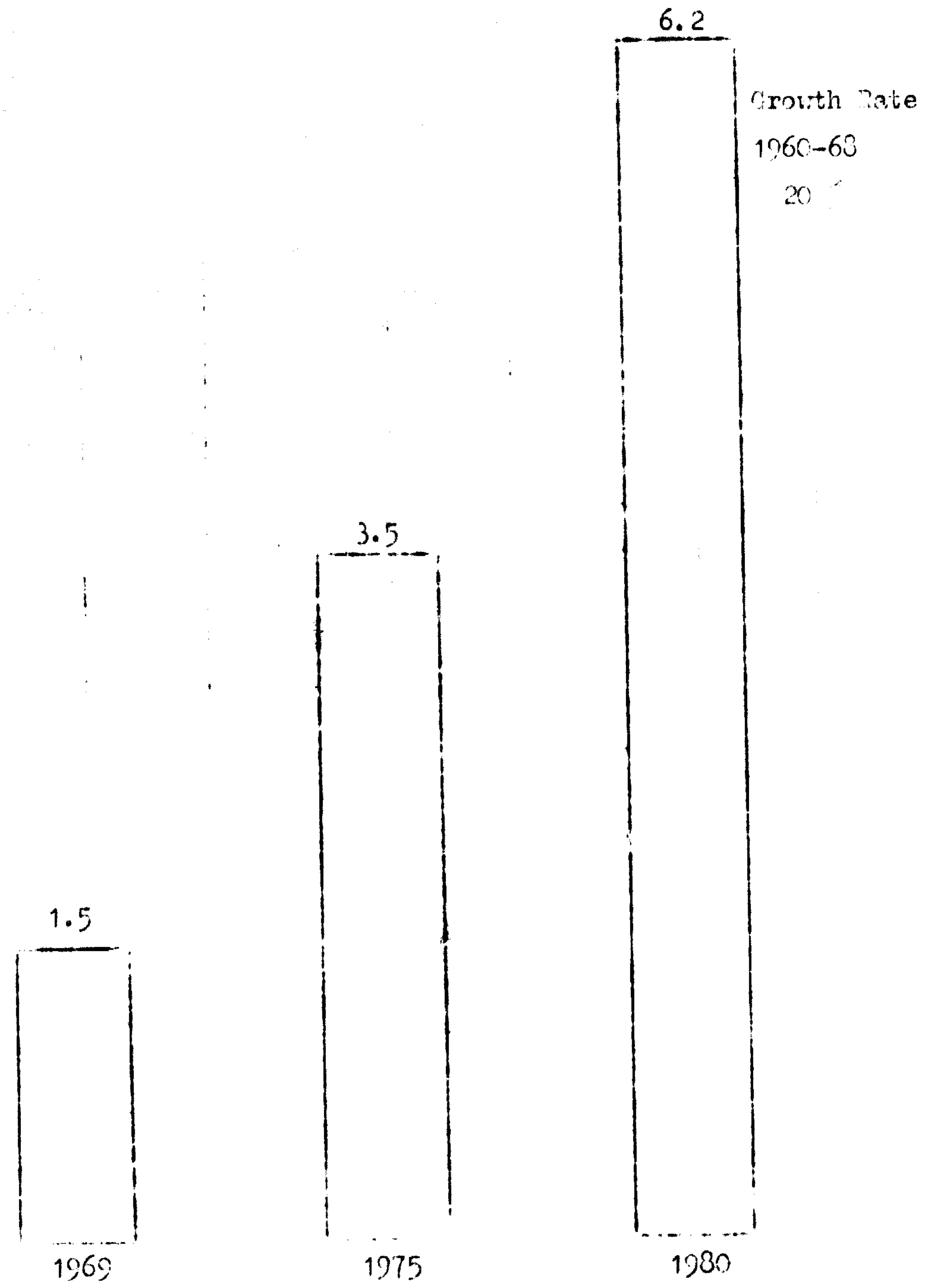


Chart IV

Oxo-Alcohol Feedstocks

('000 lbs.)

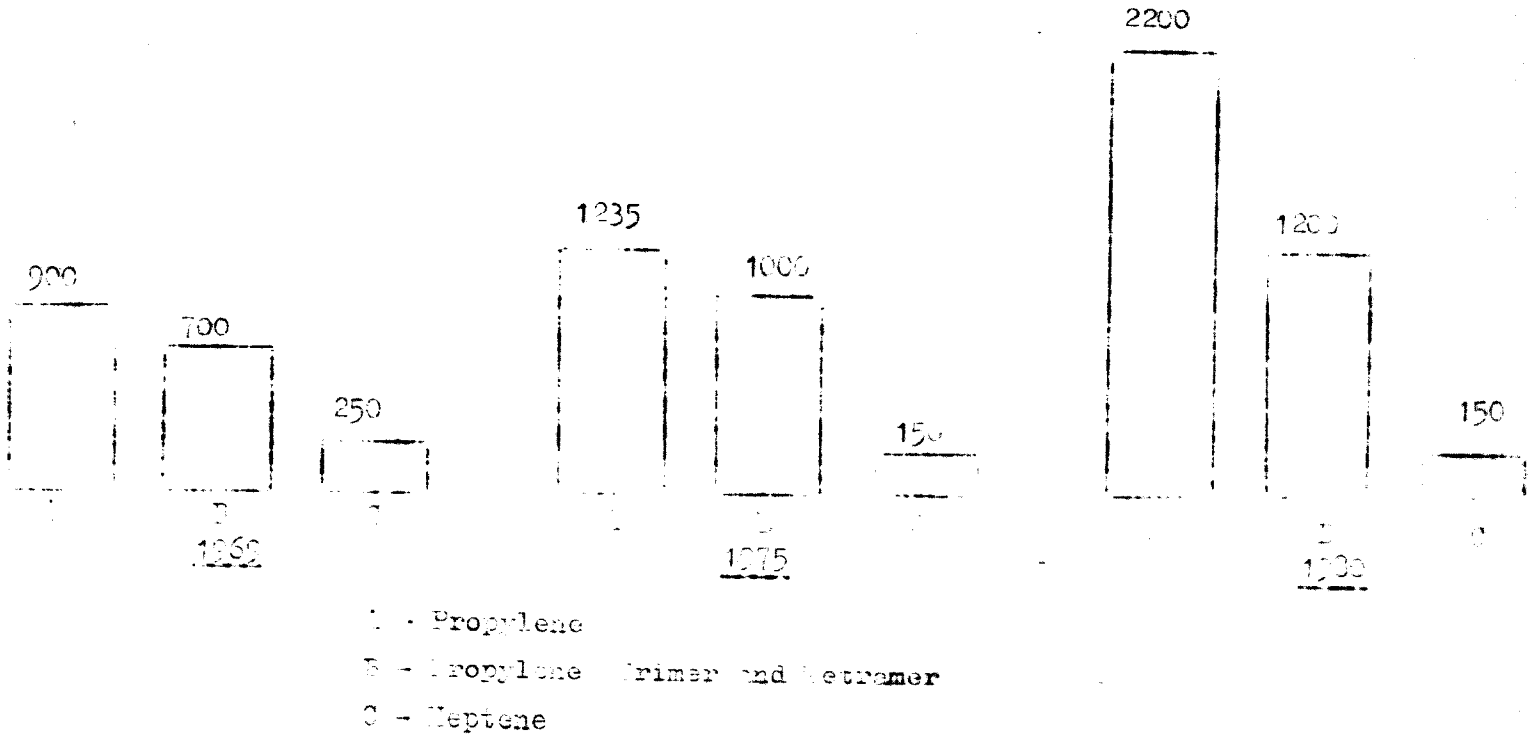
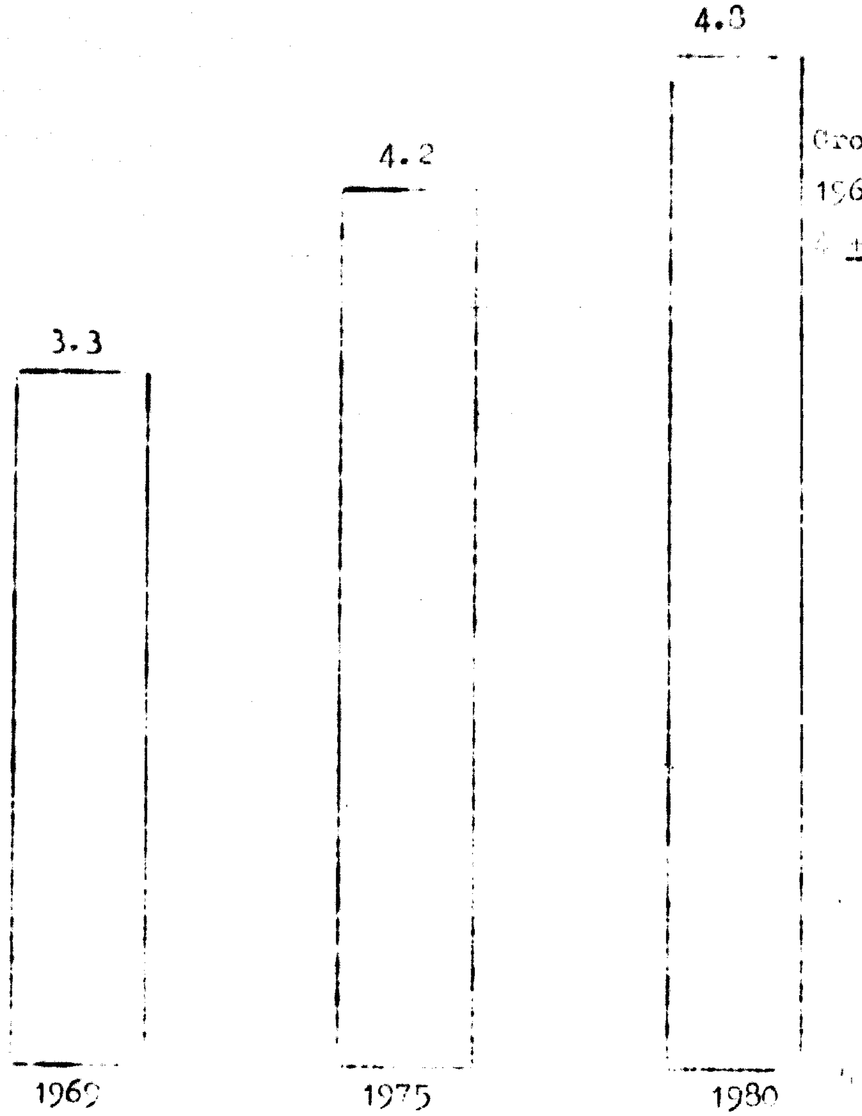


Chart [illegible]

Butadiene

(Billions lbs.)

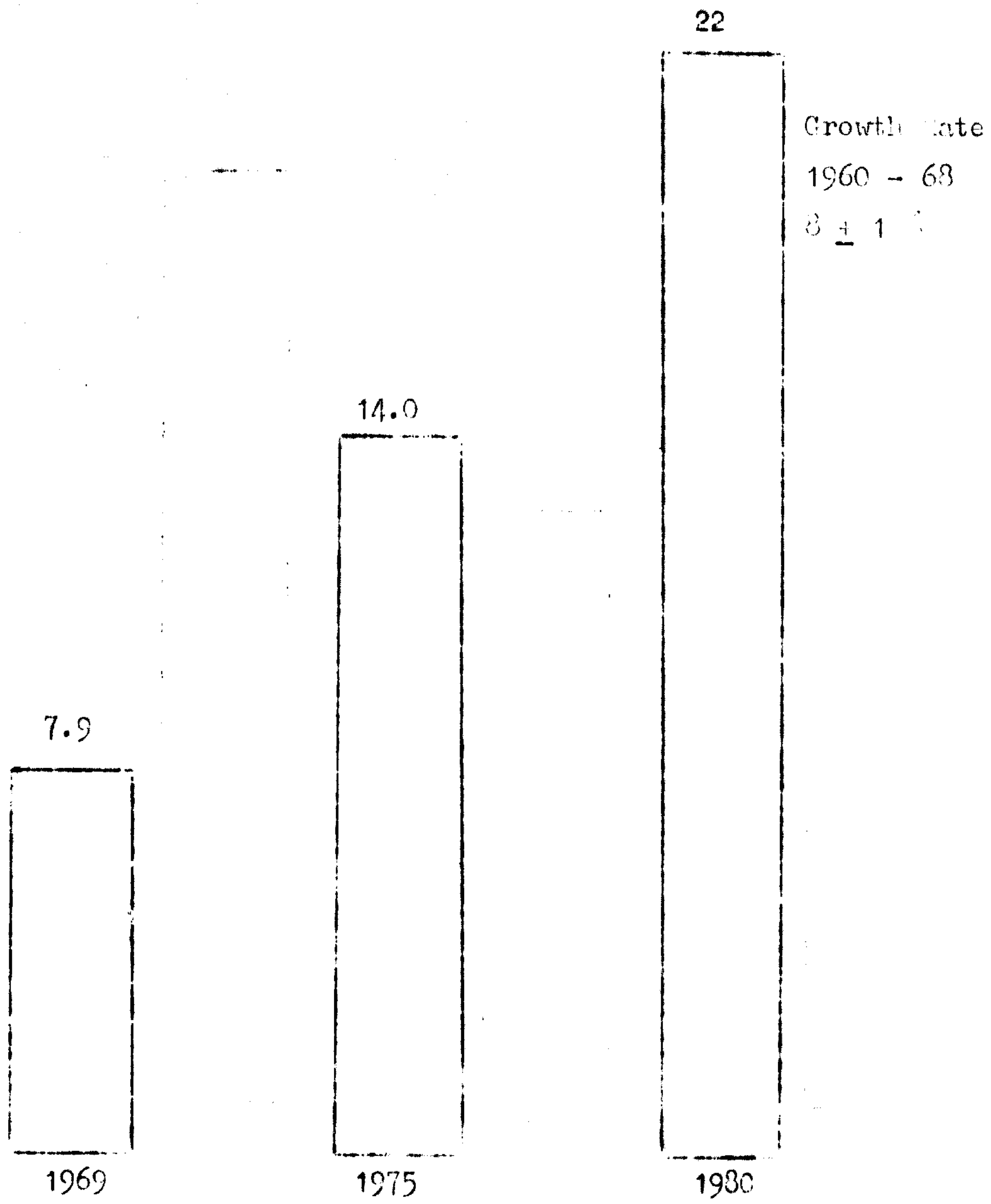


Growth Rate
1960 - 68
4 ± 1 %

Chart XVII

Benzene

(Billions lbs.)



34/7
44

Chart XVII:

Styrene Consumption

(Billions lbs.)

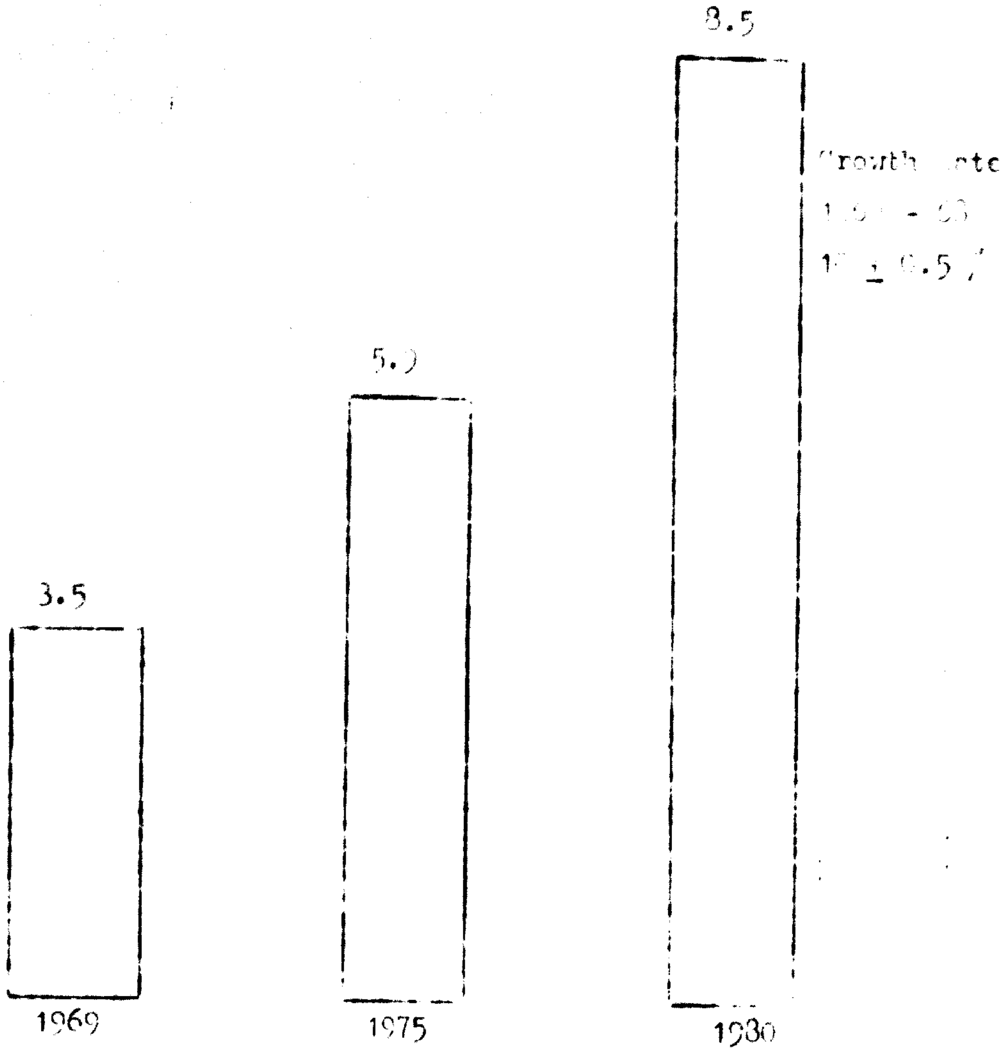


Chart [illegible]

Paraxylene Consumption

(Billions lbs.)

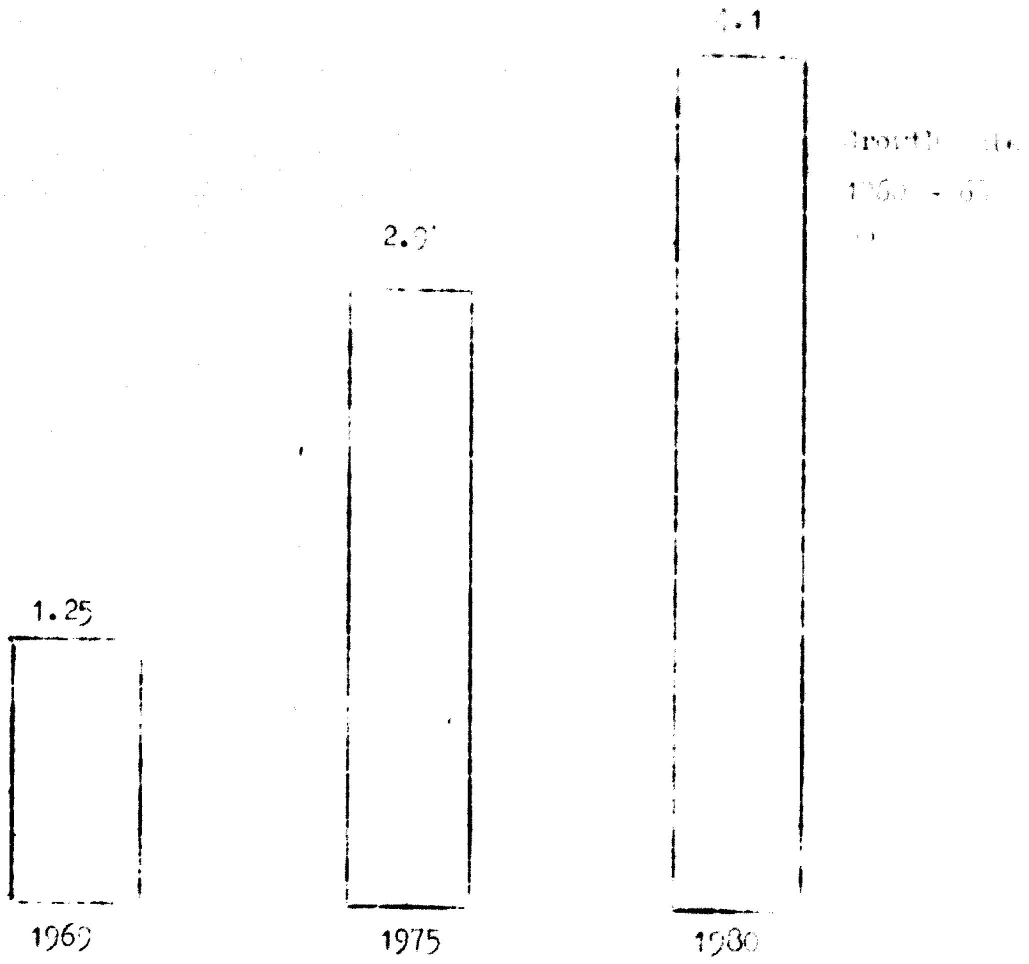
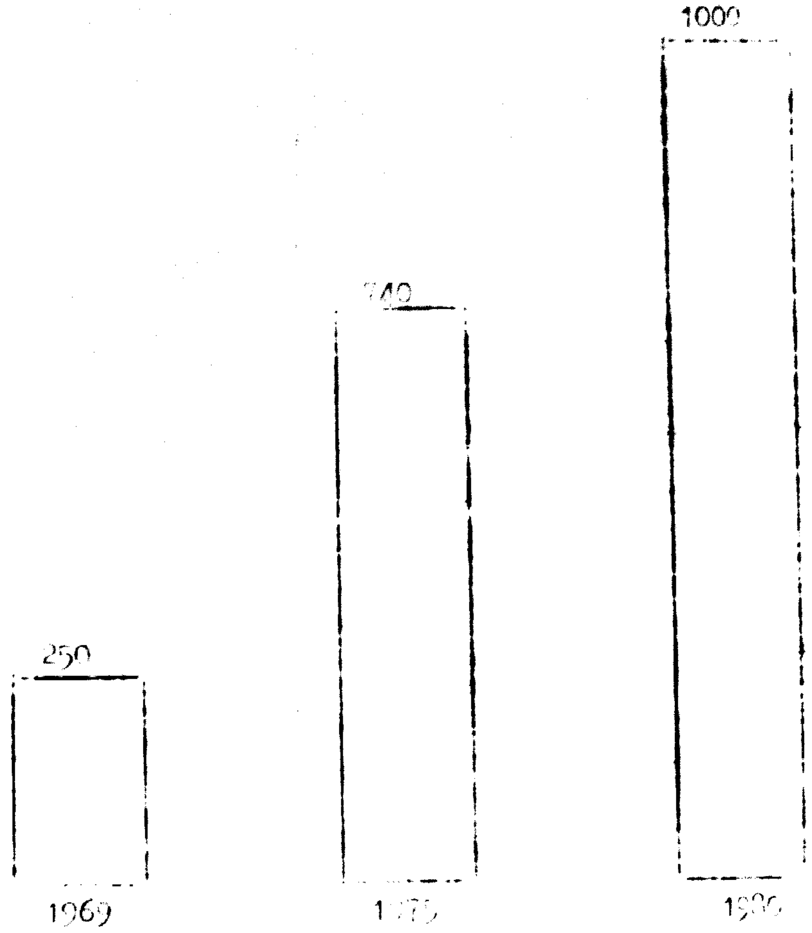


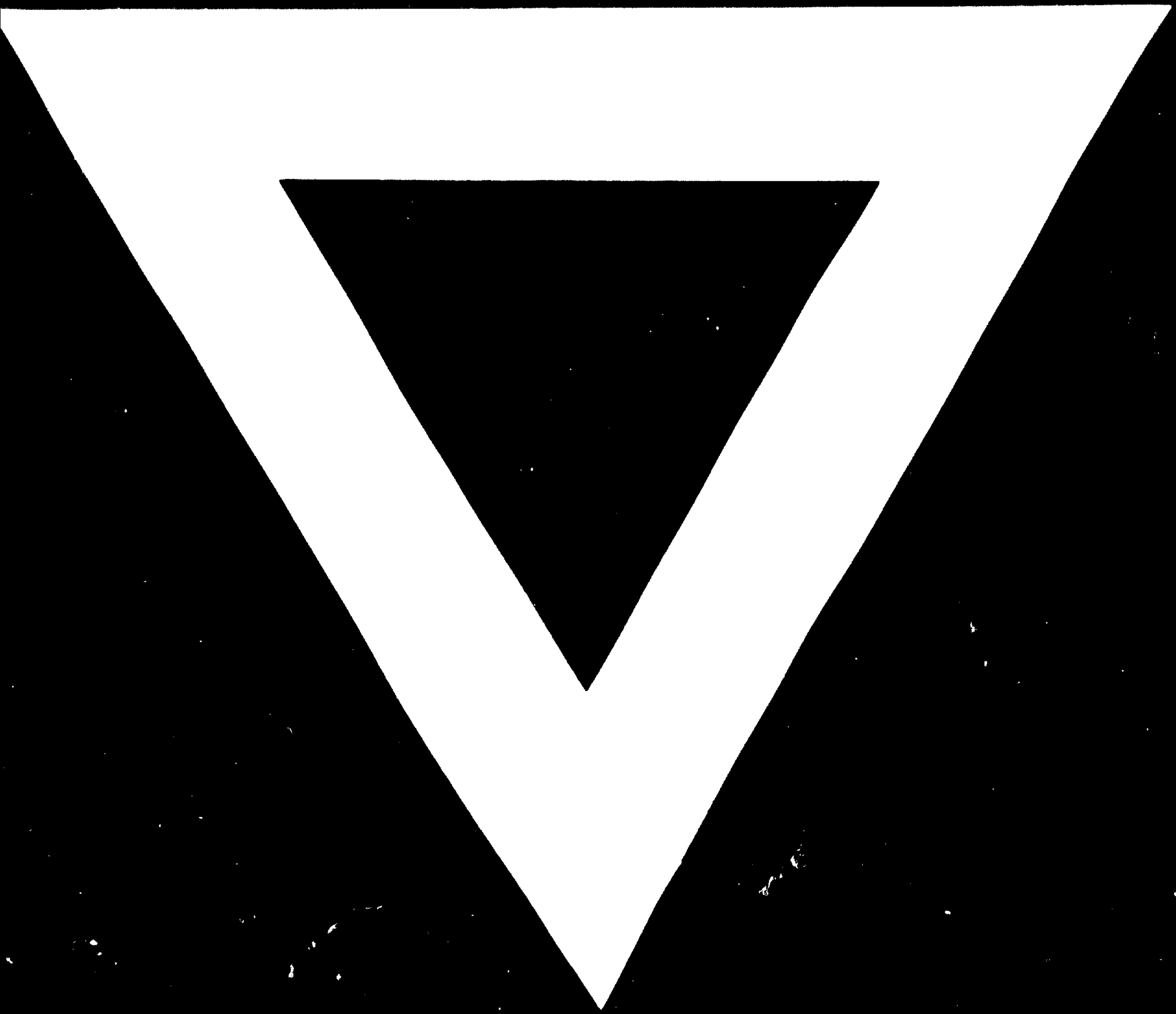
Chart XI

Orthoxylene - US Consumption

(Millions lbs.)



Growth Rate
1969-80
13 %



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