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ENGLISH

Workshop on Fermentation Alcohol for Use as Fuel and Chemical Feedstock in Developing Countries

Vienna, Austria, 26 - 30 March 1979

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FERMENTATION ALCOHOL AS BASIC RAW MATERIAL FOR A CHEMICAL INDUSTRY*

by

P. Yakovleff**
and
M. Goharel***

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ABSTRACT

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AGROCHEMISTRY COMES OF AGE FERMENTATION ALCOHOL AS BASIC RAW MATERIAL FOR A CHEMICAL INDUSTRY*

by

P. Yakovleff**

M. Goharel***

Industrialization through the building of petrochemical units has been the ambition, over the past thirty years, of many a developing country.

The precariousness of oil resources, the high level of investments required, the technological trends towards complexes of mammoth size which improves economice but complicates marketing, have made this an impossible dream for all developing nations except a few rich oil-producing onee.

The attention that has been focused worldwide on the search for new sources of energy has however opened new vistas for the development of a chemical industry in countries with no or limited oil resources and limited markets, but having abundant solar energy

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id.79-568

Such countries can produce ethyl alcohol on an industrial scale, using regenerative agricultural products, and this alcohol can be used not only as an additive to gasoline but also as a raw-material for the chemical industry.

The chemistry from alcohol can lead to a large number of consumer products duplicating over a wide range the chemicals derived from petroleum. In particular, ethylene and all its derivatives such as PVC, glycols, polyethylenes can thus be produced simply in units of reasonable size adapted to the needs of local markets.

The economics are viable in special situations such as exist in developing countries of South East Asia, Africa, Central and South America. The production of ethylene from ethanol using local and naturally renewable sources offer a unique opportunity to reduce dependence upon imported petroleum, improve balance of paymen s and increase local employment while providing economical and efficient production of limited quantities of ethylene. It provides a low cost entry into a field now exclusively reserved to petrochemicals.

The future prospects for a chemical industry based on agricultural products (sugar cane as the most common and important) are encouraging if one considers that oil prices are likely to continue rising on account of depleting sources of supply while the potential of the many agricultural products that can serve to make Fermentation alcohol is only beginning to be tapped.

INTRODUCTION

Most of the discussion and many of the papers presented during this symposium have centered on the production of fermentation alcohol, assessing alternative raw materials, environmental impact, processing costs and on the use of fermentation alcohol as an alternative source of energy, essentially in the form of an additive to or even a substitute for automotive fuel.

As a consequence of the world oil situation, many countries devoid of petroleum resources but blessed with abundant solar energy are contemplating an alcohol plan or, as it is sometimes called, a "gasohol" or "alcogas" plan. It must be stressed that this approach requires a concerted effort on the part of government and industry since it implies, in addition to large scale investments, the introduction of new legislation, a reconversion of liquid fuel transportation and distribution circuits as well as an adaptation by the automotive industry.
Such orientation can only result from a political decision aimed at gaining some degree of independence from outside sources of energy supply and at achieving savings in foreign exchanges, even if this operation results in little added value to the agricultural products thus transformed into a source of energy.

The other approach consisting of the utilization of fermentation alcohol as chemical feedstock holds in our opinion more immediate promise for a number of reasons :

a) the decision can be a limited one, taken at the level of a group of industries or even of an individual company since the investmens are more controllable and the political, economic and industrial implications are much less far reaching than for power alcohol.

b) there is much more added value in producing finished goods such as plastics, fibers, paints, etc... as compared with automative fuel.

In the years up to the oil crisis of 1973, when oil was available at low cost in abundant and regular supply, petrochemistry was the only way to industrialization in the chemical field in developing and developed countries alike.
The building of petrochemical complexes of varying sophistication was the ambition of many a developing country and was the symbol of its degree of industrial development.

The evolution since 1973 as regards petroleum resources and supply costs on a world scale has turned this ambition into an impossible dream for developing countries with no or little oil resources. The path to industrialization via petrochemistry for these countries is now irreversibly blocked.

However for those developing countries that are blessed with favorable climatic conditions, namely abundant solar energy, agrochemistry meaning that based on the derivatives of fermentation alcohol offers aviable alternative to petrochemistry and can provide a low cost entry into the field of chemical industrialization.

PETROCHEMISTRY - THE TRADITIONAL WAY TO INDUSTRIAL DEVELOPMENT

Let us look at the importance of petrochemistry for any country and at its evolution both before 1973 in the days of cheap oil and since 1973 at a time when the precariousness of oil resources and spiraling oil costs have led every country in the world to an agonizing reappraisal of its policy in the field of energy and industrial development.

Importance of Petrochemicals and Price Trends

The phenomenal growth of petrochemicals worldwide in the course of the last 30 to 40 years is illustrated by the following graphs :

Graph 1 - Development of world petrochemicals production

Graph 2 - Plastics production in the world 1900 - 1970

Graph 3 - Trend in world fiber production

Petrochemicals are present in every aspect of modern life and contribute extensively to the improvement of living standards everywhere. In the gross national product of an industrialized country such as France, consumer goods derived from petroleum account for about 35 %, which is very important. Petrochemicals are found in housing (construction materials, plastics, textiles, paints, etc...), in automobile (paints, body parts, interior, etc...) in clothing in packaging of all sorts, in drugs and in innumerable other applications.

Yet only 3.5 to 7.7 % of the total quality of oil consumed in developed countries is used as raw materials for the production of such petrochemicals. This is very little but is rising rapidly and will undoubtedly keep on rising since petrochemistry offers the most added value and therefore best valorizes the oil used as raw material.

This trend, which is shown on Graph 4 - oil requirements until 2020, contributes to the rapid and uncontrollable rise in the costs of raw materials used for the petrochemical industry.

Exhibits 5 and 6 give examples of market trends and petrochemical price forecasts both for Europe which buys 80 % of its energy requirements outside and for the USA which, thanks to its native sources, has less than 50% dependency on imports. It is significant to observe that projections made in 1978 for 1982 have already been surpassed in January 1979 !

Conventional Raw Materials for the Petrochemical Industry

There are several raw materials that can be used for the production of ethylene, the most important building block of the petrochemical industry. These are different fractions obtained in petroleum refining namely :

- Liquefied gases (ethane, propane, butane)
- Light gasoline
- Naphtha wich is a medium cut
- Gas oil which is a semi-heavy cut

As shown on Exhibit 7, the choice of raw material conditions the production of ethylene and the quality of co-products inevitably made in the cracking process. The heavier fractions give more co-products but lower yields.

Evolution of the Petrochemical Industry

Taking into account factors of availability and costs of raw materials as well as problems of storage and transportation, the trend in developed countries before 1973 was towards using increasingly heavier fractions as raw materials because these are less costly and furnish a greater variety of sellable co-products, although the loss gets bigger for an equivalent quantity of ethylene produced as shown on Exhibit 8.

Since 1973, this trend has accelerated. Furthermore, the ever-rising costs of energy have led to building petrochemical complexes of increasing sophistication in order to save energy and of mammoth size in an attempt to lower unit costs per ton of production.
Graph 9 illustrates the evolution between 1972 and 1974 of the various elements making up the cost of a naphtha steam cracker.

The present outcome of such an evolution has been to make steam crackers of a capacity lower than 450,000 MTA of ethylene essentially non-economical and non-competitive. The level of investment (running into several billion dollars) is extremely high and well beyond the means of many a developing country particularly if the market is limited and the economics have to be predicated upon large scale exports.

What are the consequences of this evolution on non-oil producing developing countries wanting to build a petrochemical industry despite the initial handicap of a total and unavoidable dependency on outside supply of raw materials ?
Therr options are open :

a) Import propane and build a steam cracker on this liquefied gas :
   - investment is comparatively limited (medium size, few co-products)
   - cost of raw material is high and aggravated by cost of stransportation and storage

b) Import ethylene :

- investment is limited to installing a terminal involving cryogenic storage
- the cost of transportation and storage burden beyond reason the cost of ethylene which in itself is an expensive raw-material

c) Build a steam cracker based on imported naphtha :

- raw material cost is relatively "low"
- investment is extremely heavy particularly on account of the necessity to build large size units and to valorize all co-products.

None of these options appear very attractive and all are wrought with large financial risks.

The picture is grim indeed and vital answers to critical questions are uncertain : what will be the rise in cost of oil or naphtha imposed by exporters between the time the decision is made to build a cracker and the time the unit gets on stream ? Under what conditions will it be possible to export the surplus production of all co-products inherent with the building, thru economical necessity, of an oversized complex ?

What economical and social upheavals will a large petrochemical complex create when it is built in a country devoted to agricultural production and with little industrial infrastructure ?

One way out is agrochemistry.

AGROCHEMISTRY : THE ALTERNATIVE TO CHEMICAL INDUSTRIALIZATION

For many a developing country, the only reasonable way out to industrial development in the chemical field is to use regenerative home-grown agricultural products to produce ethylalcohol and to build a chemical industry based on this alcohol as feedstock.

It should be recalled that in the years 1925 to 1950 and particularly during the second world war, many chemical products were made starting with ethanol. Table 10 gives a synopsis of the principal processes of alcohol chemistry and of the many products that can be derived industrially from alcohol.

What are the factors essential to the success of an industrial development scheme based on the use of fermentation alcohol ?

1) Ethyl alcohol must be available in sufficient quantities at competitive prices

Many of the papers submitted during this symposium show that this goal is well within reach. The picture, as regards price forecasts is brightened on the one hand by the many new and interesting developments in fermentation alcohol technology and on the other hand by the increasing variety and availability of alternative agricultural crops used as raw materials in the production of fermentation alcohol.

2) Themarket must be sufficeint to ensure local consumption of the agrochemicals produced.

This should not be very difficult to achieve considering that the minimum economical size of units based on alcohol chemistry is much lower than for petrochemical units.

As an exemple units of :

20,000 MTA for polyethylene

35,000 MTA for polyvinylchloride

which should cover the needs of a population of 10 to 15 million inhabitants are economically viable.

3) Modern and efficient technology for the production of ethylene from ethanol and for ethylene derivatives.must be available.

This problem has been solved. In the case of ethylene from ethanol units, it can be considered that efficient units ranging in size from 10,000 to 120,000 MTA ethylene can be built and operated economically.

Tables 11 and 12 give typical production and yield data for two agrochemical complexes based on the production of two vital "petrochemicals" polyethylene and PVC starting from either molasses or sugar cane.

ECONOMIC CONSIDERATIONS

It can be stated that the comparative economics of producing ethylene and ethylene derivatives by the petrochemical route and the agrochemical route are running neck in neck todayif one considers a developing country entering the field now.

Looking at world trends, this situation can only shift in favor of agrochemistry as time goes by.

Exhibit 13 shows the latest evolution of prices of ethylene made from naphtha depending upon the size of the cracker. The range is from 500 US dollars per ton to 700 US dollars. It must be stressed that such a price can only be achieved if one accepts the most optimistic assumptions with respect to the valorization of all co-products which, in the case of naphtha cracking, account for 50% of the ethylene price.

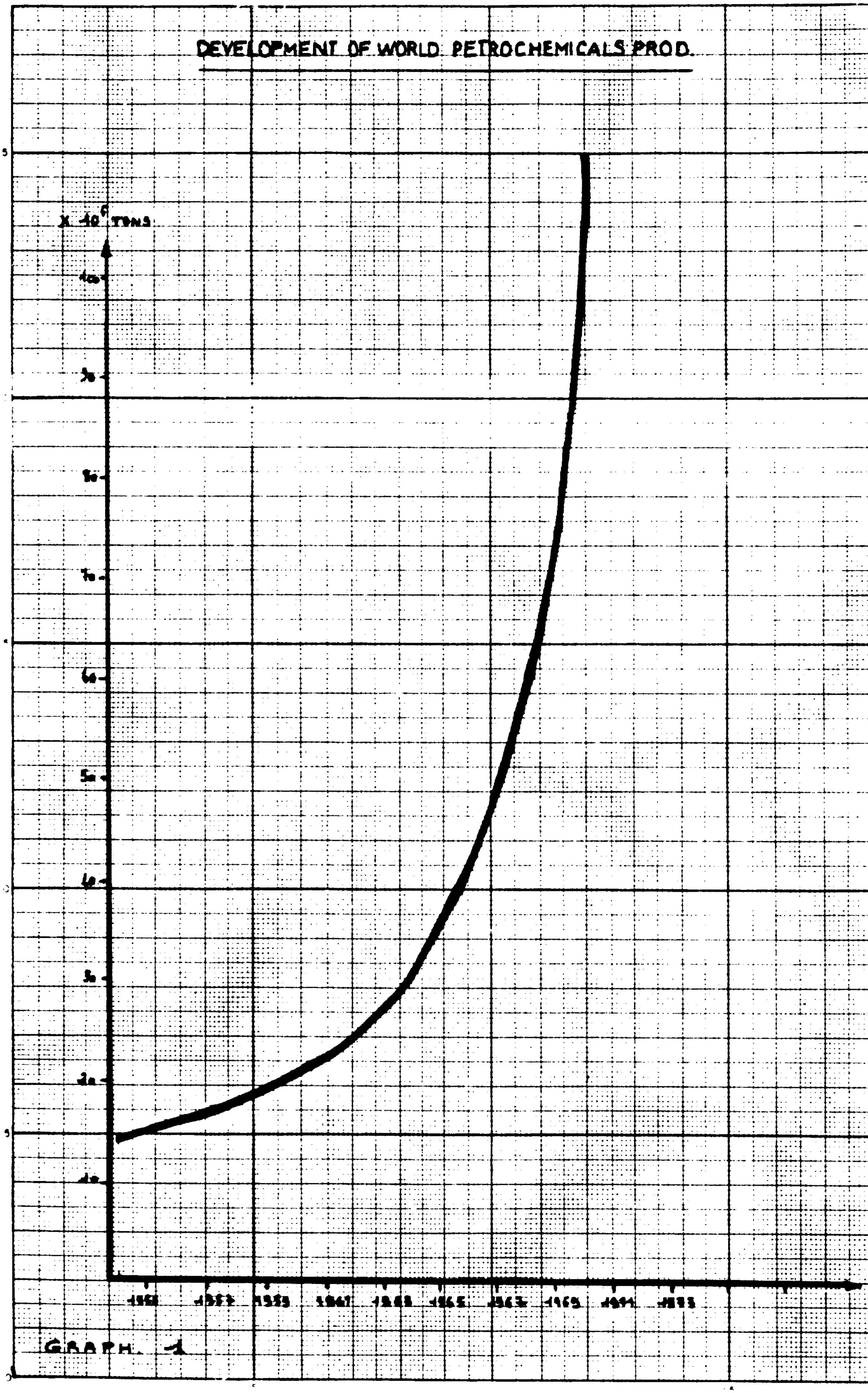
The price range for ethylene made from ethanol in smaller and more manageable units, compares more than favorably with these figures as shown on Exhibit 14.

In conclusion, these are many aspects that should make it interesting for a developing country to contemplate building a chemical industry based on fermentation alcohol :

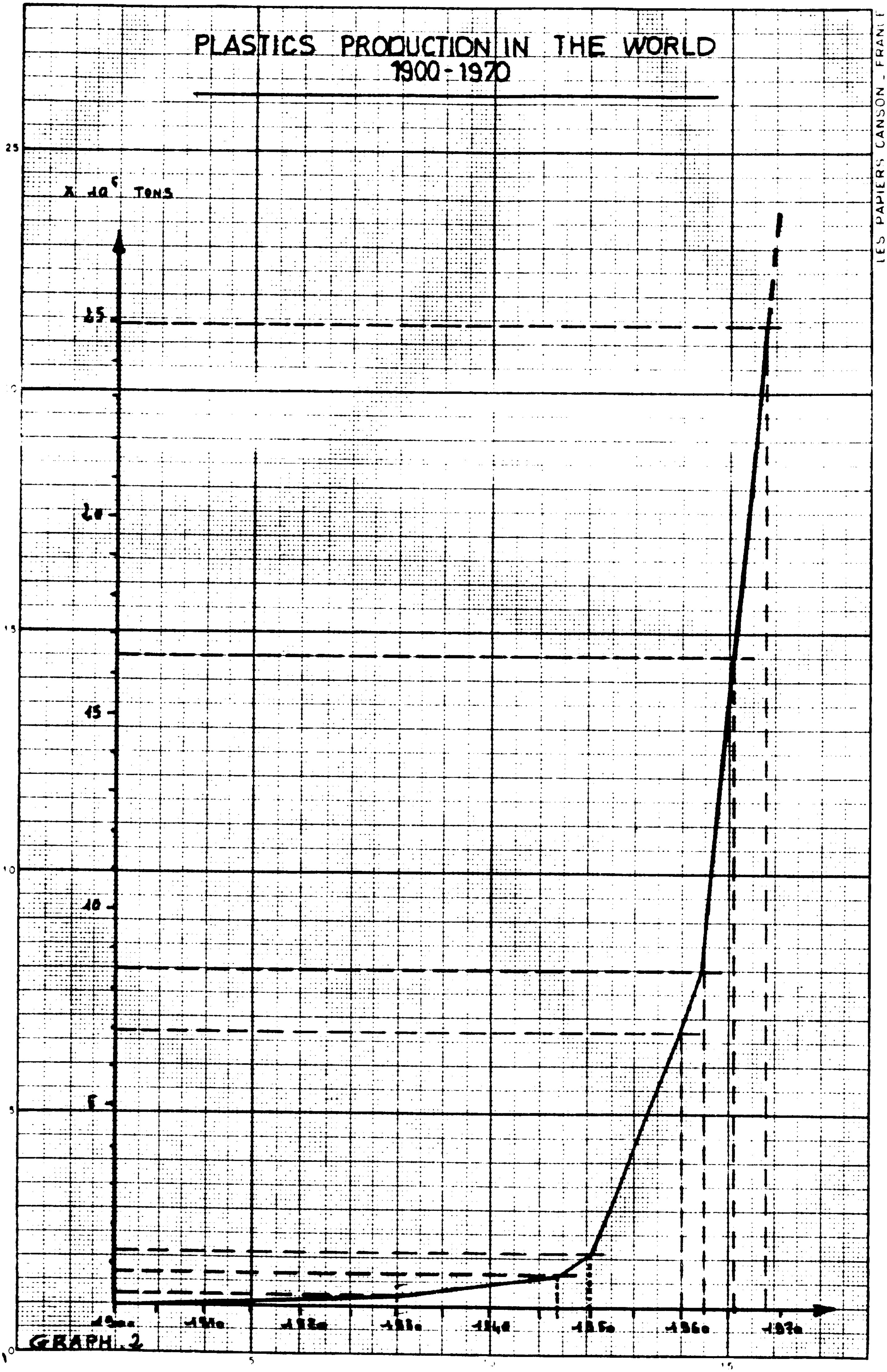
- investments involved are relatively low and can be adapted more easily to moderate market requirements
- agrochemistry is more labour intensive
- raw materials, essentially agricultural crops, are regenerative and home grown in many areas which means that costs of these raw materials are controlled nationally, largely immune from outside pressures.
- indigenous production of widely used chemicals having high added value such as polyethylene and PVC ensures substantial savings in foreign exchange at the same time as it effects independence from imported raw materials.

The prospects for a chemical industry based on agricultural products through fermentation alcohol are therefore most encouraging if one considers that oil prices are rising steeply while the potential of the many agricultural products that can serve to produce fermentation alcohol is only beginning to be tapped.

GRAPH I -

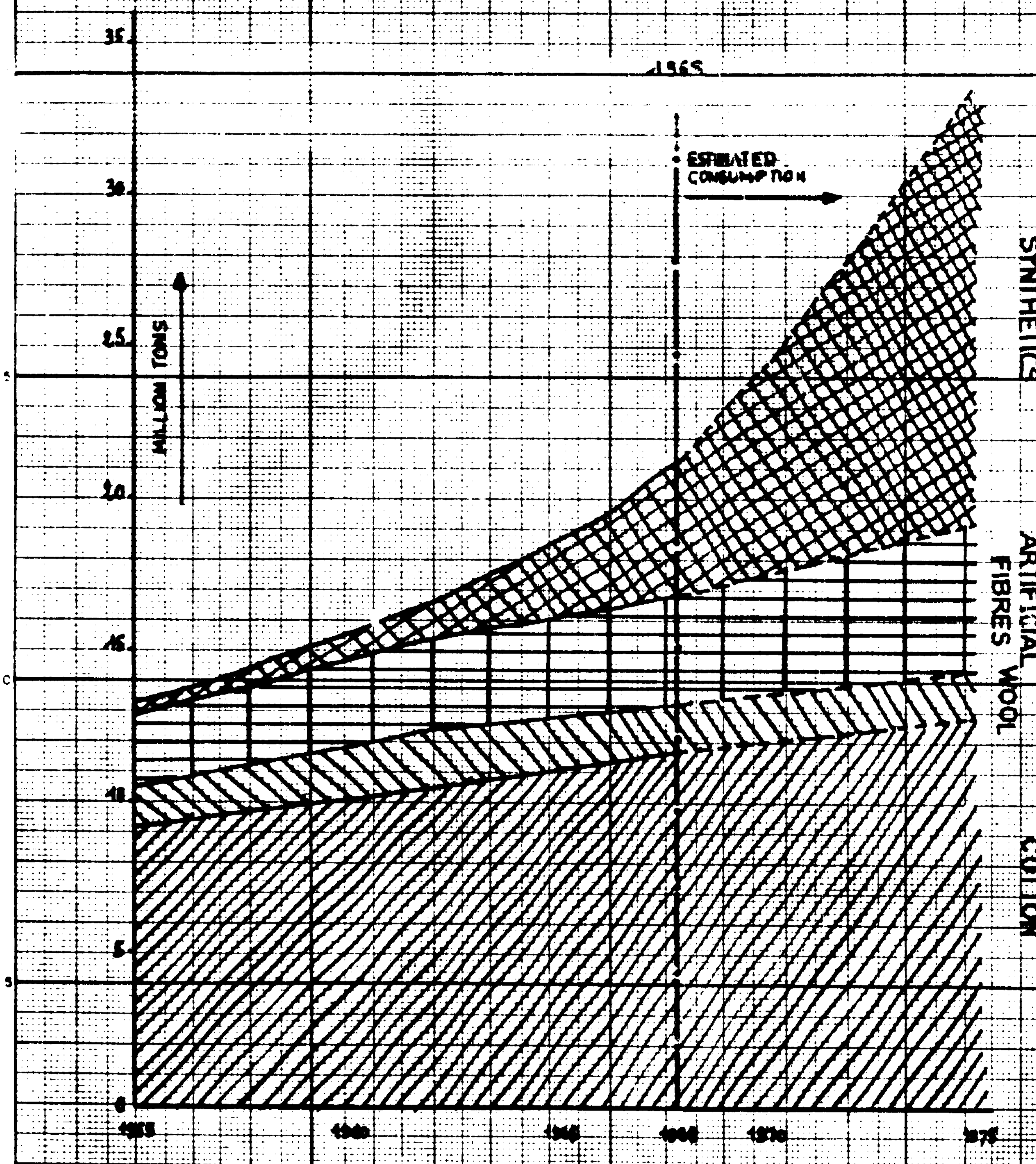

DEVELOPMENT OF WORLD PETROCHEMICALS PROD.
1965
1969
GRAPH. 1

GRAPH 2 -


PLASTICS PRODUCTION IN THE WORLD
1900-1970
x 10⁶ TONS
15
10
GRAPH. 2

GRAPH 3 _

TREND OF WORLD FIBER PRODUCTION



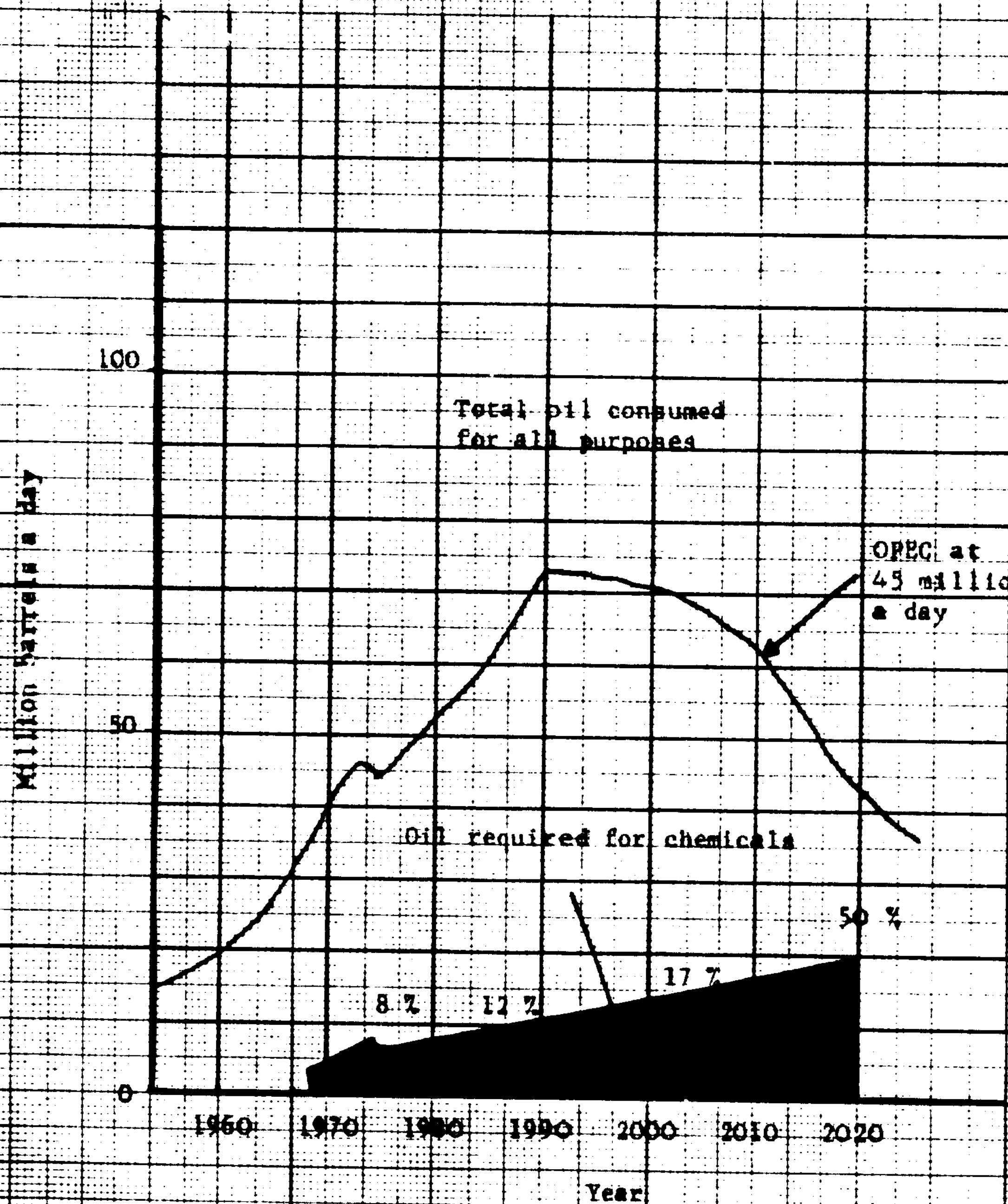
GRAPH 3

GRAPH 4 -

NOVEMBER 1977

PERSPECTIVE FROM NIGEL CHAMPLAN

OF B.P. CHEMICALS



Oil requirements until 2020

EXHIBIT 5.

ECN **market trends** EUROPEAN CHEMICALS NEWS

Bulk chemical price report (US dollars/tonne)

DATE	Product					
	Ethylene			Naphtha		
	European contract price range	European spot price range	US price range	European contract price range	European spot price range	US price ran[ge]
March 24, 1978	331-365	n.a.	286	123-50-125	127-50-129-75 (cif)	n.a.
November 3, 1978	373-390	n.a.	286	150-159 (nom)	178-180 (cif)	n.a.
[D]ecember 22/29, 1978	373-410	425-475	286 nom	150-160 (nom)	180-182 (cif)	n.a.
[J]anuary 22, 1979	460-460	—	291-5	—	202-204 (cif)	n.a.

EXHIBIT 6.

European Chemical News, November 24, 1978

Petrochemical price forecasts

For those who feel brave enough to consider petrochemicals prices nine years ahead we show below some estimates produced by Brian Budd, director of energy and materials management for Monsanto Europe, at a recent Institute of Purchasing and Supply meeting in London.

Budd feels that oil prices will barely follow inflation until the mid-1980s, when they will begin to increase in real terms reflecting supply:demand pressures and the cost of marginal production. Naphtha will come under increasing pressure from rising demand for gasoline and derivatives prices may look something like this:

Petrochemical price projections 1977-87
$/ton delivered N.W. Europe

	1977	1982	1987
Crude oil	101	126	180
Naphtha	130	160	225
Benzene	230	305	435
Ethylene	340	415	560
Styrene	400	480	635
Butadiene	500	545	725

Budd also predicted that butadiene would move into increasingly tight supply in the USA in the mid-1980s, following the phase-out of dehydrogenation plants by 1982-83, producing a shortfall of 440 000 tons by around 1985. At the same time, he reckons that Europe could have a butadiene surplus of some 600 000 tons, which could mean a reasonable transatlantic balance. But his figures ignore the possibility of a major surplus of butadiene in the Far East and, possibly, the Comecon area, which could keep the product in long supply throughout the period.

Composantes of naphta cracking cost and evolution between 1972 and 1974

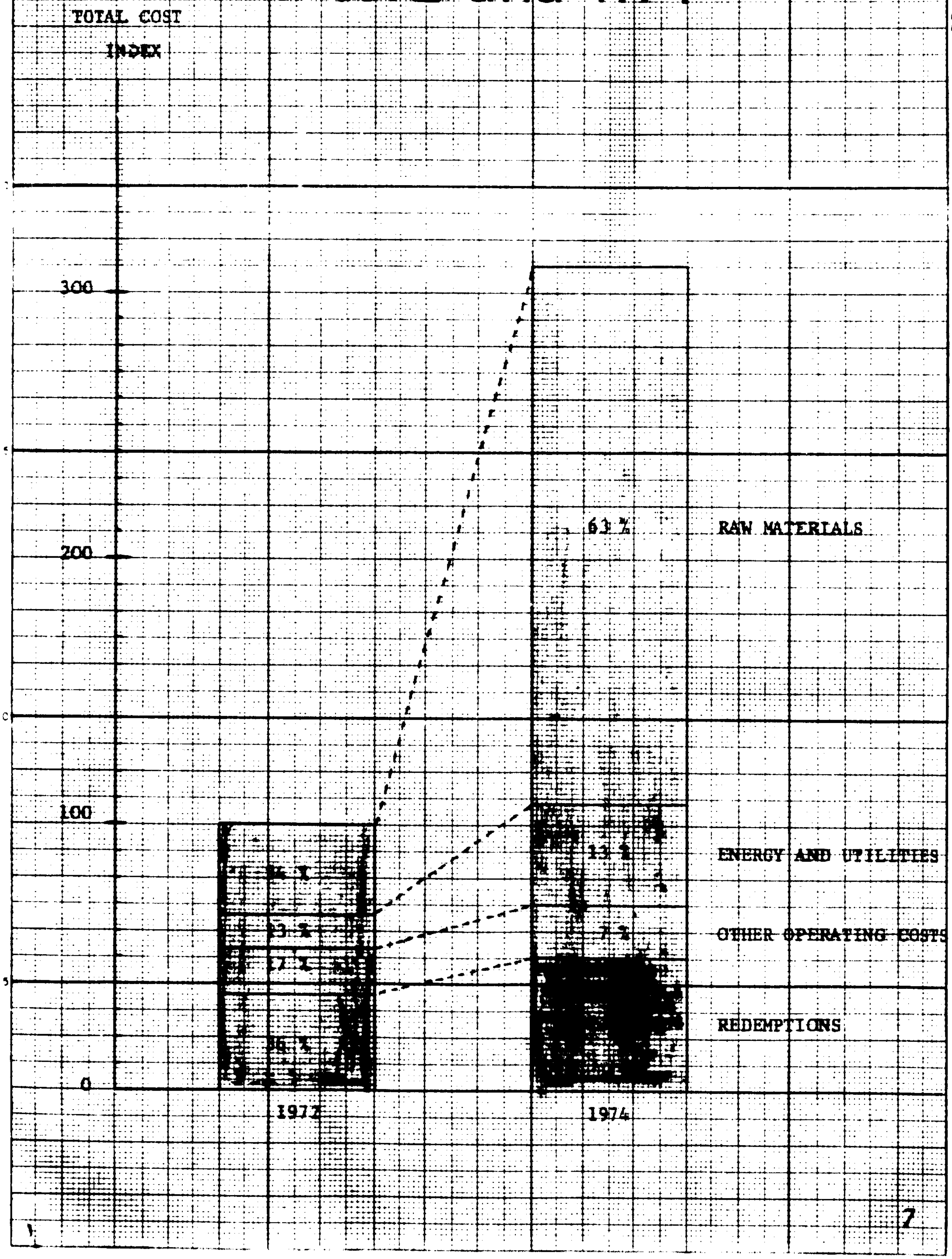


EXHIBIT 7

CHEMICAL AGE - 11 NOVEMBER 1977

Table 1 - YIELD DATA % WT

FEEDSTOCK	ETHANE	PROPANE	NAPHTHA	GAS OIL	VACUUM GAS OIL
Products % wt					
Hydrogen	8.0	2.5	1.5	1.0	1.0
Methane	6.0	28.0	16.0	12.5	9.5
Ethylene	77.0	41.5	29.0	24.5	21.0
Propylene	3.0	14.5	14.0	14.0	12.5
Butadiene	1.5	3.0	4.0	4.5	5.0
Other C_4's	1.5	1.0	5.0	5.0	4.0
Gasoline	1.0	7.0	24.0	17.5	17.0
Fuel Oil	-	0.5	4.5	19.0	28.0
Loss	2.0	2.0	2.0	2.0	2.0
TOTAL	100.0	100.0	100.0	100.0	100.0

EXHIBIT 8

Table 2 - MATERIAL BALANCES 000 TONNE/YEAR

FEEDSTOCK	ETHANE	PROPANE	NAPHTHA	GAS OIL	VACUUM GAS OIL
Products % wt					
Hydrogen	51.9	30.1	25.9	20.4	23.8
Methane	39.0	337.4	275.8	255.1	226.2
Ethylene	500.0	500.0	500.0	500.0	500.0
Propylene	19.5	174.7	241.4	285.7	297.6
Butadiene	9.8	36.1	69.0	91.8	119.1
Other C_4's	9.8	12.1	86.2	102.0	95.2
Gasoline	6.5	84.3	413.8	357.1	404.8
Fuel Oil	-	6.0	77.6	387.8	666.7
Loss	13.0	24.1	34.5	40.8	47.6
TOTAL	649.5	1204.8	1724.2	2040.7	2381.0
Propylene : Ethylene	0.04	0.35	0.48	0.57	0.60
Butadiene : Ethylene	0.02	0.07	0.14	0.18	0.24

OLEFINS PLANTS

RAW MATERIALS	ETHANE	ETHANE PROPANE	FULL-RANGE NAPHTA	HEAVY GAS-OIL
Ratio of capital investment	1	1,14	1,35	1,48
. Other units (Butadiene extraction, light fuel hydrogenation, BTX extraction, toluene delakylation)	0	0,024	0,227	0,24
. Off-Sites	0,5	0,583	0,797	0,87
TOTAL FIXED CAPITAL	1,5	1,747	2,374	2,59
+ Interest during construction (3 years)				
+ Start-up cost (11 % of fixed capital)				
+ Working capital (10 % of fixed capital)				
TOTAL CAPITAL INVESTMENT	2,12	2,46	3,34	3,65
Feed	1,287 kg	1,669	2,833	3,717
Products				
Ethylene	1 000 kg	1 000	1 000	1 000
Propylene		164	470	569
Butadiene			147	242
Butylene			130	223
Benzene			178	212
Toluene			136	126
Xylene			51	30
Gazoline		70	116	134
Light fuel oil			26	284
Excess fuel gas		109		
Value TOTAL PRODUCTS / Ethylene =	1	1,20	2,12	2,50
Return on investments before taxes	5,5 %	5,9 %	14,1 %	21,2

OLEFINS PLANTS

ECONOMICALS FOR UNITS PRODUCTING 450 KT/YEAR OF C^2H^4

DEPENDING ON USED RAW MATERIALS

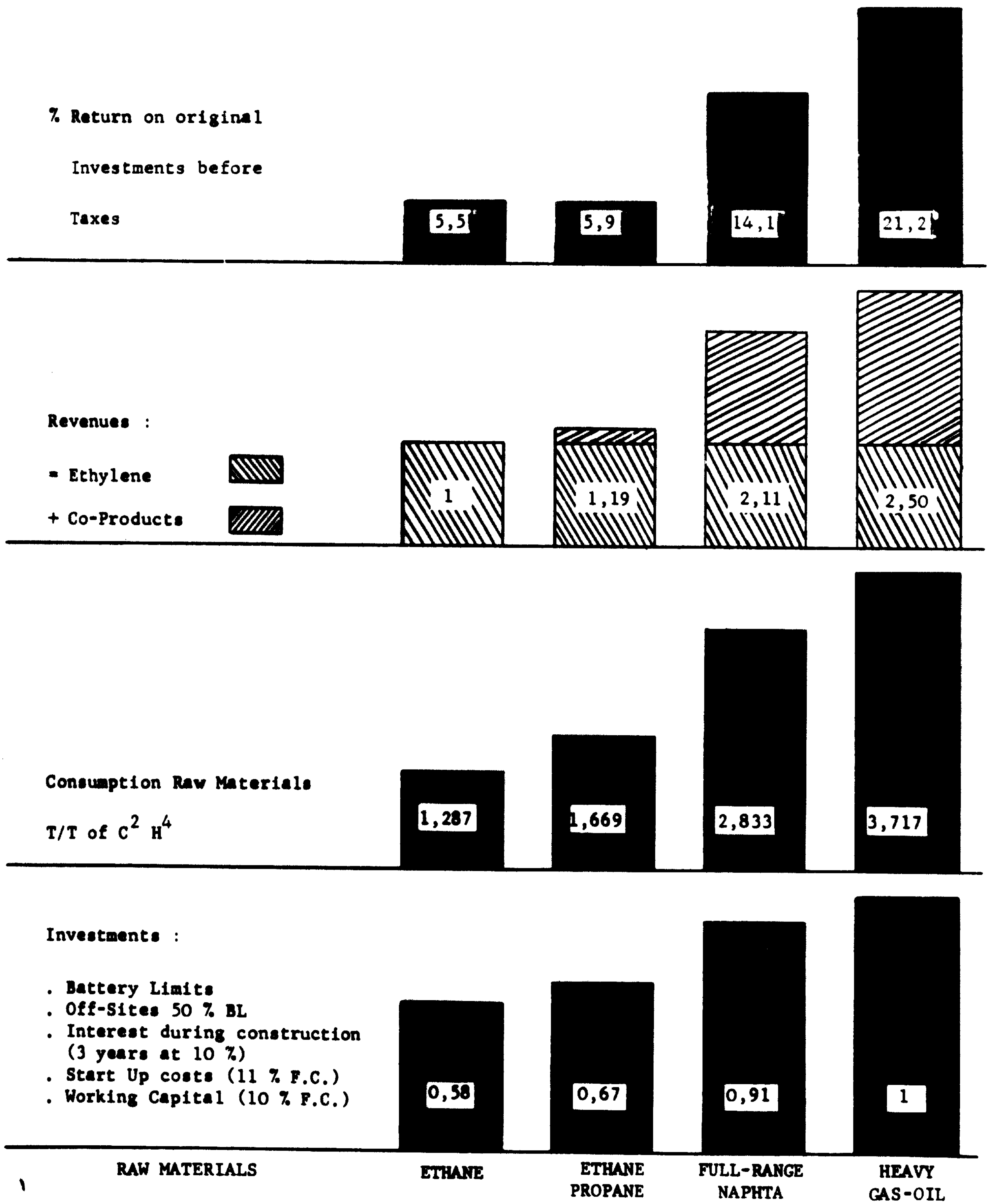


TABLE 10

CHEMISTRY FROM ALCOHOL

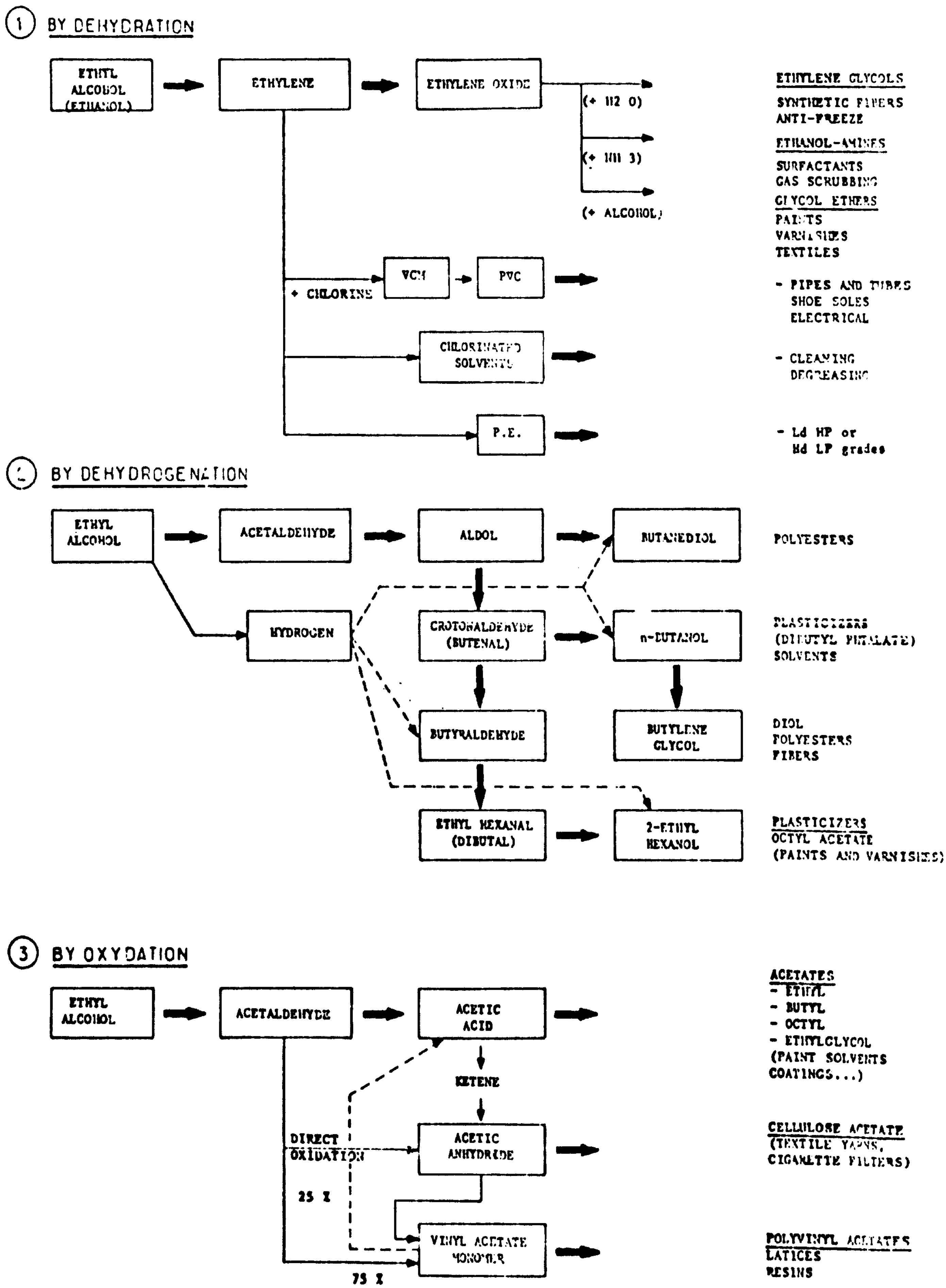


Table 1

PRODUCTION AND YIELD CHART FOR A POLYVINYL CHLORIDE / POLYETHYLENE COMPLEX BASED ON 50.000 METRIC TONS PER YEAR ETHYLENE FROM MOLASSES

100 000 HECTARES (247.000 ACRES) OF SUGAR CANE PLANTATION
WITH A YIELD OF 85 TO 100 TONNES/HECTARE
(Source : U.S. Department of Agriculture - 1974 Data Base)

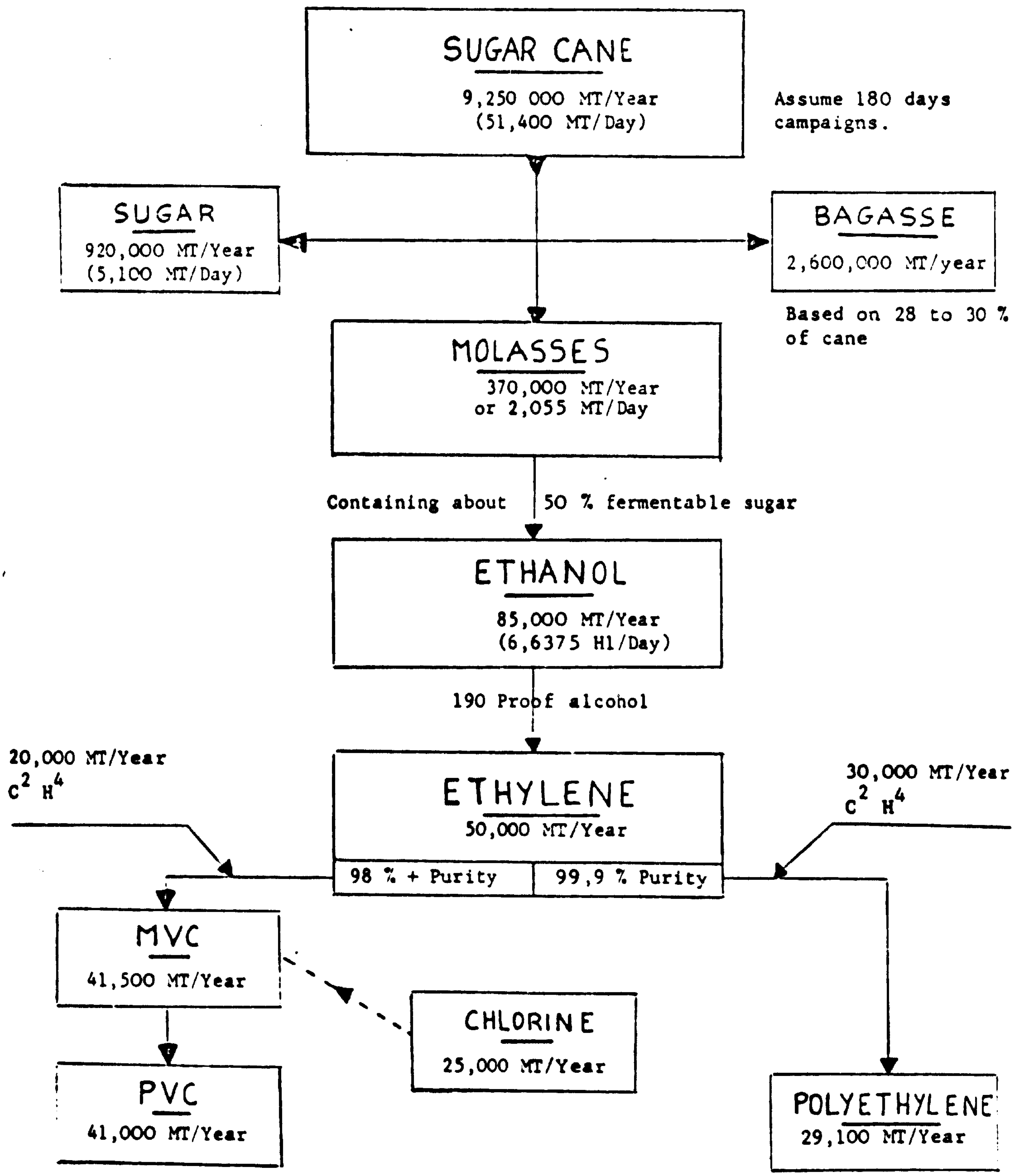


TABLE 12

TABLE 2

PRODUCTION AND YIELD CHART FOR A POLYVINYL CHLORIDE / POLYETHYLENE COMPLEX BASED ON 50,000 METRIC TONS PER YEAR ETHYLENE FROM SUGAR CANE

16 800 HECTARES (41500 ACRES) OF SUGAR CANE PLANTATION
WITH A YIELD OF 85 TO 100 TONNES/HECTARE
(Source · U. S. Department of Agriculture-1974 Data Base)

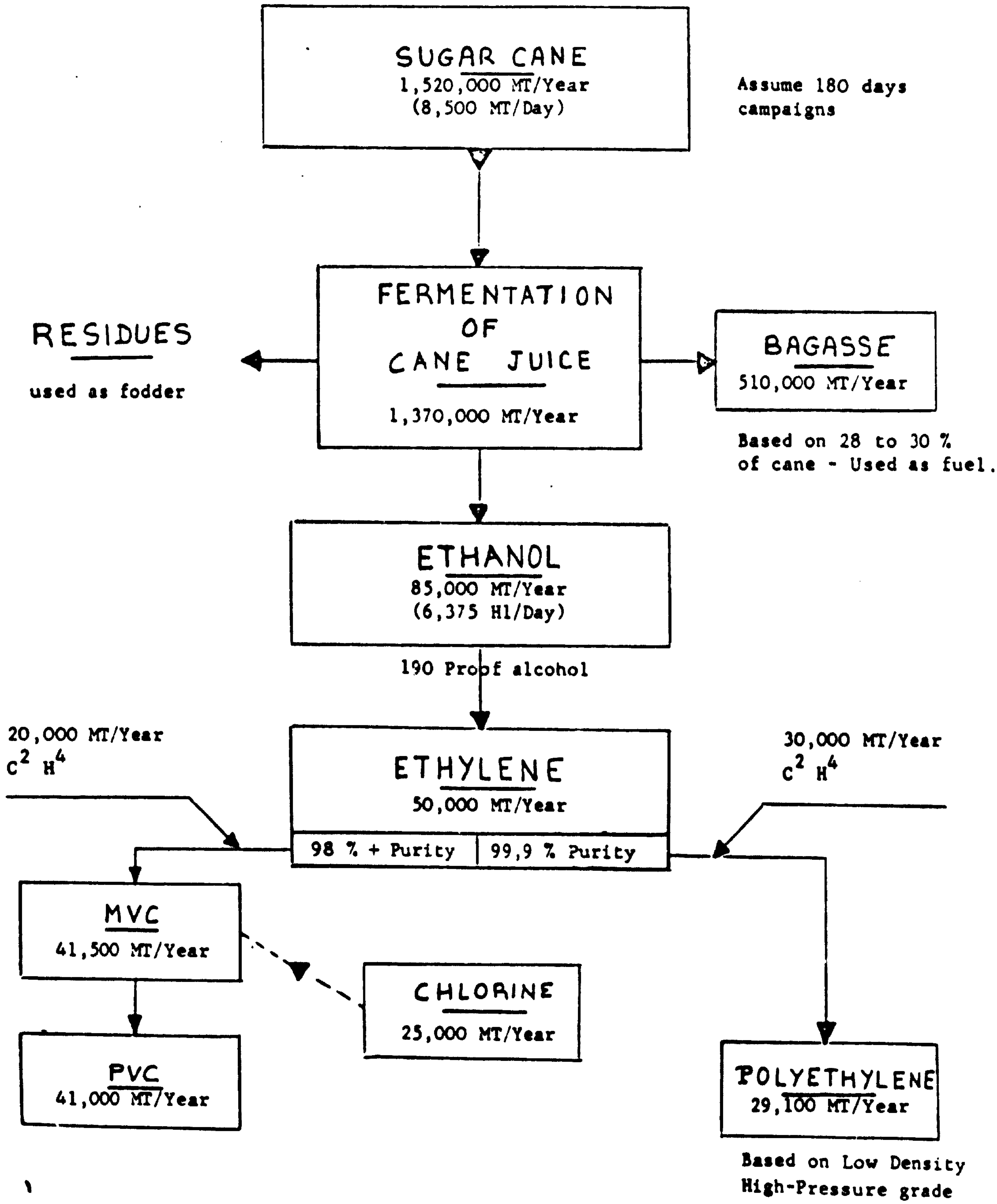
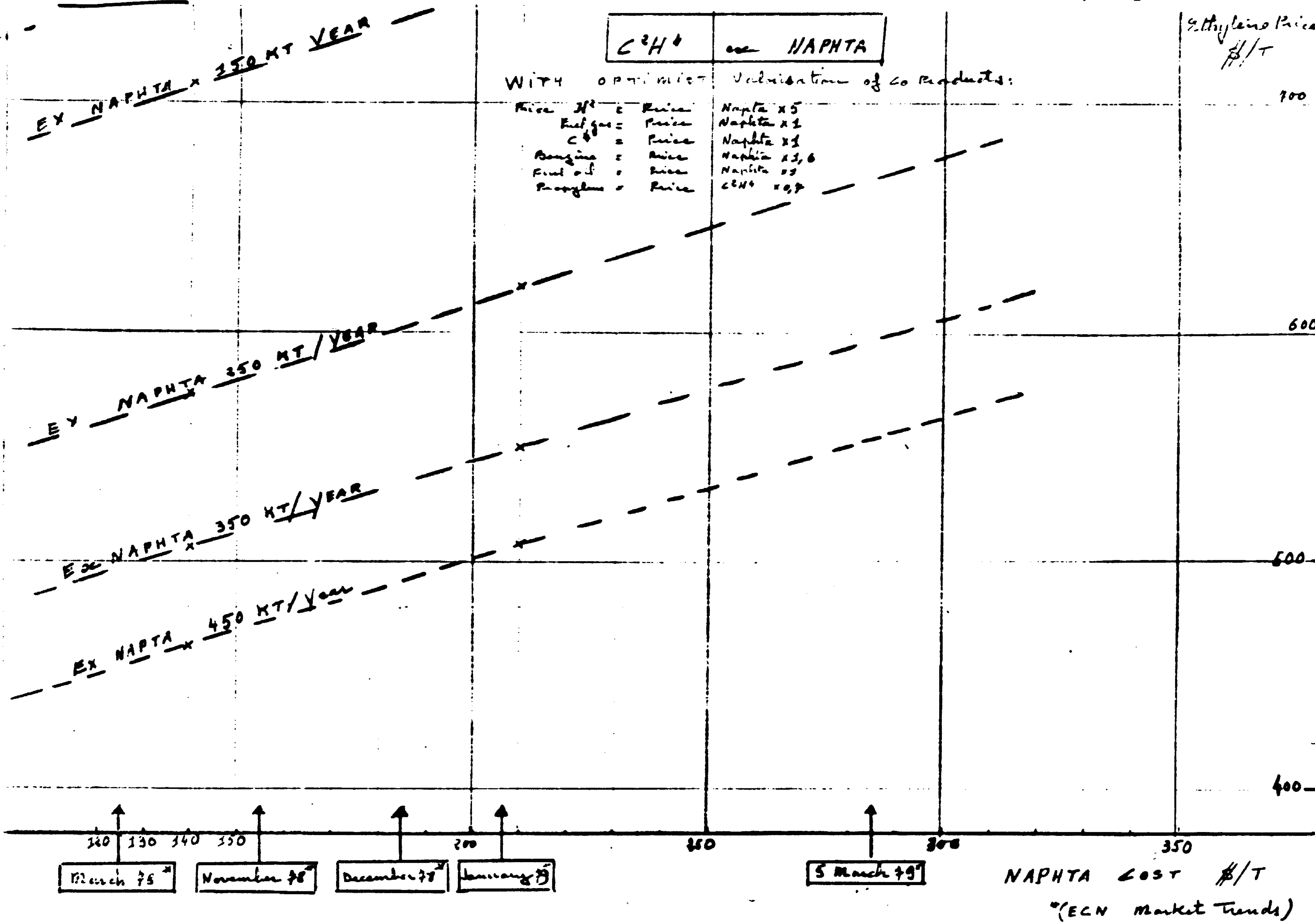
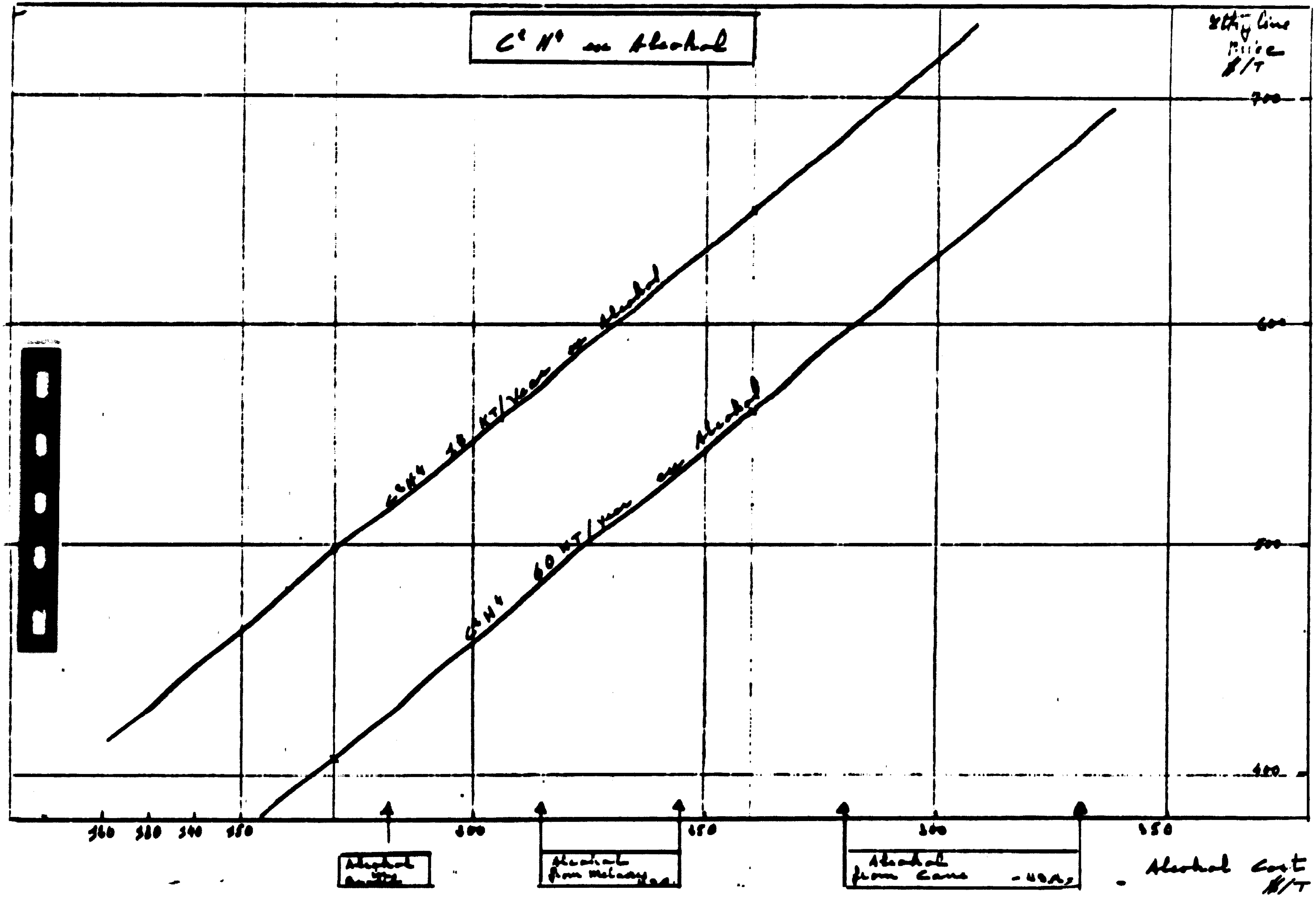


EXHIBIT 13



C^2H^4 on NAPHTA
WITH optimist valorisation of co-products:
Price H^2 = Price Napta x 5
Fuel gas = Price Naphta x 1
C^4 = Price Naphta x 1
Benzine = Price Naphta x 1,6
Fuel oil = Price Naphta x 1
Propylene = Price C^2H^4 x 0,7
EX NAPHTA x 250 KT YEAR
EX NAPHTA x 350 KT/YEAR
EX NAPHTA x 350 KT/YEAR
EX NAPTA x 450 KT/Year
Ethylene Price $/T
700
600
500
400
120 130 140 150
200
250
300
350
March 75
November 78
December 78
January 79
5 March 79
NAPHTA COST $/T
(ECN Market Trends)

EXHIBIT 14


C² H⁴ ex Alcohol
Ethylene Price $/T
700
600
500
400
C²H⁴ 18 KT/year ex Alcohol
C²H⁴ 60 KT/year ex Alcohol
160
180
140
150
200
250
300
350
Alcohol from Molasses
Alcohol from Cane
Alcohol Cost $/T

B-83

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