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Vienna, Austria, 26 - 30 March 1979

THE ETHANOL-BASED CHEMICAL INDUSTRY IN BRAZIL*

by

F.A. Ribeiro Filho**

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THE ETHANOL - BASED CHEMICAL INDUSTRY IN BRAZIL*

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F.A. Ribeiro Filho**

The monograph presents the Brazilian background in the production of ethanol-based chemicals as well as the future outlook for the sector.

Such alcohol based industries flourished in Brazil for a period of time. Nevertheless several of them were shutdown due to the use of petrochemical feedstocks for the production of those chemicals.

Following the energy crisis and the associated increase in the price of crude oil, which have particularly affected the economics of the developing countries that depend on oil imports, a new emphasis has been given in Brazil to the use of ethyl alcohol, either as motor fuel or as raw material for the chemical industry.

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In regard to the chemical industry, a great number of old alcohol-based facilities are being reactivated and new ones are also being planned.

A list of all ethanol-based chemical plants in Brazil is presented, with their respective capacities, process licensors, markets, the present status and eventually their plans for expansions.

On the other hand, the prospective use of new alcohol-based chemical routes in Brazil is discussed.

The main processes ever used in Brazil for the production of ethanol-based chemicals are presented and evaluated from the economical point of view, comparing them to the conventional petrochemical routes.

SUMMARY

Brazilian ethanol-chemical experience is analysed at different historical moments.

Initially, the author describes the most important facts of the ethanol-chemical industry in Brazil, from installation of the first industrial units to manufacture several products in a small scale, through 1973-74 when some large projects were already implemented.

Next there is a more detailed review of present situation of the ethanol-chemical industry and its trends. After analysing the impact of the petroleum crisis, which, through the National Alcohol Plan, led to a comeback and strengthening of this industrial activity in the country, the author discourses about the prospects of implementation, during the next years, of several ethanol-based chemical projects.

The principal ethanol-chemical processes already utilized by producing companies are described and evaluated, from a technical and economical point of view, to better judge their competitiveness as compared to alternative petrochemical routes.

The author, finally, ponders about the future of the ethanol-chemical industry in Brazil, and tries to point out the courses of future developments.

1. DEVELOPMENT OF THE ETHANOL-CHEMICAL INDUSTRY IN BRAZIL

The ethanol-chemical industry, in the sense attributed to is in this paper, relates to the manufacture of chemicals using ethanol as raw material.

Markedly distinct phases characterize the development of this activity in Brazil until 1974, as set forth below.

1.1. Pioneer Phase (1920 - 57)

Commencement of the ethanol-chemical industry in the country goes back probably to the first years of the twenties, when PRODUTOS QUÍMICOS ELEKEIROZ, USINA COLOMBINA and CIA. QUÍMICA RHODIA BRASILEIRA, all installed in the State of São Paulo, obtained popularity by manufacturing perfume-squirters based on ethyl chloride, from ethanol.

Besides ethyl chloride, RHODIA BRASILEIRA manufactured, in its Santo André unit, acetic acid and ethyl ether in small quantities, both also obtained from ethanol.

In 1929, the sector had a significant upswing with the installation of CIA. BRASILEIRA RHODIACETA which in subsequent years began to manufacture cellulose acetate using acetic acid and acetic anhydride, the latter also synthesized from ethanol. Later (1965) this company and RHODIA BRASILEIRA would merge to form RHODIA INDÚSTRIAS QUÍMICAS E TÊXTEIS (RIQT).

By 1940 the following derivatives of ethanol were already being produced in Brazil: ethyl chloride, ethyl ether (at RHODIA and at the War Ministry, in Piquete, State of São Paulo), acetic acid and acetic anhydride.

In the early fifties, USINA VICTOR SENCE, installed at Conceição de Macabu, in Rio de Janeiro, started commercial production of butanol and acetone from residual molasses fermentation. In 1952 the company inaugurated its plant to produce acetic acid from ethanol, as well as a continuous esterification unit for the production of butyl acetate.

1.2. Expansion Phase (1958-69)

In late fifties, Brazilian ethanol-chemical industry was directed toward refinery ethylene production, then insufficient to meet requirements of the first petrochemical units using it as raw material.

Two alcohol ethylene units were installed, one by UNION CARBIDE DO BRASIL, in 1958, to supply its low density polyethylene plant, and the other by CIA. BRASILEIRA DE ESTIRENO, in 1959, to supply its styrene plant.

In 1962, INDÚSTRIAS QUÍMICAS ELETRO CLORO started its ethylene production by means of ethanol dehydration to meet requirements of its high density polyethylene plant. Around the same time RHODIA's vinyl acetate unit started operations, employing acetylene and acetic acid obtained from ethanol.

Molasses availabilities then abundant which permitted alcohol production in large scale and at marginal costs, encouraged the implementation of more enterprising ethanol-chemical projects.

CIA. PERNAMBUCANA DE BORRACHA SINTÉTICA - COPERBO in 1965 started to produce butadiene from ethyl alcohol, according to a process developed by UNION CARBIDE in the States during the Second World War. Processing facilities also covered production of the intermediate acetaldehyde.

In 1969 began production of 2-ethylhexanol, by means of an entirely ethanol-chemical route, by ELEKEIROZ DO NORDESTE, and butanol, acetic acid and ethyl acetate were obtained in the same unit as by-products.

The sixties determined therefore an outstanding growth of the Brazilian ethanol-chemical industry, which then was already covering a widely diversified range of products.

1.3. Decline Phase (1970-74)

In the earlies seventies, reflecting the problems which began to be felt at the end of the preceding decade, difficulties in supplying ethyl alcohol to the chemical industry worsened. Raw material was scarce and suffered successive price increases (a 67% increase during period 1967-69), in view of the favorable circumstances displayed by molasses and sugar international market.

Therefore, competitivity of ethanol-chemical products as compared to imported similar products became extremely difficult, since the latter were manufactured from a negligible price (less than \$2.00/bbl.) raw material (petroleum).

On the other hand, implementation in the country of large petrochemical projects, to take advantage of the effects of economies of scale and of the utilization of processes more advanced than those of the ethanol-chemical industry, rendered even more unfeasible use of the latter to manufacture the same products.

Such facts made the operation of some ethanol-chemical units non-economical and the ethylene units of CIA. BRASILEIRA DE ESTIRENO (1970) and UNION CARBIDE (1971) and the butadiene unit of COPERBO (1971) were shut down.

ELETRO CLORO ethylene unit even stopped for three months, in 1973, but was started up again in view of the difficulties to supply petrochemical ethylene, and is in operation until this date.

2. COMEBACK AND STRENGTHENING OF THE SECTOR

With the supply crisis and continuous increase in petroleum prices, which affected specially the economy of developing countries depending upon imported raw material, emphasis began again to be given in Brazil to using ethyl alcohol, both as a fuel and for the manufacture of chemicals.

In this sense, the Brazilian Government, in November 1975, instituted the National Alcohol Plan (PROALCOOL), with the main purpose of rapidly expanding alcohol production in the country through modernization, expansion and implementation of independent distilleries or annexed to sugar mills and its corresponding agricultural projects.

For the purpose of defining the incentives, policies, priorities and execution plans of the program and to review applications for acceptance of projects, the National Alcohol Commission was created, composed of representatives of six State Departments, and with the operational support of the Sugar and Alcohol Institute (IAA) and the National Petroleum Council (CNP).

From late 1975 through March 1979, the National Alcohol Commission had approved 218 projects for distilleries throughout the national territory, 95 of which were annexed to mills and 123 independent distilleries.

Such facilities, expected to begin normal operations until the 1982/83 crop, represent a total production capacity of 4,9 billion liters per year.

The first results of PROALCOOL are already being felt. And therefore, as evidenced in Table I, national alcohol production increased from 551,7 million liters in the 1975/76 crop to 1,47 billion liters in the 1977/78 crop.

TABLE I

BRAZILIAN ALCOHOL PRODUCTION

ANNUAL CROPS	TOTAL liters	INDUSTRIAL		ANHYDROUS	
		liters	%	liters	%
1970/71	637,238,053	384,841,365	60.39	252,396,688	39.61
1971/72	613,068,236	223,120,029	36.40	389,948,207	63.60
1972/73	680,971,982	292,080,849	42.89	388,891,133	57.11
1973/74	665,817,333	359,605,851	54.01	306,215,482	45.99
1974/75	625,166,230	408,638,389	65.36	216,527,841	34.64
1975/76	551,731,642	322,441,931	58.44	229,289,271	41.56
1976/77	664,021,701	363,682,092	54.76	300,339,609	45.24
1977/78	1 470,403,833	293,455,959	19.95	1,176,947,874	80.05
1978/79 (*)	2,560,000,000	-	-	-	-

(*) Estimated

Present trend, as can be seen from said Tabl , is toward an increase in percentage of anhydrous alcohol with a view to its progressive utilization in carburant blends added to gasoline.

Taking as a reference year 1977, from January through December, it was found that, from 1.38 billion liters of alcohol produced, 79% were in anhydrous alcohol and the remainder in industrial alcohol. During the same year, alcohol consumption for carburant purposes was 741 million liters, whereas the portion destined to chemicals production (excluding cosmetics and pharmaceutical specialties) was of the order of 100 million liters.

The ethanol-chemical industry, therefore, is shown as a secondary factor in view of use of alcohol as a fuel, to the extend that raw material availabilities, as estimated in the National Alcohol Plan, ensure its future expansion with no significant reflection on the volume intended for automotive uses.

Still in respect of the chemical industry, the Brazilian Government decided to subsidise production from ethyl alcohol of such organic derivatives which could be manufactured alternatively by a petrochemical route. In this sense, price of a cubic meter of ethanol for such use is ensured in up to 35% of price per ton of petrochemical ethylene, and the National Petroleum Council is entrusted with establishing the quotas to be destined to the industries, whereas the Sugar and Alcohol Institute is in charge of promoting, prioritarily, its supply.

On the other hand, scarcity, in the international technology market, of competitive ethanol-chemical processes, where scale levels and economicability are concerned, as compared to processes in modern chemical industry, have led companies and research institutions in the country to take up again studies for the development of new processes and to improve those already existing.

Amongst such initiatives the works already carried out by CENTRO DE PESQUISAS DA PETROBRAS - CENPES, should be pointed out. They comprise particularly the basic design of a 60,000 ton/year ethylene unit, from ethyl alcohol, to be constructed by SALGEMA INDÚSTRIAS QUÍMICAS S.A., intended to supply its dichloroethane plant.

Works in this area, originally intended to scale-up units already existing in the country (capacity limited to around 3,000 ton/year (per reactor), culminated in the development of a new process, which efficiency was already tested in a pilot plant.

COMPANHIA PERNAMBUCANA DE BORRACHA SINTÉTICA - COPERBO, a company within PETROBRAS System, has been performing experiments, likewise successful, to obtain ethylene from alcohol at its former butadiene unit.

It should be further pointed out that PETROBRÁS QUÍMICA S.A. - PETROQUISA, through its TECHNICAL MANAGEMENT - GETEC, is presently implementing a technological development program in the acetic acid production field. A similar program, involving technologies for acetaldehyde, acetic acid and butanol, is being carried out by OXITENO INDÚSTRIA E COMÉRCIO S.A.

3. ALTERNATIVE RAW MATERIALS FOR ALCOHOL PRODUCTION IN BRAZIL

In addition to a formidable territorial extent (8,512,000 Km2), of which only a negligible fraction represents cultivated areas (about 430,000 Km2), Brazil gathers other favorable ecological conditions for the production of ethyl alcohol of vegetal origin, such as a tropical climate, high insulation and quality of soil appropriate to the required cultures.

Within this context, several raw materials are being considered to produce alcohol in large scale in the country, particularly saccharineous materials such as sugar cane and sorghum, and starchy materials such as manioc (cassava) and babassu.

Table II gives a summary of main technological characteristics of such raw materials, from an agricultural and industrial standpoint, with a view to their utilisation for alcohol production. Figures indicated correspond to average values presently prevailing in Brazil. In practice such values are subject to high fluctuations in accordance with the variety cultivated and the region. Therefore, in certain areas of the Center-South region of Brazil, sugar cane productivity has reached values as high as 65-70 t/ha.

Table III lists the projects for distilleries approved by the National Alcohol Commission until March 1979, which sum a total production capacity of the order of 4.9 million cubic meters of ethanol per year.

3.1. Sugar Cane

Sugar cane, which for centuries has been produced and industrialized in Brazil, stands out as the most immediate use raw material for alcohol production, and shall be liable for the major part of the increase in supply of such product during the next years, specially through the so-called "annexed distilleries",

TABLE II

RAW MATERIALS FOR ALCOHOL PRODUCTION

RAW MATERIALS	COMPOSITION (%) OF NATURAL OR FRESH MATERIAL		GROWTH CYCLE	AGRICULTURAL PRODUCTIVITY t/ha	ALCOHOL PRODUCTION		
					BASIC STEPS	AVERAGE YIELD	
	SUGARS*	STARCH	Months	(Avge.Brazil)		liter/ton	liter/ha
1. SUGAR CANE (stalk)	13-17		18	50	Grinding Fermentation Distillation	67	3350
2. SORGHUM			4				
2.1 Stalk	12-17			35		70	2450/4900**
2.2 Grain	1-2	55-70		3	Disintegration Cooking Saccharification Fermentation Distillation	340	1020/2040**
2.3 Stalk + Grain						410	3470/6940**
3. MANIOC (roots)	2-5	25-35	22	12,5		180	2250
4. BABASSU (coconut)		12-16	84-96	2,5		80	200

* As Glucose

** Estimated production considering one/two crops per year, respectively

TABLE III

PROJECTS FOR CONSTRUCTION OF ALCOHOL DISTILLERIES

APPROVED BY NATIONAL ALCOHOL COMISSION UNTIL MARCH 1979

RAW MATERIALS	ANNEXED DISTILLERIES			INDEPENDENT DISTILLERIES			TOTAL		
	NUMBER	CAPACITY		NUMBER	CAPACITY		NUMBER	CAPACITY	
		10^3 1/day	10^6 1/year		10^3 1/day	10^6 1/year		10^3 1/day	10^6 1/year
SUGAR CANE	123	18,[illegible]	2,745	83	10,670	1,823	206	29,110	4,[illegible]8
MANIOC	-	-	-	11	1,110	335	11	1,110	335
BABASSU	-	-	-	1	30	9	1	30	9
TOTAL	123	18,440	2,745	95	11,810	2,167	218	30,250	4,912

which use molasses coming from sugar mills.

To lesser the effects of international sugar market fluctuations on the domestic alcohol production, the Brazilian Government decided to encourage the construction of "independent distilleries", so called those which employ cane juice directly as raw material for alcohol production.

From sugar cane, in the preliminary phase of the industrial process, are separated the juice and the bagasse. Such two elements are the starting point to obtain a great number of industrial products, as can be seen from Figure 1.

Brazilian sugar cane production is presently approximately 100 million tons per year, with a cultivated area of the order of 2.1 billion hectares.

3.2. Sorghum

Sorghum (*sorghum vulgare*), a gramineous plant native of Africa, was according to FAO statistics for 1974, the fifth cereal in importance around the globe in relation to cultivated area, surpassed only by wheat, rice, corn and barley.

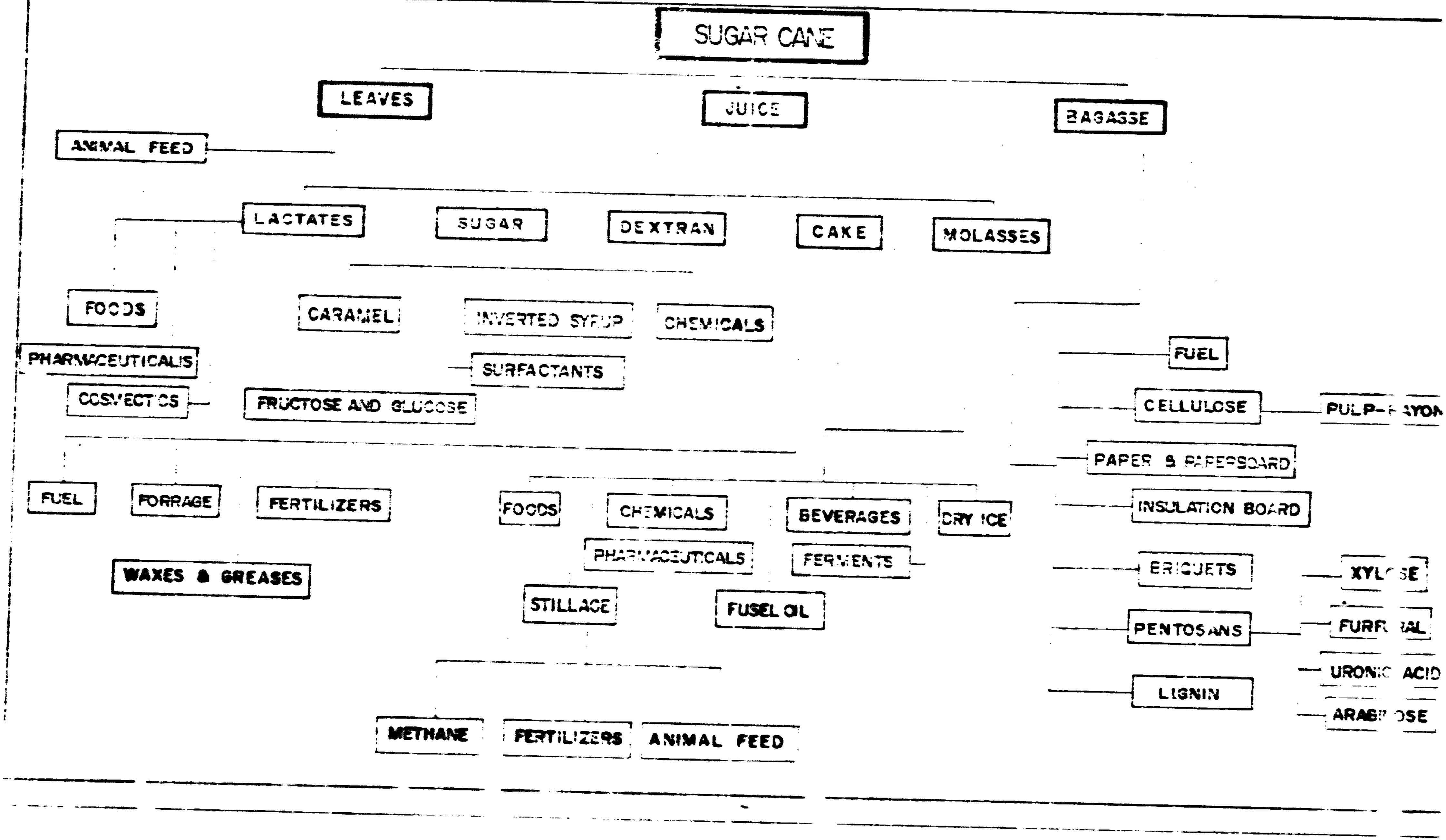
The use of sacchurineous varieties of sorghum, whose stalk is rich in sugar, to produce ethyl alcohol has been deserving a special attention in Brazil, in view of the possibility of extracting and fermenting the juice in the same equipment used for sugar cane, which therefore represents an alternative for better utilization of installed capacities of distilleries based on sugar cane use.

Other advantages noted for sorghum are:

i) short cultural cycle, which permits two crops per year;

FIGURE— 1

SUGAR CANE DERIVATIVES



ii) suitability of the culture to limited hydric resources regions;

iii) possibility of using the grains, rich in starch, to produce alcohol, which would permit full utilization of the plant.

The commercial exploitation of sorghum in Brazil is still beginning, and the implementation of this culture in the country depends on agronomical studies to determine the cultivation characteristics and to establish the ecological regions most suitable to obtain high productivity indices.

3.3. Manioc

Production in industrial scale of manioc (*Manihot esculenta*) alcohol was previously carried out in Brazil at the Divinopolis Mill, in Minas Gerais, which operated during ten years (1932-42), producing a total estimated at 5,300 liters of alcohol. Sundry factors, such as low agricultural yield, competition with low price petroleum derivates, and problems with the industrial processing for starch hydrolysis, have contributed for the halting of such production.

This activity was recently resumed, with the installation by PETROBRÁS of a manioc alcohol distillery at Curvelo, Minas Gerais, with a nominal capacity of 60,000 liters/day. The process used is based on the enzymatic hydrolysis of the starch and was entirely developed by the NATIONAL TECHNOLOGY INSTITUTE.

As yet, the main problem with manioc utilization in manufacturing alcohol lays in its low agricultural yield which however may be explained by the fact that this is a characteristically subsistence culture, which causes this euphorbiaceous plant to be cultivated in a totally empiric manner. With the implementation of alcohol distilleries from manioc, whose supply is to be based on an industrial culture, it is expected that productivity indices above 20 t/ha will be attained.

. A manioc alcohol production complex (as shown in Figure 2) comprises an integrated agro-industrial pole, with the economic feasibility of the project depending highly on the marketing of several by-products.

As regards stillage (a production of the order of 13 liters per liter of alcohol), with polluting characteristics, several solutions have been submitted for its utilization, such as:

i) as a fertilizer;
ii) as a producer of a fungal biomass used as animal feed;
iii) as a methane gas generating source.

Brazilian production of manioc is the largest in the world. In 1975 it was slightly higher than 26 million tons, with a cultivated area of 2.0 million hectares.

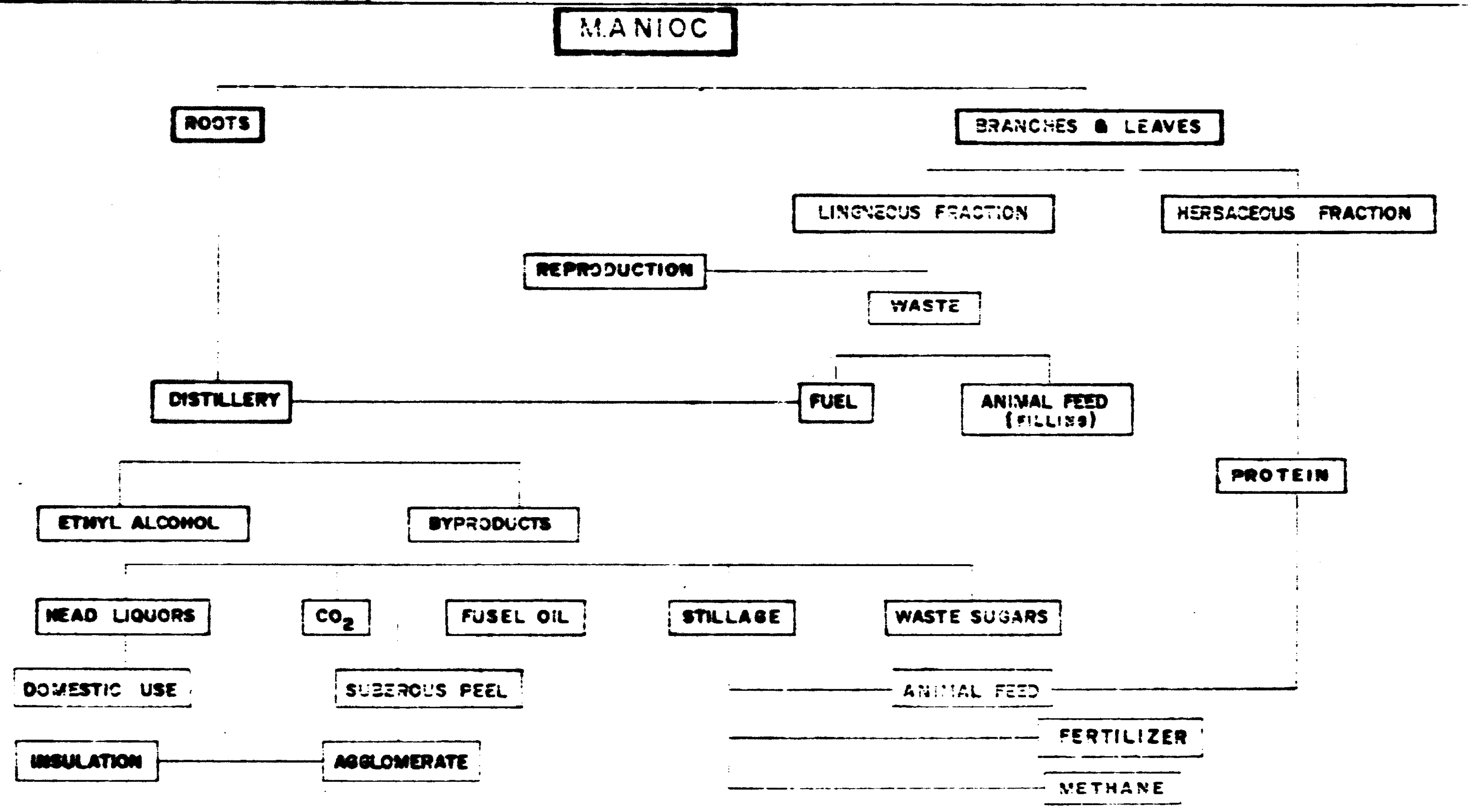
3.4. Babassu

Babassu is a palm tree native of Brazil, and under this name several species of genus *Orbignya* and *Attalea* are known.

Frutification of the palm-tree commences between the seventh and the eighth year, and it produces from 3 to 6 clusters/year, each containing an average of 150 to 300 coconuts. The palm-tree's productive life is estimated between 10 and 35 years.

The babassu coconut is constituted of three layers: epicarp (11% of the coconut, as an average), fibrous outside layer; mesocarp (23%), starchy-fibrous intermediate layer; and endocarp (59%), ligneous inside

FIGURE — 2 PRODUCTS FROM THE WHOLE PROCESSING OF MANIOC



layer, where the kernels (7%) are lodged.

The mesocarp has an average content of 65-68% starch (15-16% of the coconut), proving to be an important raw material for ethanol production.

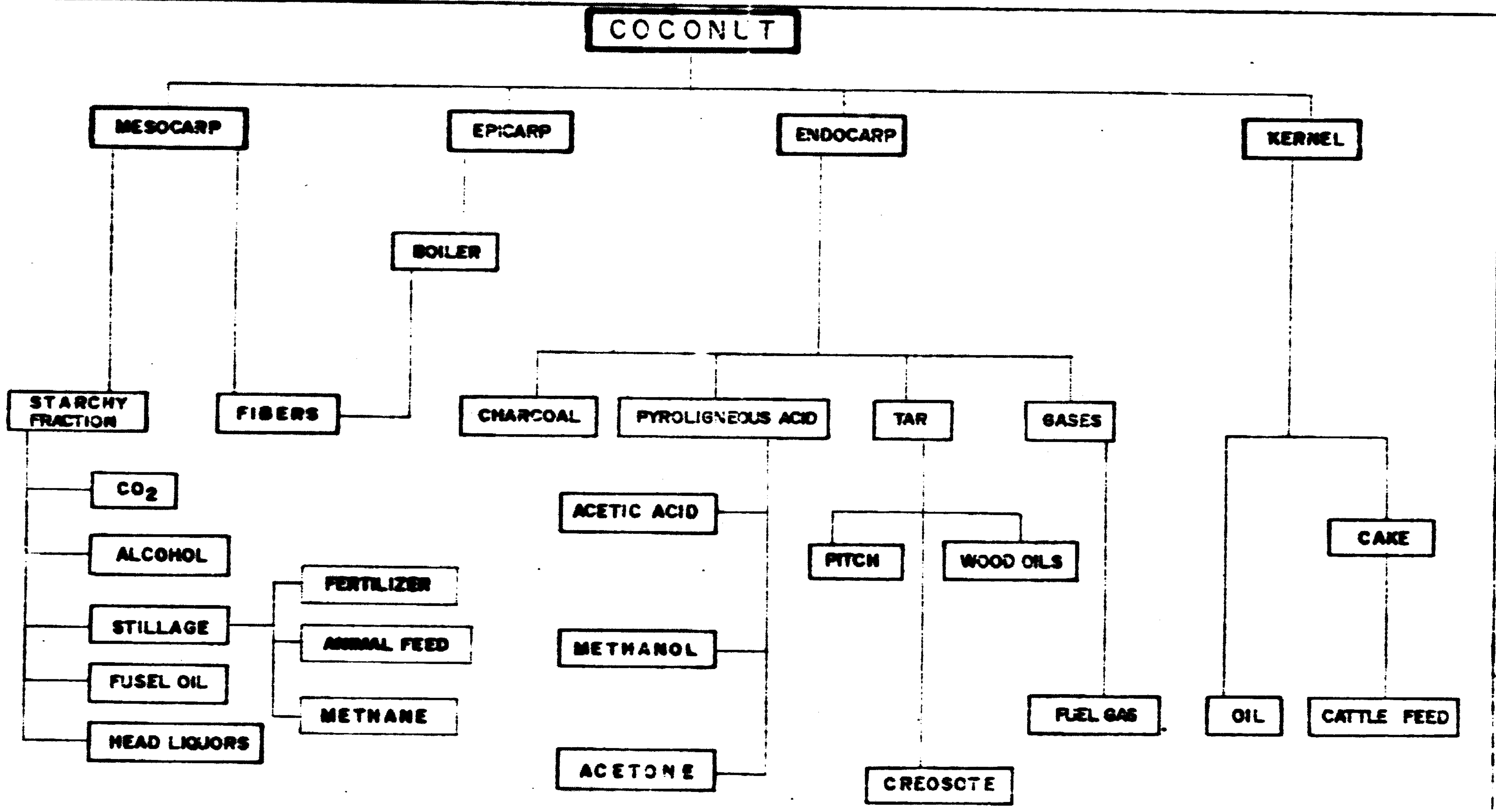
By an integrated processing of the different parts of the babassu coconut, a great variety of important by-products is obtained, as shown in Figure 3. It should be pointed out, however, that such processing has only now become feasible, with the appearance of modern equipment to crack the coconut in an industrial scale, which used to be traditionally done in an empiric way for the sole purpose of utilizing the kernels.

In Brazil, the agricultural productivity of babassu and the palm-tree's occurrence area are data still largely debated, and it is believed, however, according to surveys made, that 2.5 ton of coconut per hectare and 15.0 million hectares are, respectively, representative values. Taking into account that only 33% of this area has a productive coverage, a productive potential of the order of 12.4 million tons of coconut per year are estimated, which could be converted into the following quantities of by-products:

By-Products	Unit/ton Coconut	Total/Year
Alcohol (liters)	80	1.0×10^9
Charcoal (tons)	0.19	2.4×10^6
Gas - 3,850 Kcal/Kg (ton)	0.11	1.4×10^6
Pyroligneous Acid (ton)	0.24	3.0×10^6
- Acetic acid (ton)	(0.04)	(0.5×10^6)
- Methanol (ton)	(0.0065)	(0.8×10^5)
Tar (ton)	0.05	0.6×10^6
Epicarp - 4,260 Kcal/Kg (ton)	0.11	1.4×10^6
Oil (ton)	0.04	0.5×10^6

The above data clearly indicate the enormous

FIGURE — 3 PRODUCTS FROM THE WHOLE PROCESSING OF BABASSU



potential of babassu as a source of energetic by-products and chemicals.

3.5. Other Raw Materials

Within this year a pilot plant for the production of ethanol and foundry coke from vegetable residue (leaves and branches) will be in operation at Lorena, State of São Paulo, employing an acid hydrolysis process developed by the NATIONAL TECHNOLOGY INSTITUTE.

Annual availabilities of vegetable residue originating from the lumber industry are estimated at 15 million tons, which, if fully utilized, could produce approximately 4 billion liters of ethanol and 3 million tons of coke.

4. PROSPECTS OF NEW ETHANOL-BASED CHEMICAL PROJECTS

Figure 4 shows the routes of an ethanol chemical industry, stressing those already manufactured and those about to be utilized in Brazil, with defined operating units. The others represent projects which may be feasible, presently under consideration by different producing companies.

The already defined projects represent investments of approximately US$ 100 million (historic value) and involve an additional alcohol consumption of the order of 400 millions liters/year.

Prospects of implementation in the country of some specific projects are set forth below.

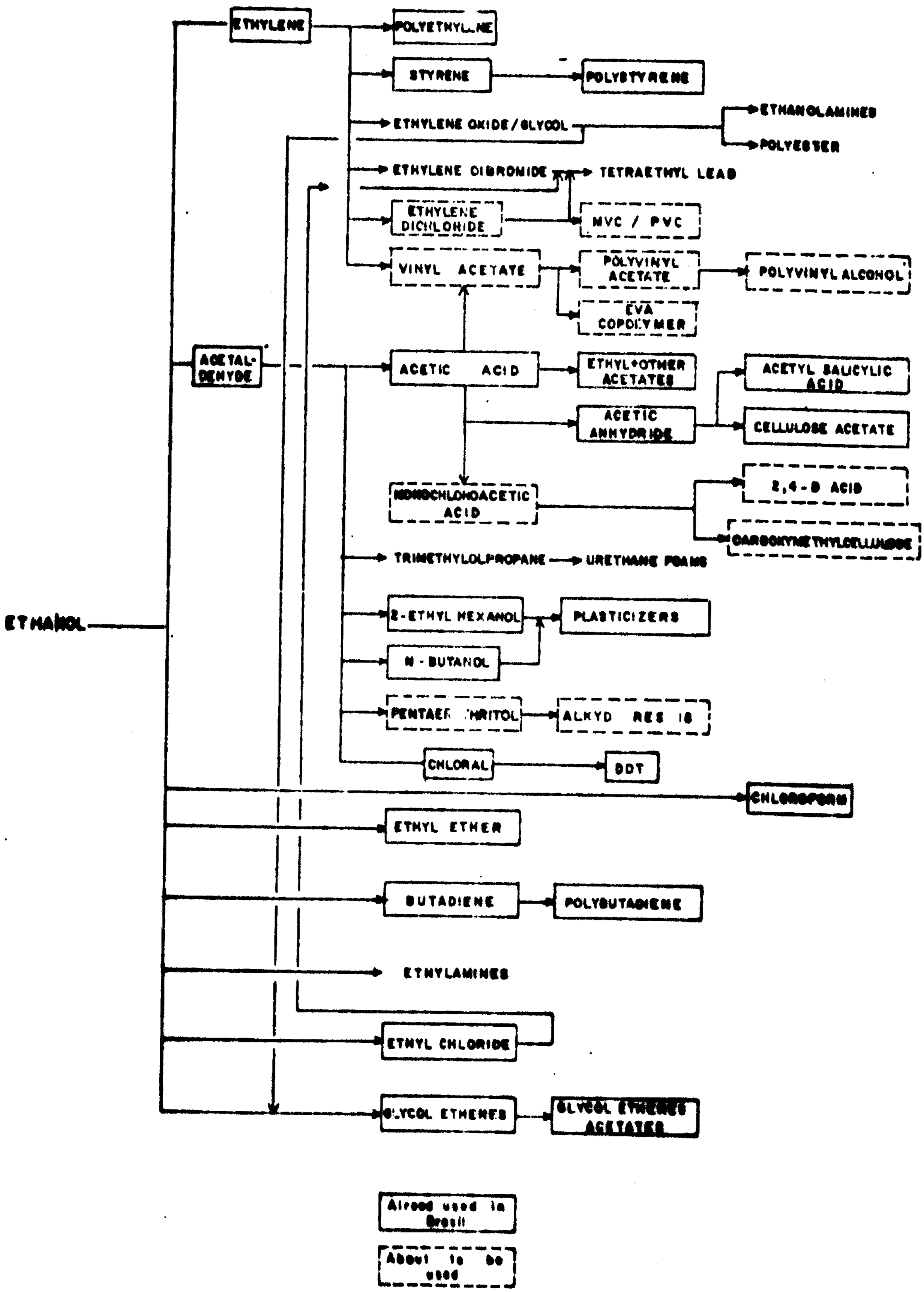
4.1. Production of Ethylene and Derivatives

Brazil has at present, in operation, two large basic petrochemical complexes (PETROQUÍMICA UNIÃO S.A., in São Paulo, with a 330,00 ton/year of ethylene capacity, and PETROQUÍMICA DO NORDESTE S.A. - COPENE, in Bahia, with a 384,000 ton/year ethylene capacity), and a third under project to start up in 1981 (PETROQUÍMICA DO SUL - COPESUL, in Rio Grande do Sul, with a 420,000 ton/year ethylene capacity).

The production of ethylene by means of ethanol dehydration, therefore, shall probably take up, still in the future, a fundamentally supplementary character in relation to the manufacture of same by means a petrochemical route, and be directed toward strategic projects, so considered those which:

- require small quantities or raw material;
- attend to small expansions of ethylene consuming units, which would not justify expansion of naphta pyrolysis complexes;
- are located far from petrochemical producing complexes;

FIGURE — 4 ETHANOL - BASED CHEMICAL ROUTES



— meet regional raw material supply schedules.

Within this picture is included the above mentioned project of SALGEMA ethylene unit at Macció, Alagoas, intended to produce dichloroethane locally, which shall be sent to MVC/PVC processing units in other parts of the country. This plan shall not only allow utilization of the chlorine produced there but also the regional availabilities of ethyl alcohol.

COPERBO on its turn, as anticipated, has been studying the adaptation of its butadiene unit to produce ethylene.

On the other hand, the Ethylene Unit of CIA. BRASILEIRA DE ESTIRENO has just been modernized and expanded to provide the requirements of its Ethyl-benzene-Styrene Unit, to supplement petrochemical ethylene feedstock.

At the same time, other opportunities are being investigated, among which the utilization of ethyl alcohol in Campos, State of Rio de Janeiro, as a possible supplement to feasible petrochemical projects.

4.2. Production of Acetaldehyne and Derivatives

Acetaldehyne and its closer derivatives (acetic acid and solvents) were always produced in Brazil by means of an exclusively ethanol-chemical route, and we can say that the technology for obtaining them from ethanol has been entirely absorbed by the companies employing same in the country.

COPERBO has a project for integrated production of MVA from ethyl alcohol and in this respect, in addition to the aforementioned plans for ethylene production, it shall be promoting the reactivation of its acetaldehyne unit and the installation of an acetic acid plant, for which the possibility of adapting existing domestic know-how is being considered.

RHODIA, on its turn, has a project to manufacture ethyl acetate at its industrial complex, at Paulinea, São Paulo, expanding its capacity from 9,800 to 25,000 ton/year.

The technology to produce n-butanol and 2-ethylhexanol from ethyl alcohol may also be considered fully absorbed. Products obtained by means of this route are being placed competitively in the market, and ELEKEIROZ DO NORDESTE has a project to expand five-fold its installed capacity.

Another alcohol, the local production of which is foreseen for the next years, is pentaerythritol, obtained from formaldehyde and from acetic aldehyde. Such product shall be produced at the industrial set-up which COMPANHIA PETROQUÍMICA DO NORDESTE - COPENOR is implementing at Camaçari, Bahia.

Another project already defined in this area is for production of monochloroacetic acid at Camaçari, Bahia.

HOECHST DO BRASIL QUÍMICA E FARMACÊUTICA S.A. has been utilizing acetaldehyde to produce chloral and DDT at its São Paulo facilities, and we are informed of a new project for the manufacture of such derivatives in Maceió, Alagoas.

Production of butadiene from ethanol process is still considered non-economical in Brazil, and it is anticipated that there will be a growing supply of this basic item as co-product in the manufacture of petrochemical ethylene.

4.3. Production of Other Ethanol Derivatives

The technology to produce ethyl chloride, practiced during may years in the country and for some time suspended by producing companies, has been recently taken over by CIA. BRASILEIRA DE ESTIRENO, which developed its own process.

Such process, already successfully tested, has been utilized in a pilot plant to produce ethyl chloride consumed by the company as a catalyst in ethylbenzene manufacture.

As regards ethyl ether and glycol ethers, manufacturing processes are controlled by companies utilizing same. RHODIA intends to expand and modernize its ethyl ether plant, while OXITENO DO NORDESTE S.A. has a project for a new glycol ethers production unit.

Table IV shows the list of ethanol-chemical units already installed and under implementation in Brazil. The list is limited to immediate ethanol derivatives,despite the fact that from the intermediates indicated therein other chemicals already produced in Brazil are obtained, such as vinyl acetate, cellulose acetate, acetic anhydride and chloral.

TABLE IV

ETHANOL-BASED CHEMICAL INDUSTRY IN BRAZIL

PRODUCT	PLANTS				REMARKS
	COMPANY	CAPACITY /a...	PROCESS	USES	
ETHYLENE	UNION CARBIDE DO BRASIL S.A.	23.000	U.C.C.	LDPE	The unit operated from 1958 to 1969.
	INDÚSTRIAS QUÍMICAS ELETRO CLORO S.A.	10.000	SCIENTIFIC DESIGN	HDPE	In operation since 1962.
	COMPANHIA BRASILEIRA DE ESTIRENO S.A.	4.000	KOPPERS	ethylbenzene-styrene	The unit operated from 1959 to 1970. The operation was taken over in 1978.
	SALGEMA INDÚSTRIAS QUÍMICAS S.A.	60.000	PETROBRÁS CENPES	Ethylene dichloride	Scheduled start-up: 1981.
	COMPANHIA PERNAMBUCANA DE BORRACHA SINTÉTICA-COPERBO	30.000	COPERBO	Vinyl acetate	Adaptation of butadiene facilities, already existent; Scheduled start-up: 1982.
ACETALDEHYDE	RHODIA INDÚSTRIAS QUÍMICAS E TÊXTEIS S.A.	40.000	RHONE POULENC	Acetic acid and solvents	In operation.
	HOECHST DO BRASIL QUÍMICAS E FARMAC. S.A.	4.200	HOECHST	Acetic acid and solvents	In operation.
	USINA VICTOR SENCE S.A.	360	MELLE	Acetic acid and solvents	In operation.
	COMPANHIA PERNAMBUCANA DE BORRACHA SINTÉTICA-COPERBO	50.000	U.C.C.	Acetic acid-vinyl acetate	The unit operated from 1965 to 1971. Being reactivated at present.
OCTANOL (ethylhexanol)	ELEKEIROZ DO NE IND. QUÍMICA S.A	3.300	MELLE	Plasticizers	In operation. Expansion to 16.500 ton/yr at present.
BUTANOL	ELEKEIROZ DO NE IND. QUÍMICA S.A.	150	MELLE	Solvent and Plasticizers	Byproduct of Octanol Unit, expansion to 730 ton/yr.
	RHODIA INDÚSTRIAS QUÍMICAS E TÊXTEIS S.A.	4.800	MELLE	Solvents	In operation.
	HOECHST DO BRASIL QUÍMICA E FARMAC. S.A.	1.530	HOECHST	Solvents	In operation.
BUTADIENE	COMPANHIA PERNAMBUCANA DE BORRACHA SINTÉTICA-COPERBO	33.000	U.C.C.	Polibutadiene	The unit operated from 1965 to 1971. There is a project to adaptate it in order to produce ethylene. (see above)
ETHYL ETHER	RHODIA INDÚSTRIAS QUÍMICAS E TÊXTEIS S.A.	1.400	RHONE POULENC	Chemicals and pharmaceuticals	In operation. There is a project for expansion and modernization of the unit.
	IMBEL-IND. DE MATERIAL BÉLICO DO EXÉRCITO	480		Explosives	In operation.
ETHYLENE GLYCOL MONOETHYL ETHER	OXITENO S.A. INDÚSTRIA E COMÉRCIO	1.300	HALCON	Acetates and solvents	In operation since 1973.
DIETHYLENE GLYCOL MONOETHYL ETHER	OXITENO S.A. INDÚSTRIA E COMÉRCIO	1.900	HALCON	Acetates and solvents	In operation since 1973.
ETHYL CHLORIDE	COMPANHIA BRASILEIRA DE ESTIRENO S.A.	60	CBE	Catalyst in ethylbenzene production	In operation (pilot plant).

5. MAIN ETHANOL-CHEMICAL PROCESSES UTILIZED IN BRAZIL

We give below a description of a few ethanol-chemical processes already utilized in the country, as well as a preliminary economical evaluation of units employing such processes.

5.1. Description of Processes

5.1.1. Ethylene Production

The basic feature of the traditional process for the production of ethylene, as that used in Brazil by ELETRO CLORO, is the direct dehydration of ethanol using a silica-alumina catalyst:

$$C_2H_5OH \longrightarrow C_2H_4 + H_2O \quad - \quad 10,9 \text{ Kcal/mol}$$

The reaction is carried out at temperatures between 300 - 360°C and low pressure over a catalyst bed in a tubular reactor. It results in the formation of several byproducts, such as coke, ethyl eter, carbon monoxide and carbon dioxide. Heat for the reaction, is supplied by the circulation through the reactor's shell of a heating fluid (for example, "Dowtherm"). Ethylene is produced 97-98% pure, being necessary further distillation to give a 99 per cent pure product.

PETROBRAS RESEARCH CENTER - CENPES has developed an adiabatic variation of this process, spurred on by the high costs of the earlier isothermic process.

Feeding ethanol and steam into a row of reactors resulted in a large reduction in coke formation, longer catalyst activity, and appreciable increase in conversion and considerably less byproduct production, when tested on a pilot-scale. It was then necessary to test the process semi-comercially, which was done with a prototype plant at REFINARIA DUQUE DE CAXIAS' site at Duque de Caxias, Rio de Janeiro. The capacity of the reactor was determined by the adiabatic behaviour of the reaction, without the need of additional heat to replace that lost.

The 60 ton/year prototype has been in operation for a year and seems to confirm the efficiency of the adiabatic reaction. Results of running the plant have so far shown that conversion is in the order of 98 per cent and there is no loss of activity or selectivity of the catalyst.

Industrial alcohol may be used with no treatment, such as purification. Also, there is a possibility of operating the reactor at higher pressures than previously with no loss of product conversion.

The flowsheet of the CENPES process is shown in FIGURE 5 (reaction section) and FIGURE 6 (purification section).

The process is carried out by using a configuration of three reactors in a row, giving greater efficiency for lower investment and operating costs.

Reactors are a conventional fixed bed, where the reaction is carried out. The temperature falls through the bed, due to the endothermic reaction.

Heat for the reaction is supplied by direct heating of the alcohol and injections of superheated steam in direct contact with the alcohol.

FIGURE — 5

ETHYLENE CENPES PROCESS

ETHANOL CATALYTIC DEHYDRATION UNIT

— REACTION SECTION —

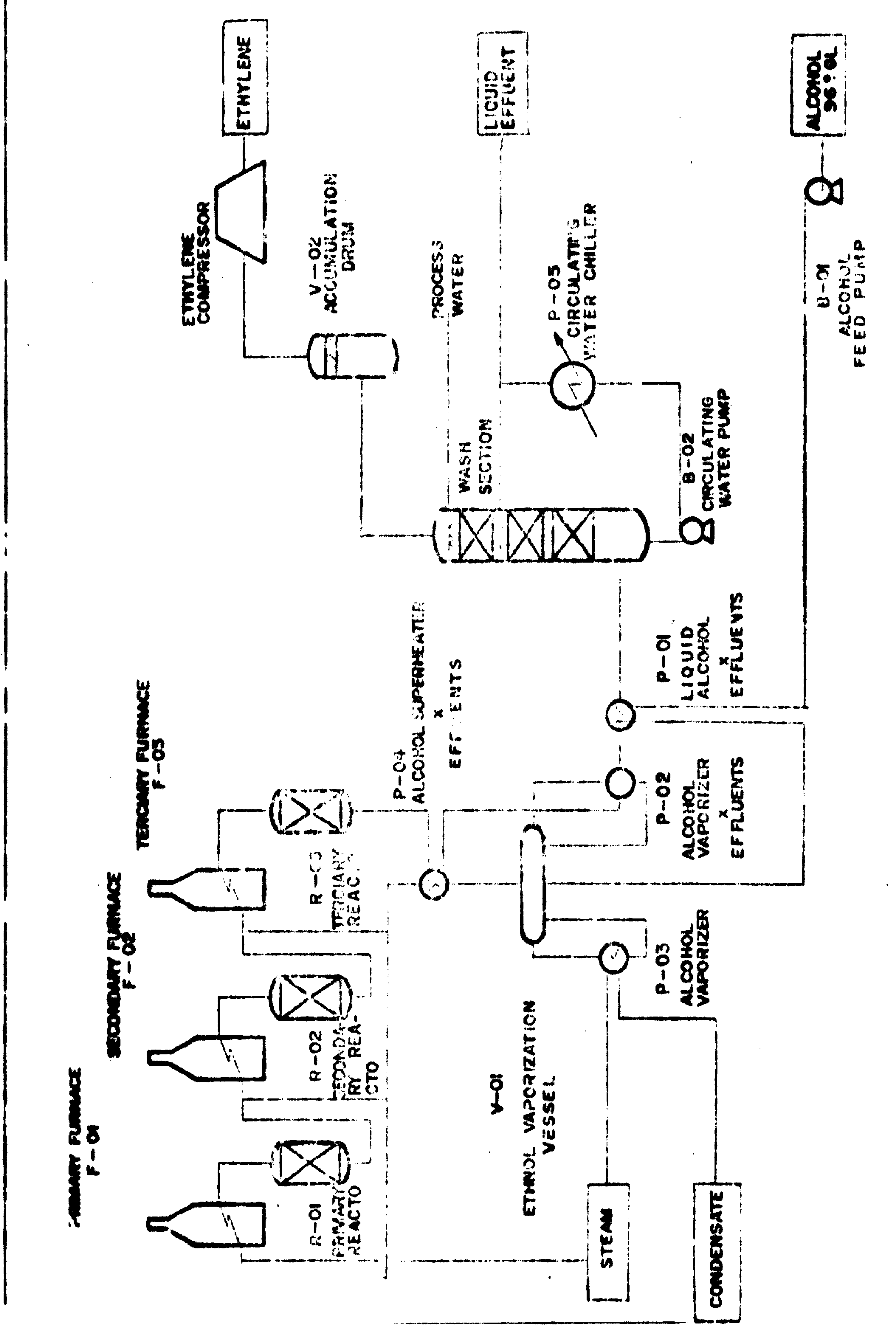
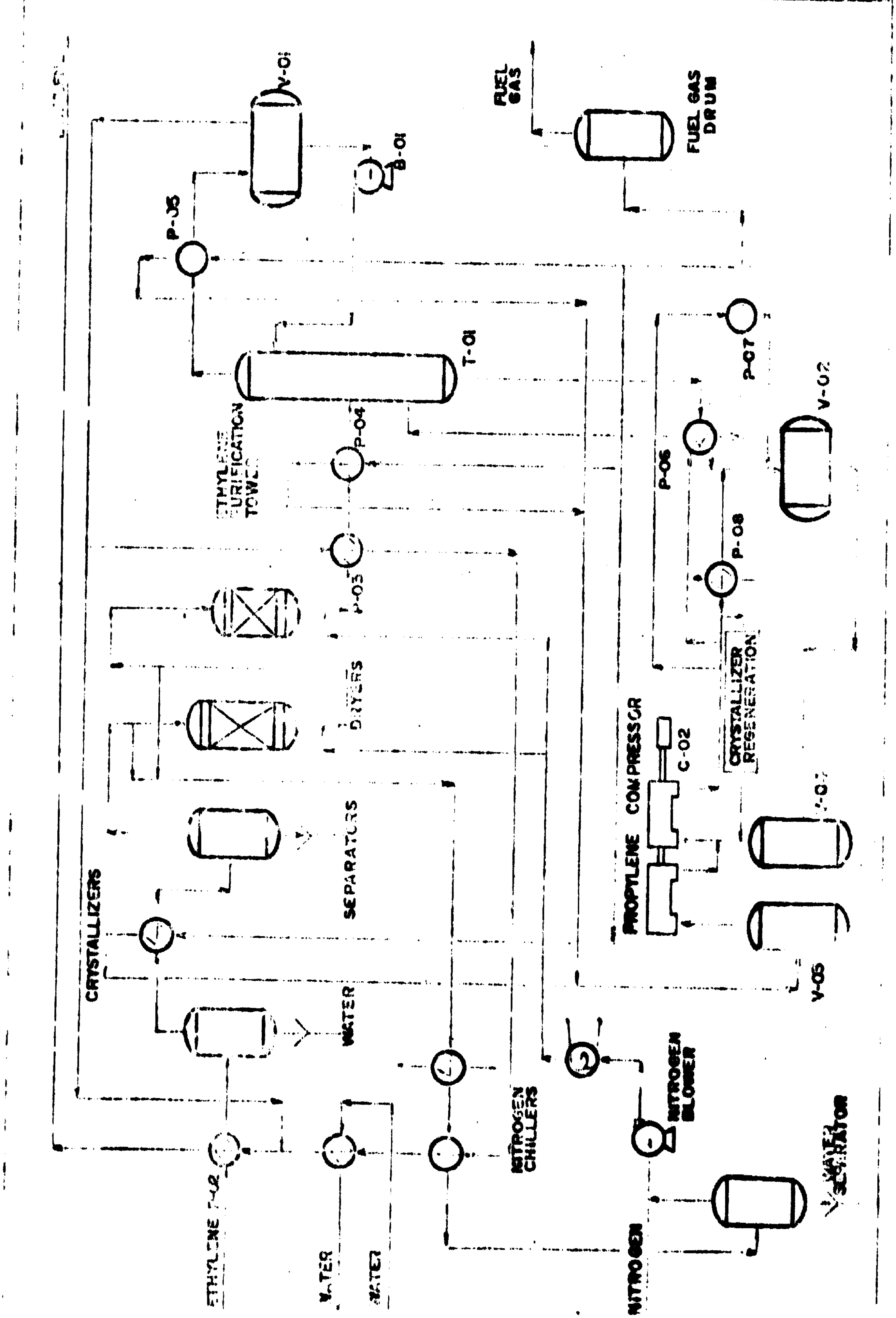


FIGURE — 6

ETHYLENE CENPES PROCESS
ETHANOL CATALYTIC DEHYDRATION UNIT
— PURIFICATION SECTION —



The configuration of three reactors in a row allows to operate each reactor with the same inlet-outlet difference of temperature and processing a greater amount of alcohol in the second and third reactors.

Impure ethylene is produced at a 5 kg/cm^2 gage pressure.

The ethylene is compressed and sent to the purification section, where it is first refrigerated and then fed into crystallizers to promote the formation of hydrate. It is then passed through a molecular sieve, to remove residual water, and a distillation column, where propylene and heavier hydrocarbon impurities are removed at the bottom.

The resultant ethylene contains a maximum of 50 ppm propylene, 0.5 percent ethane and its dew point is -40°C.

5.1.2. Production of Acetaldehyde

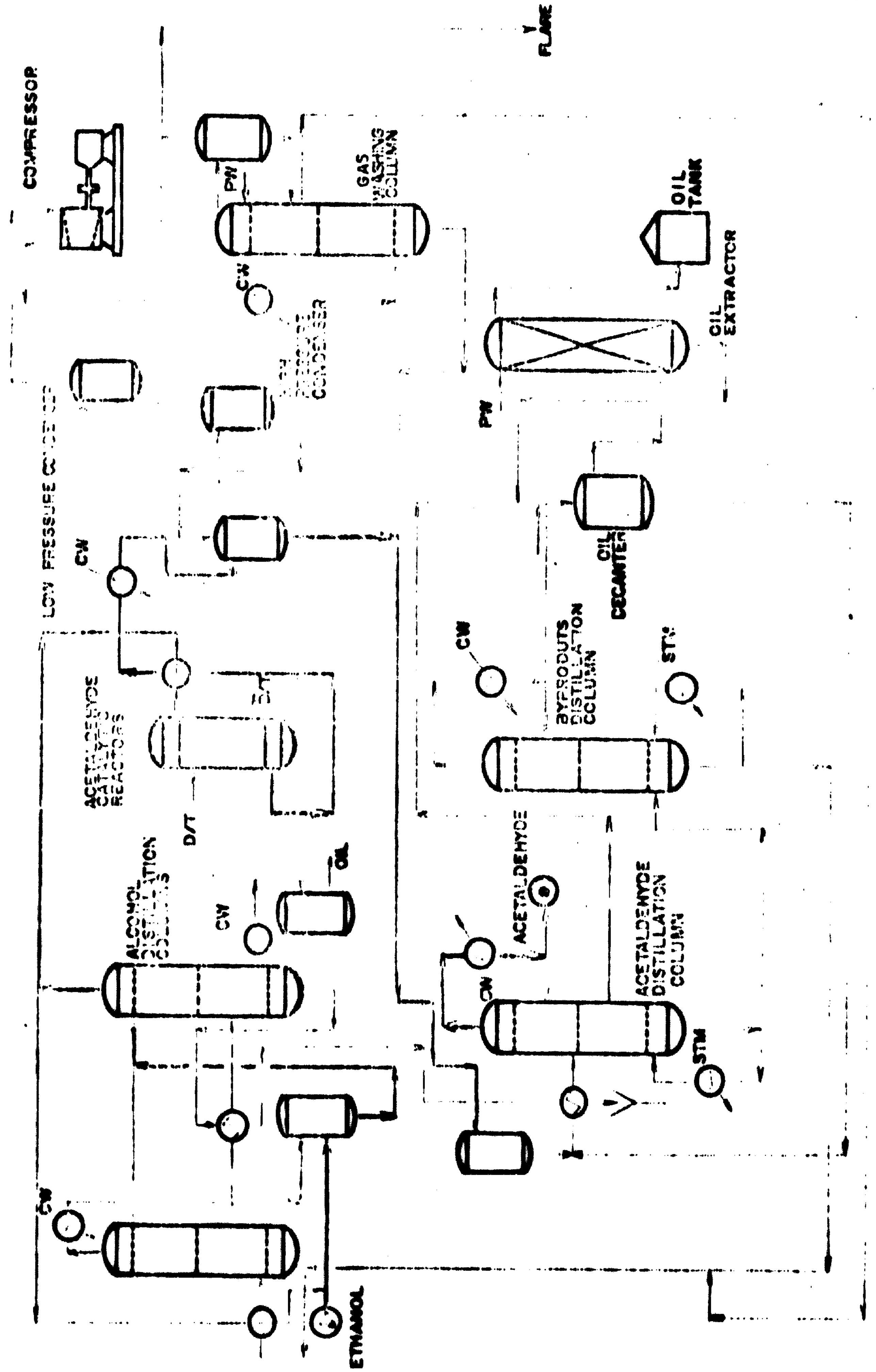
The process utilized in Brazil comprises the catalytical dehydrogenation of ethanol, in the steam phase, according to the following reaction:

$$\underset{\text{ethanol}}{CH_3\text{-}CH_2OH} \xrightarrow[\text{Cu-Cr}]{260^{\circ}C} \underset{\text{acetaldehyde}}{CH_2\text{-}CHO} + H_2$$

Flowsheet of process is shown in Figure 7.

The ethanol in the storage tank, together with alcohol recovered in the process, is vaporized and fed into a reactor (one or more converters), wherein it goes through a chrome-copper catalyst, over a fixed bed, at 260-330°C temperature and low pressure (3-8 psig).

FIGURE 7 | ACETALDEHYDE FROM ETHANOL PROCESS



Efficiency for acetaldehyde is 85-92% for liquid byproducts 12-6%, and gaseous byproducts 3-2%. Main byproducts are ethyl acetate and acetic acid and, in smaller quantities, butyraldehyde, methyl-ethyl-ketone, ketone, butanol, methane, ethylene, carbon dioxide and monoxide and unidentified oils.

The catalyst is regenerated from time to time, which is done in two stages: withdrawal of carbon deposited by using as a burning agent air diluted with dry steam and reduction of copper oxide into metal by passing a hydrogen stream.

Normal operation period of a converter is 700-1300 hours, and reactivation period is 70-90 hours.

The acetaldehyde recovery system consists mainly of two condensers, one low-pressure and the other high-pressure, and a gas washing tower.

The major portion of latent heat of the converter's effluent is removed in the first condenser wherein the largest part of un-reacted acetaldehyde and alcohol is liquefied.

The remaining gas is then compressed and goes through the second condenser to remove further the heat, and is subsequently washed in a tray column. The hydrogen withdrawn at the top of the gas washer leaves the unit to be used as a fuel or sent for flare.

The washing tower bottom stream joins with the low-pressure condenser liquid effluent and, after being mixed in line with an acetaldehyde stream recovered in the process it is fed into a distillation column where high purity acetaldehyde is separated at the top and goes into storage.

The acetaldehyde column bottom stream, containing mainly ethanol and water and a smaller quantity of light and heavy byproducts is sent to the byproducts distillation column. In this tower, compounds of a boiling point lower than ethanol are separated at the top, whereas unreacted ethanol and higher boiling point compounds are removed at the bottom.

The overhead is sent to an oil washing system to recover acetaldehyde and other byproducts. Such system comprises mainly an oil decanter, an oil extractor and an oil storage tank.

Initially, the byproducts column overhead is mixed with water, in line, and the resulting mixture is sent to the oil decanter where the major part of ethanol and acetaldehyde present is removed, and is recycled into the acetaldehyde distillation column.

The overlaying oil feeds the oil extractor in counter-current with a flow of process water. The bottom stream of this column, which contains a large quantity of byproducts, is fed again into the washing system or returns to the distillation system and from there to the acetaldehyde converters. The residual oil leaving the top of the tower is transferred to the storage tank and used as fuel.

The bottom product of the byproducts distillation column, in the form of an ethanol water solution, is fed into a set of distillation columns, where alcohol is recovered and purified and water and byproducts are discharged into the sewage or sent to the oil recovery equipment.

The recovered alcohol is let out vaporized and serves to feed the convertors. Fresh alcohol coming from the storage section is also vaporized with the recycled material replenishing the required feed volume.

5.1.3. Production of Acetic Acid

The acetic acid process developed by PETROQUISA consists of an improvement of the existing domestic acetic acid technologies based on the liquid phase oxidation of acetyldehyde.

A basic feature of this process is the utilization of the oxidation gas (air), prior to the reaction, to recover the acetaldehyde contents of the reactor effluent. Also, the catalyst is held in a closed loop system, so reducing losses.

The unit operates at low pressure and temperature, and a special design of the reactor, sparged, allows to operate with high gas space velocity without excessive acetaldehyde entrainment.

At present, a new catalyst system is under development toward obtaining a selectivity improvement.

Figures 8 and 9 show the reaction and purification sections of the process.

Fresh high-purity acetaldehyde, oxidation gas, recovered acetaldehyde and catalyst are continuously fed to the reactor, where oxidation takes place.

The reaction, which can be represented by

$$CH_3\,CHO + 1/2\,O_2 \longrightarrow CH_3\,COOH$$

is highly exothermic, being developed around

FIGURE — 8

ACETIC ACID FROM ACETALDEHYDE PROCESS
—REACTION SECTION—

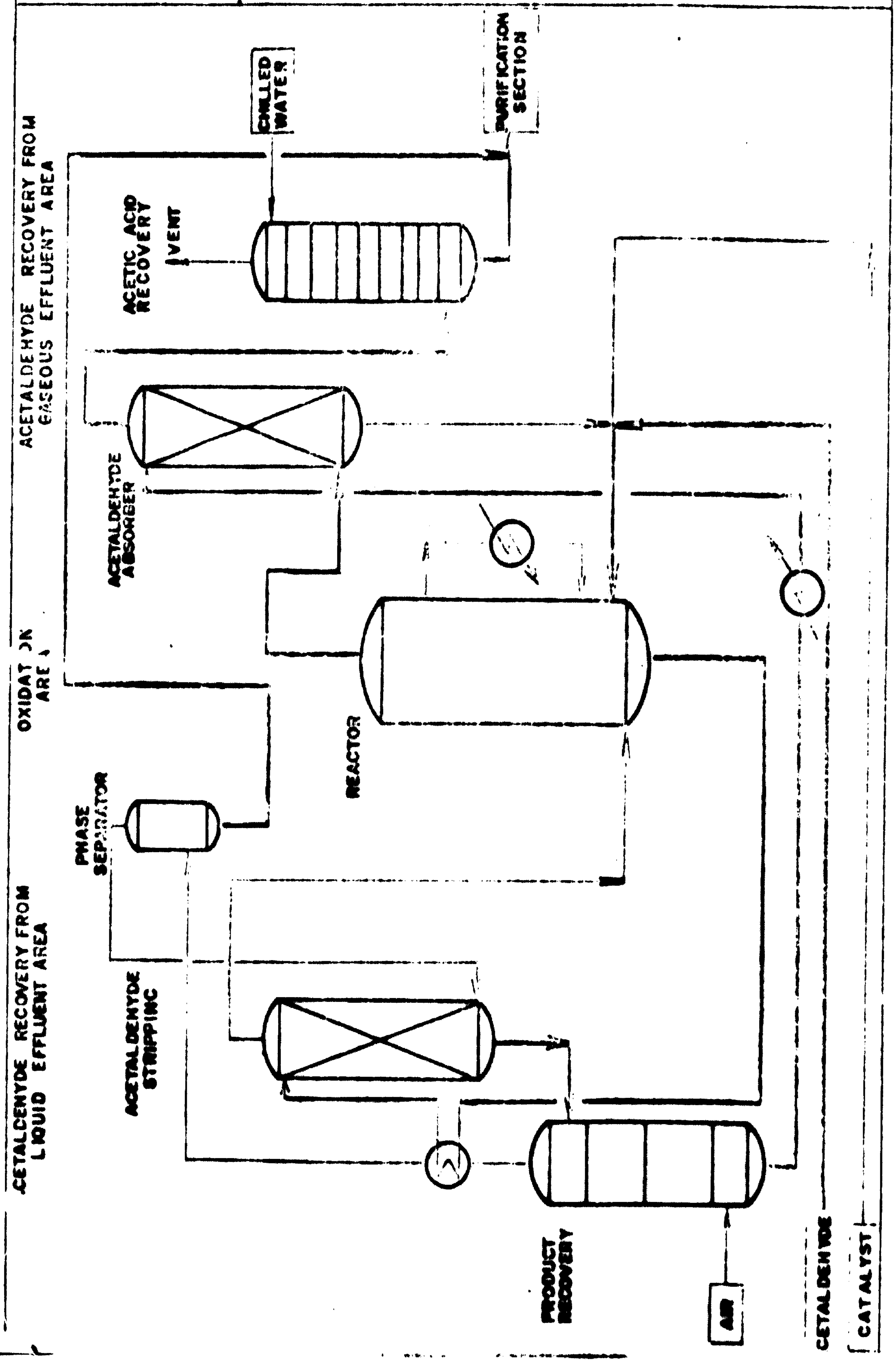
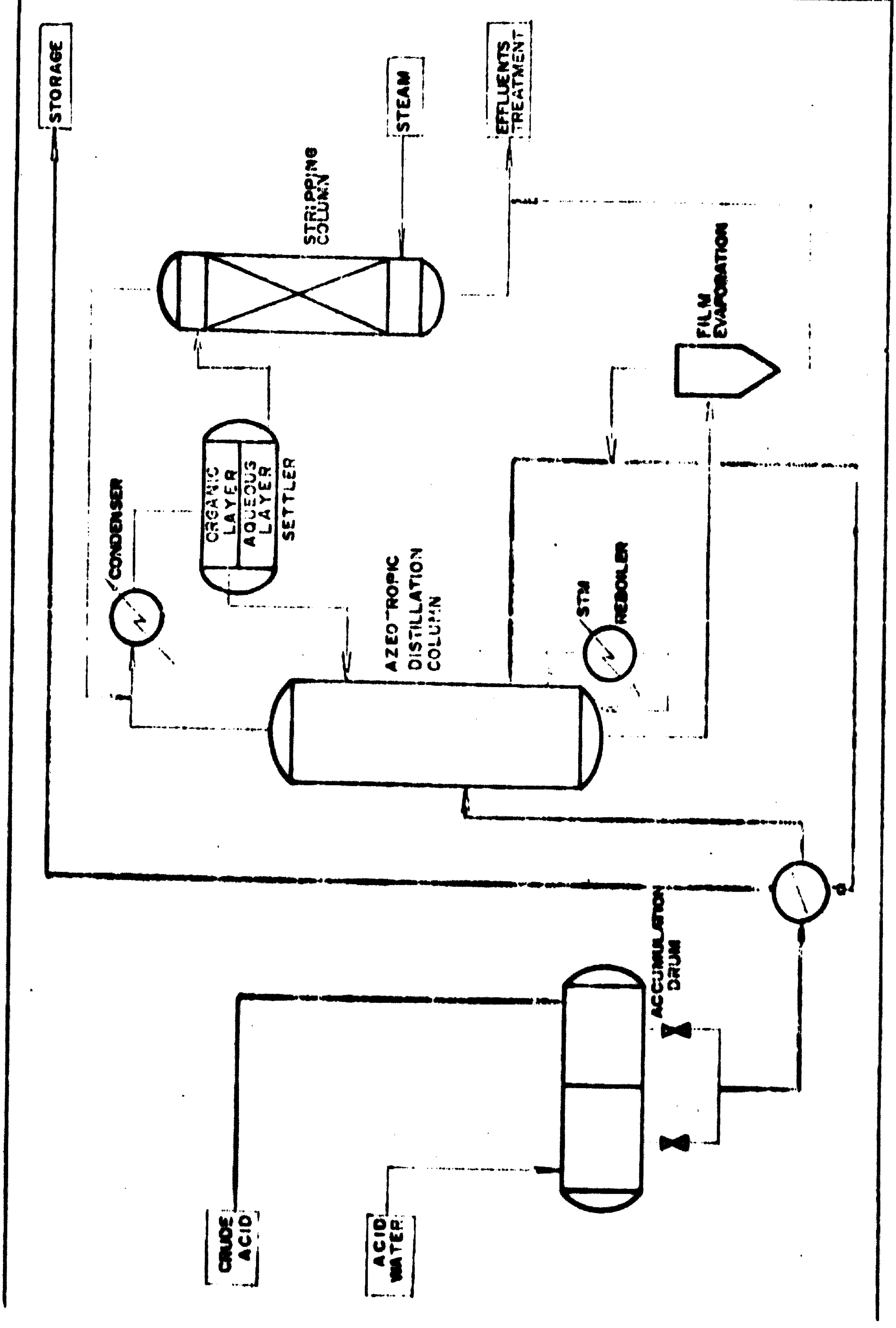


FIGURE - 9

ACETIC ACID FROM ACETALDEHYDE PROCESS
—PURIFICATION SECTION—



70 Kcal/mol. In order to remove the heat of the reaction, the substract from the reactor is circulated through outside coolers.

The liquid effuent from the reactor contains mainly acetic acid and small amounts of by-products, such as formic acid, methyl acetate and others. This stream is first stripped of its acetaldehyde contents in the acetaldehyde stripping column. The temperature and pressure in this column are set to maintain, for safety purposes, a certain amount of acetic acid in the top stream, that goes further to the reactor.

The bottoms go to the product recovery column, where the incoming air is saturated with acetic acid. This stream is condensed and the resulting condensate, crude acetic acid, is sent to the purification section.

The gaseous effluent from the reactor contains mainly unreacted acetaldehyde, carbon dioxide, nitrogen and oxigen, of which concentration is kept low to avoid fire hazards. This stream is first washed with cooled acetic acid, in the acetaldehyde absorption column, in order to remove the entrained acetaldehyde.

The acetic acid leaving this tower in the overhead stream is recuperated in the acetic acid recovery column by washing with chilled water. The vent gas is discharged into the atmosphere and the bottoms are sent to the purification section.

The purification section receives two main streams. The first one, crude acetic acid, is the condensate from the product recovery column; the second one comes from the acetic acid recovery column.

This section consists of an azeotropic distillation system, where ethyl acetate is employed as a solvent.

Acetic acid coming from the reaction section is fed into the azeotropic distillation column. The solvent is fed few plates below the top plate.

Water and light byproducts are entrained by ethyl acetate, and leave the column as overhead. After condensation, this stream splits into two layers. The organic layer returns to the column.

The acqueous layer is stripped, with steam, of its ethyl acetate contents, and then is reutilized. The acetic acid product is recovered as a liquid from 3 to 6 plates above bottom and, after cooling, goes into storage. The bottoms, mainly heavy byproducts, go to a film evaporator, where they are exhausted of acetic acid contents and then sent to disposal.

5.1.4. <u>Butanol and Octanol Production</u>

In Brazil, the traditional process to obtain such products from ethanol is used.

In this route, acetaldehyde (by dehydrogenation of ethanol, such as explained in item 4.1.2. above) and crotonaldehyde (by aldolization of crotonaldehyde and subsequent dehydrogenation of aldol) are initially produced.

Next follows hydrogenation of crotonaldehyde whereby the n-butanol and butyraldehyde are obtained, the latter by uncomplete hydrogenation.

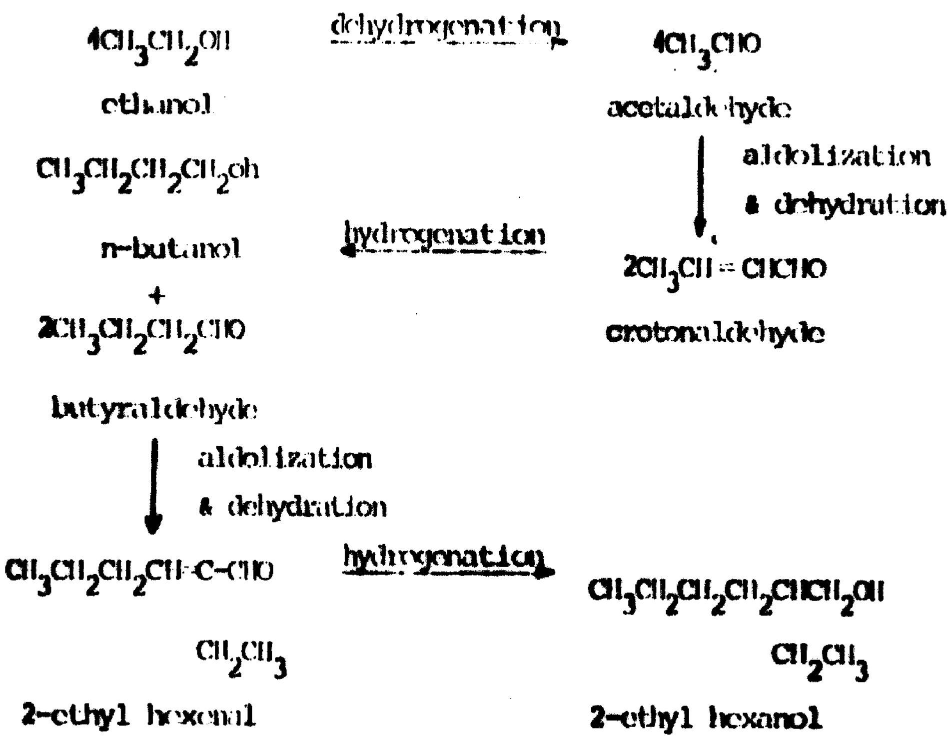
The production rates of n-butanol/butyraldehyde may be controlled in order to produce a larger or smaller quantity of butyraldehyde. The reaction control is done mainly by the concentration of circulating hydrogen.

If the purpose is primarily production of n-butanol, butyraldehyde may be recycled until complete extinction.

If, on the contrary, the process is intended to obtain octanol (2-ethylhexanol), hydrogenation is controlled in such a way as to maximize butyraldehyde production, which however does not prevent formation of n-butanol as a byproduct.

In this last case, butyraldehyde goes through an aldolization and subsequent dehydration, forming 2-ethyl hexenal. The latter is hydrogenated to 2-ethyl hexanol.

Schematically, the above route may be represented as follows:



The flow-sheet of the process, comprising from aldolization of acetaldehyde until recovery of n-butanol, is shown in Figure 10.

Acetaldehyde, in the presence of small amounts of dilluted soda (10%), is fed into a column where, by condensation, it is converted into aldol. Aldolization is carried out at a temperature of 5 to 25°C and conversion of acetaldehyde by pass ranges from 48 to 60%. Unconverted acetaldehyde is recovered as overhead and recycled.

Aldolization product is sent to a dehydration column system to be transformed into crotonaldehyde, which is done in the presence of monosodium phosphate.

Bottoms of the first column consists mainly of water eliminated during the reaction, which is recovered and reutilized in the process.

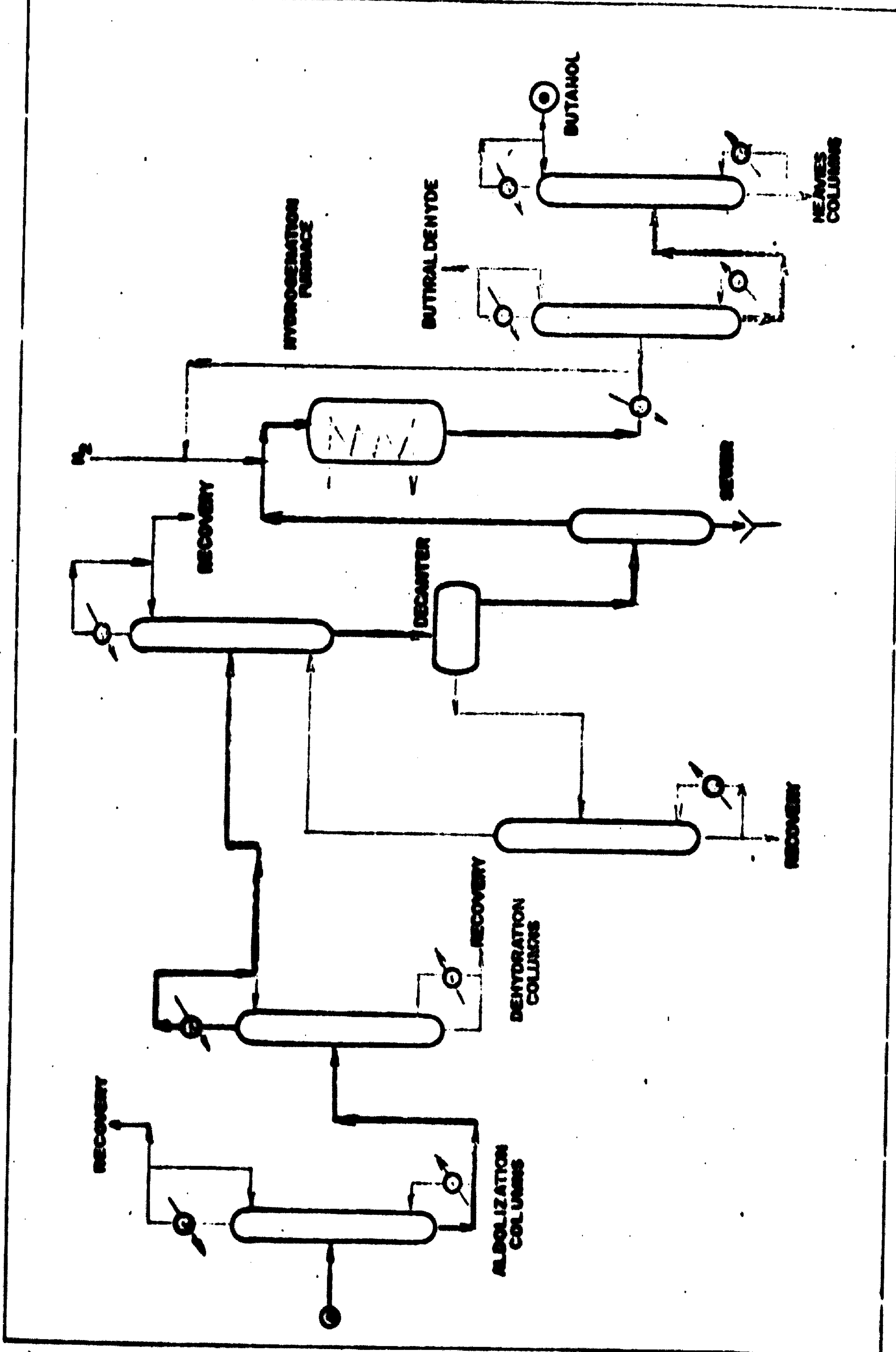
Dehydration in this column is not complete and its ove head is sent t a second column to proceed with the reaction. Here, unreacted acetaldehyde is further recuperated as overhead and recycled.

Reaction mixture leaving the second column is sent to a decanter to separate the crotonaldehyde and is then fed into a third column. The overhead of the latter is recycled into the second column, whereas a new stream of process water is recovered from bottoms.

Crotonaldehyde follows toward the evaporator and then to the hydrogenation furnace, where, in the presence of a nickel-chromo catalyst, it is converted into n-butanol and butyraldehyde. Temperature of the operation is 180°C and pressure 30 psig.

FIGURE—10

BUTANOL AND BUTIRALDEHYDE FROM ETHANOL PROCESS



Reaction product is finally split in a two rectification towers system, and butyraldehyde is obtained from overhead of the first and n-butanol from overhead of the second tower. When the intention is to produce only n-butanol, butyraldehyde returns to the reaction for further hydrogenation to that alcohol.

Figure 11 shows, on the other hand, the flow-sheet of 2-ethyl hexanol production from butyraldehyde.

Butyraldehyde is fed into the alcolic condensation reactor to form 2-ethyl hexenal. Small quantities of C_8 isomers are also produced.

Reaction is carried out in the presence of NaOH 10%, and fresh soda, joined with recycled soda, fed into the reactor top. This is provided with a serpentine for internal cooling to remove the heat of reaction.

The organic layer split at the decanter of overhead is cooled and sent to a tank where it joins the organic layer split in the bottoms decanter. The acqueous layer of the overhead constitutes the soda recycle, whereas the acqueous layer of the bottoms is sent for treatment and disposal.

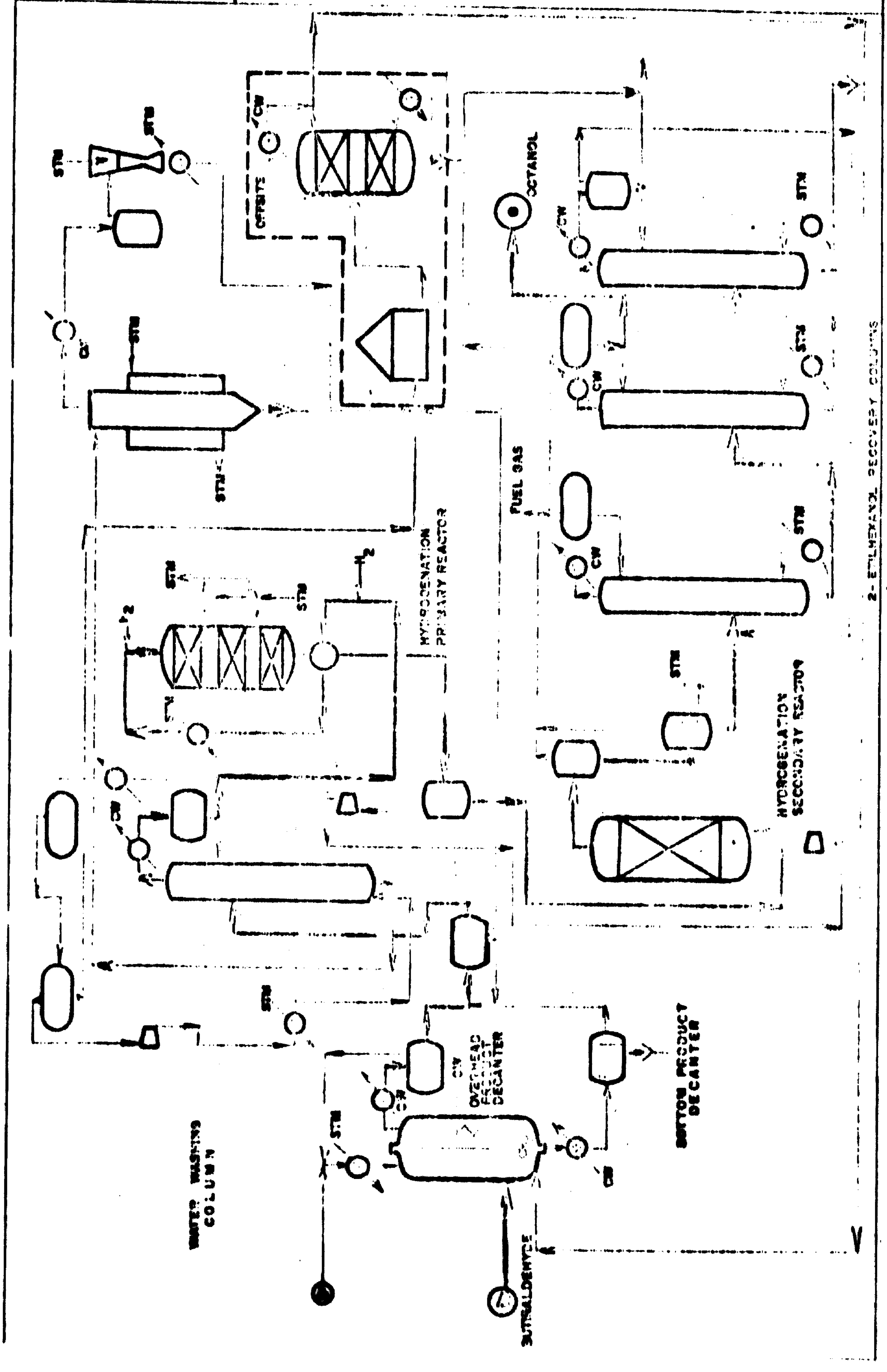
The organic product then follows to be washed with water in order to remove the major part of entrained soda, whence it is transferred to the first stage of the evaporator.

Hydrogen is used to lower the steam pressure of the 2-ethyl hexenal misture, in order to minimize the product's thermal degradation.

The liquid originated from the overhead

FIGURE— II

2 - ETHYLHEXANOL FROM BUTIRALDEHYDE PROCESS



of the two stages of the evaporator, rich in 2-ethyl hexenal, follows to the hydrogenation section.

The steam resulting from the first stage of the evaporator, containing mainly hydrogen, is recompressed and reintroduced into the evaporator base.

2-ethyl hexenal is combined with hydrogen and, after pre-heating by means of exchange of heat with the effluent of the primary hydrogenation reactor, is fed into it. This equipment is provided with a fixed bed, containing a nickel catalyst. Reaction is carried out in steam phase, at a temperature of 140°C and pressure of 135 psig, and about 99% of 2-ethyl hexenal is converted at this stage. The reactor's product is cooled and the uncondensed steam is recycled for further conversion.

The liquid product then goes onto the secondary hydrogenation reactor. Reaction is carried out in th liquid phase, at about 60°C and 1500 psig pressure, and through it unreacted aldehydes originated from the first hydrogenation stage are hydrogenated. Unreacted hydrogen separate from the reactor's effluents to be used as a fuel.

Hydrogenation crude product consists mainly of 2-ethyl hexanol, and has as impurities n-butanol, aldehydes and heavy compounds.

Recuperation and purification of 2-ethyl hexanol is carried out in three distillation columns. The first column separates in the overhead the n-butanol and other light components, which may be further distilled to recover n-butanol.

The second column recovers 2-ethyl hexanol as overhead, while the bottoms go on to the next column. In the latter, the overhead, containing 2-ethyl hexanol, is recycled to the first column, while heavier products are rejected.

5.1.5. Butadiene Production

In this process, which has been used in Brasil by COPERBO, the following chemical reaction occurs:

$$CH_3CHO + CH_3CH_2OH \longrightarrow CH_2CHCH{=}CH_2 + H_2O$$

acetaldehyde ethanol butadiene water

It is believe, however, that such reaction takes place in two phases:

(1) $$2CH_3CHO \longrightarrow CH_3CH{=}CHCHO + H_2O$$

acetaldehyde crotonaldehyde water

(2) $$CH_3CH{=}CHCHO + CH_3CH_2OH \longrightarrow CH_2{=}CHCH{=}CH_2 + CH_3CHO + H_2O$$

crotonaldehyde ethanol butadiene acetaldehyde water

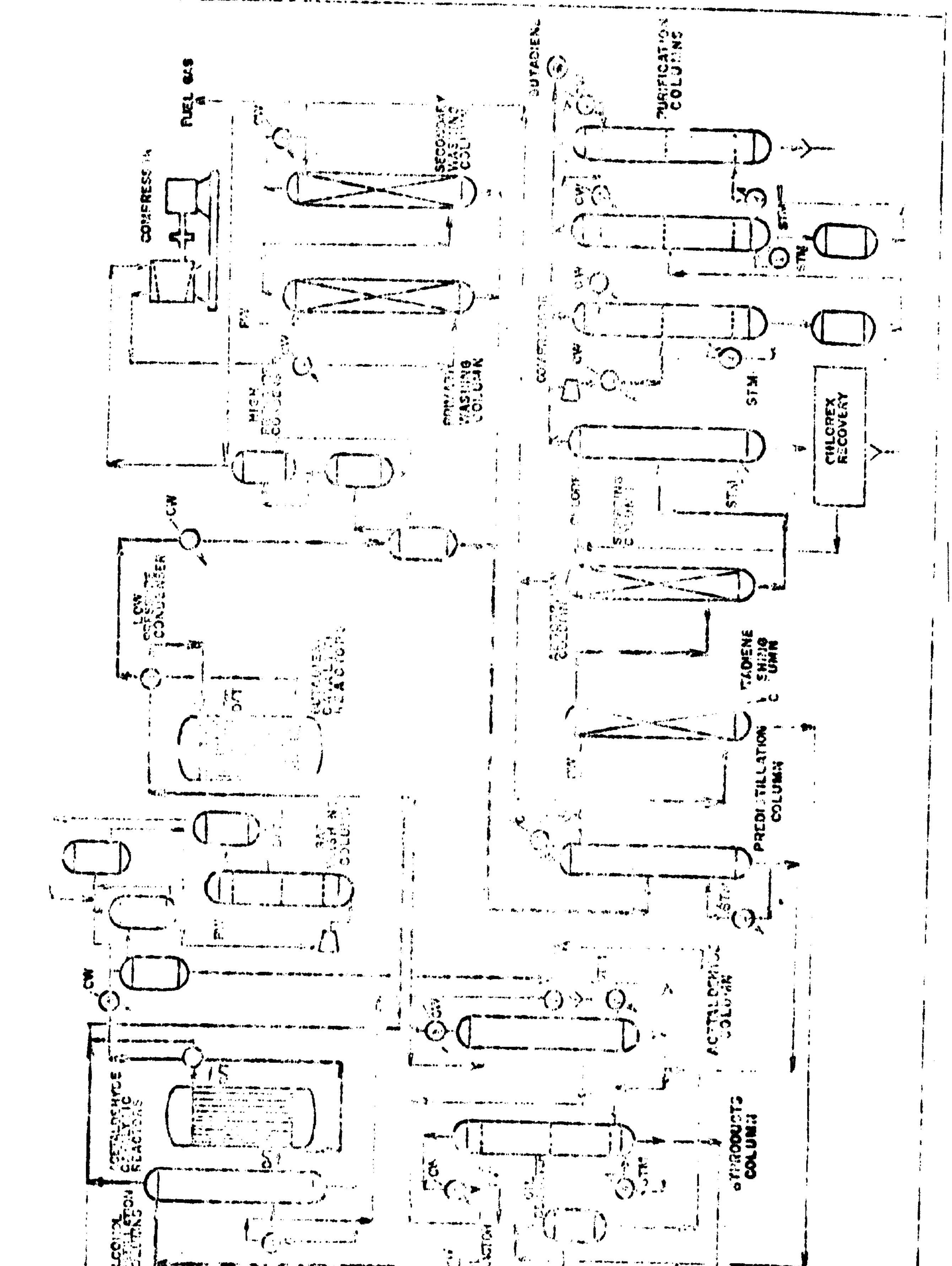
The process' integrated flow-sheet, from ethy alcohol, is shown in Figure 12.

The first stage of the process comprises dehydrogenation of ethanol to acetic aldehyde, and is completely identical to the process shown in item 4.1.2.

The second stage involves manufacture of butadiene proper, and is examined in more detail below.

Acetic aldehyde and ethanol vapours, from distillation columns overhead of the acetaldehyde section, are mixed at a rate of 2.5 mols ethanol for 1 mol acetic aldehyde, pre-heated and fed into

FIGURE — 12 BUTADIENE FROM ETHANOL PROCESS



the butadiene converters. Here they are drained through the catalytic bed (silica gel saturated with 1.75 - 2.25% tantalum oxide), at low pressure (3 - 8 psig) and high temperature (320-350°C).

Under normal operation the conversion by pass is rather low (8 - 12% butadiene, in weight), and it is necessary to recover and recycle the major part of the unreacted feed stream.

The effluent from converters, in addition to butadiene and steam, contains byproducts which comprise from gases, mainly ethylene, up to high molecular weight hydrocarbons, carbon deposits, and some exigenated compounds such as ethyl ether, n-butanol and acetic acid.

Total efficiency in ethanol-based butadiene ethanol normally ranges between 50-63%, including losses in efficiency in acetic aldehyde production and losses relating to product recuperation and transfer.

Converters consist of several steel tubes, filled with catalyst, closed inside a tubular furnace. The reaction is endothermic and the heat for the reaction is provided by a Dowtherm bath, which surrounds the tubes.

After a 80-120 hour production period, the catalyst is reactived throughout 24-48 hours by burning carbon through a controlled passage of air at 400-420°C.

Vapour from the converters passes through feed pre-heaters and goes into the low pressure condenser. The condensate goes to the low pressure condensate tank, while uncondensed vapours flow to the top of the tank through two separate strippers, are compressed and sent to the high pressure condenser.

The high pressure condensate and the cooled vapour feed the bottom of the primary washer, whose gaseous overhead flow to the bottom of the secondary washer. The gaseious overhead of the latter leaves the unit to be used as a fuel. The low pressure condensate joins with the liquid bottoms of the washers and follows toward the pre-distillation column.

The overhead of this column, under normal operating conditions, has 80-85% butadiene and 10-15% acetaldehyde. Bottoms are taken to the byproducts distillation column, and from there goes through other stages to recuperate other useful components.

The overhead stream of the pre-distillation column goes into the base of the washing tower where the process water is introduced at the top and absorbs the acetic aldehyde and other soluble impurities. This stream is normally carried to the oil washing systems or, alternately, sent to the feed tank of the acetaldehyde column or down the drain.

Under normal running conditions, the overhead gas of the washing tower contains about 95% (in volume) butadiene. Such stream is taken to a tower, where butadiene is absorbed selectively by Chlorex (ether di (2-ethyl chlorine)), and is separated from the major part of other component gases (methane, ethylene, propylane and butene).

In the stripping column, pressure is

reduced and the butadiene-Chlorex solution is distilled to steam to strip all hydrocarbon present. The chilled vapour is compressed and fed to the butadiene purification columns.

The residual gas of the absorber is recycled to recuperate butadiene and butenes, or may be sent as fuel to the Dowtherm furnaces.

The water-Chlorex solution leaving the bottom of the stripping column is sent to a distillation column to recuperate Chlorex. The latter is reutilized in the absorption tower.

The butadiene purification systems consists basically of three distillation columns in a row.

Vaporized feed, containing 96-96.5% butadiene goes in at the first column, where the butadiene goes out as overhead, while the bottoms, containing 50-75% butadiene, passes on to the second column. Here, basically, all butene-1 is separated in the overhead so that the critical separation effected in the second column if of butene-2 from butadiene.

In the overhead from the first and second columns butadiene has a purity of about 98%, and such streams represent the final product, which is sent to storage.

The third column operates with a high reflux to exhaust any butadiene still present in the butene mixture leaving the bottom of the second column. Butenes and heavy residues are collected in the circulation drum, to the extent that the butadiene content reduces evenly. At last, batch distillation of the fraction of butenes left in the heavy residues is done.

5.2. Technical and Economical Evaluation

Tables V through XVl present a technical and economical evaluation of the units which employ the processes described above, comprising an estimate of investments, operating costs and sales price of the products, under Brazilian conditions as of September 1978.

Tables are self-explanatory in relation to criteria utilized to calculate investments and operating costs of the respective units.

The fundamental object of this review was to evaluate the impact of the subsity instituted for alcohol over final prices of the products, as well as the competitiveness of processes under consideration in relation to those of the petrochemical industry.

In this sense, two price alternative of the raw material (ethanol) were contemplated in each case:

— industrial alcohol, at effective price in domestic market (US\$293/ton ethanol);

— alcohol subsidised for the chemical industry, at a price per cubic meter equivalent to 35% of price per ton of petrochemical ethylene (US\$170/ton ethanol).

Moreover, since the acetaldehyde and the acetic acid are only produced in Brazil from ethyl alcohol, in addition the review of its production by a petrochemical route was done.

Table XVll summarizes, for each product, the sales prices estimated for the two above alternatives, comparing same with effective prices (or which could be

TABLE - V

PROCESS ECONOMICAL EVALUATION

PRODUCT Ethylene
PROCESS Petrobrás - CENPES
CAPACITY 60,000 MTY
LOCATION Brazil
DATE 1st trim. 1979

ESTIMATED INVESTIMENT

I T E M	V A L U E (US$)
BATTERY LIMITS CAPITAL COST (ISBL)	17,000,000
OFFSITES CAPITAL COST (OSBL)	4,000,000
TOTAL FIXED CAPITAL	21,000,000
WORKING CAPITAL	5,600,000
TOTAL INVESTMENT	26,600,000

ESTIMATED MANUFACTURING COSTS AND TRANSFER PRICE

MANUFACTURING COSTS	UNIT	UNIT COST (US$/UNIT)	UNIT CONSUMPTION (UNIT / ton prod)	COST PER UNIT (US$/ton prod)	ANNUAL COST (US$)
1 - RAW MATERIALS					
Ethanol (100%)	t	293,00 (*)	1.71	501.03	30,061,800
2 - CATALYSTS AND CHEMICALS					
Catalyst	kg	1.30	0.20	0.26	15,600
3 - UTILITIES					
Cooling Water	m^3	0.06	119.00	7.14	428,400
Process Water	m^3	0.88	1.20	1.06	63,360
Steam	t	5.50	1.50	8.25	495,000
Electricity	kwh	0.025	190.00	4.75	285,000
Fuel Oil (9750 kcal/kg)	10^6 kcal	5.78	0.64	3.70	221,952
4 - OTHERS					
5 - BYPRODUCTS CREDIT					
TOTAL VARIABLE COSTS				526.19	31,571,112

FIXED MANUFACTURING COSTS	EVALUATION BASIS		
1 - LABOUR	OPERATION, MAINTENANCE AND PROCESS PERSONNEL	6.50	390,000
2 - MAINTENANCE	3% OF ISBL	8.50	510,000
3 - DEPRECIATION	10 % OF ISBL + 5% OF OSBL	31.67	1,900,000
4 - INSURE AND TAXES	2 % OF ISBL	5.67	340,000
5 - PLANT OVERHEAD	200 % OF LABOUR	13.00	780,000
TOTAL FIXED COSTS		65.34	3,920,000
TOTAL MANUFACTURING COSTS		591.53	35,491,112
RETURN ON INVESTMENT BEFORE TAX	25% OF TOTAL INVESTMENT	110.83	6,650,000
TRANSFER PRICE		702.36	42,141,112

(*) Nonsubsidized ethanol price

TABLE - VI

PROCESS ECONOMICAL EVALUATION

PRODUCT	Ethylene
PROCESS	Petrobrás - CENPES
CAPACITY	60.000 MTY
LOCATION	Brazil
DATE	1st trim. 1979

ESTIMATED INVESTIMENT

I T E M	V A L U E (US$)
BATTERY UNITS CAPITAL COST (ISBL)	17,000,000
OFFSITES CAPITAL COST (OSBL)	4,000,000
TOTAL FIXED CAPITAL	21,000,000
WORKING CAPITAL	3,700,000
TOTAL INVESTIMENT	24,700,000

ESTIMATED MANUFACTURING COSTS AND TRANSFER PRICE

MANUFACTURING COSTS	UNIT	UNIT COST (US$/UNIT)	UNIT CONSUMPTION (UNIT / ton prod)	COST PER UNIT (US$/ton prod)	ANNUAL COST (US$)
1 - RAW MATERIALS					
Ethanol (100%)	t	170 (*)	1.71	290.70	17,442,000
2 - CATALYSTS AND CHEMICALS					
Catalyst	kg	1.30	0.20	0.26	15,600
3 - UTILITIES					
Cooling Water	m^3	0.06	119.00	7.14	424,400
Process Water	m^3	0.88	1.20	1.05	63,300
Steam	t	5.50	1.50	8.25	495,000
Electricity	kwh	0.025	190.00	4.75	285,000
Fuel (9750 kcal/kg)	10^6 kcal	5.78	0.64	3.70	221,952
4 - OTHERS					
5 - BYPRODUCTS CREDIT					
TOTAL VARIABLE COSTS				315.86	18,951,312

FIXED MANUFACTURING COSTS	EVALUATION BASIS	COST PER UNIT (US$/ton prod)	ANNUAL COST (US$)
1 - LABOUR	OPERATION, MAINTENANCE AND PROCESS PERSONNEL	6.50	390,000
2 - MAINTENANCE	3% OF ISBL	8.50	510,000
3 - DEPRECIATION	10 % OF ISBL + 5 % OF OSBL	31.67	1,900,000
4 - INSURE AND TAXES	2 % OF ISBL	5.67	340,000
5 - PLANT OVERHEAD	200 % OF LABOUR	13.00	780,000
TOTAL FIXED COSTS		65.34	3,920,000
TOTAL MANUFACTURING COSTS		381.20	22,871,312
RETURN ON INVESTMENT BEFORE TAX	25% OF TOTAL INVESTMENT	102.92	6,175,000
TRANSFER PRICE		484.12	29,046,312

(*) Subsidized ethanol price

TABLE – VII

PROCESS ECONOMICAL EVALUATION

PRODUCT	Acetaldehyde
PROCESS	Ethanol Dehydrogenation
CAPACITY	45,000 MTY
LOCATION	Brazil
DATE	1st trim. 1979

ESTIMATED INVESTMENT

I T E M	V A L U E (US$)
BATTERY UNITS CAPITAL COST (ISBL)	7,700,000
OFFSITES CAPITAL COST (OSBL)	3,100,000
TOTAL FIXED CAPITAL	10,800,000
WORKING CAPITAL	3,300,000
TOTAL INVESTMENT	14,100,000

ESTIMATED MANUFACTURING COSTS AND TRANSFER PRICE

MANUFACTURING COSTS	UNIT	UNIT COST (US$ /UNIT)	UNIT CONSUMPTION (UNIT / ton prod)	COST PER UNIT (US$ /ton prod)	ANNUAL COST (US$)
1 – RAW MATERIALS					
Ethanol (100%)	t	293,00(***)	1.14	334.02	15,030,900
2 – CATALYSTS AND CHEMICALS					
Catalyst			N.A.	0.45	20,250
Dowtherm			N.A.	7.80	351,000
3 – UTILITIES					
Cooling Water	m^3	0.06	140.00	8.40	378,000
Process Water	m^3	0.88	0.60	0.53	23,850
Steam	t	5.50	6.00	33.00	1,485,000
Electricity	kwh	0.025	70.00	1.75	78,750
Fuel Oil	m^3	55.29	0.08	4.42	198,900
4 – OTHERS					
5 – BYPRODUCTS CREDIT					
Hydrogen	t	163.00(*)	0.045	(7.34)	(330,300)
Ethyl Acetate	t	766.00(**)	0.035	(26.81)	(1,206,450)
Acetic Acid	t	690.00(**)	0.018	(12.42)	(558,900)
TOTAL VARIABLE COSTS				343.80	15,471,000

FIXED MANUFACTURING COSTS	EVALUATION BASIS	COST PER UNIT (US$ /ton prod)	ANNUAL COST (US$)
1 – LABOUR	OPERATION, MAINTENANCE AND PROCESS PERSONNEL	14.20	639,000
2 – MAINTENANCE	3% OF ISBL	5.13	231,000
3 – DEPRECIATION	10 % OF ISBL + 5 % OF OSBL	20.56	925,000
4 – INSURE AND TAXES	2 % OF ISBL	3.42	154,000
5 – PLANT OVERHEAD	200 % OF LABOUR	30.00	1,350,000
TOTAL FIXED COSTS		73.31	3,299,000
TOTAL MANUFACTURING COSTS		417.11	18,770,000
RETURN ON INVESTMENT BEFORE TAX	25% OF TOTAL INVESTMENT	78.33	3,525,000
TRANSFER PRICE		495.44	22,295,000

(*) Fuel value (**) Brazilian market (***) non-subsidized ethanol price N.A. not available

TABLE - VIII

PROCESS ECONOMICAL EVALUATION

PRODUCT Acetaldehyde
PROCESS Ethanol Dehydrogenation
CAPACITY 45,000 MTY
LOCATION Brazil
DATE 1st Trim. 1979

ESTIMATED INVESTIMENT

I T E M	V A L U E (US$)
BATTERY LIMITS CAPITAL COST (ISBL)	7,700,000
OFFSITES CAPITAL COST (OSBL)	3,100,000
TOTAL FIXED CAPITAL	10,800,000
WORKING CAPITAL	2,000,000
TOTAL INVESTMENT	12,800,000

ESTIMATED MANUFACTURING COSTS AND TRANSFER PRICE

MANUFACTURING COSTS	UNIT	UNIT COST (US$ / UNIT)	UNIT CONSUMPTION (UNIT / ton prod)	COST PER UNIT (US$/ton prod)	ANNUAL COST (US$)
1 - RAW MATERIALS					
Ethanol (100%)	t	170.00 (***)	1.14	193.80	8,721,000
2 - CATALYSTS AND CHEMICALS					
Catalyst			N.A.	0.45	20,250
Dowtherm			N.A.	7.80	351,000
3 - UTILITIES					
Cooling water	m^3	0.06	140.00	8.40	378,000
Process Water	m^3	0.88	0.60	0.53	23,850
Steam	t	5.50	6.00	33.00	1,485,000
Electricity	kwh	0,025	70.00	1.75	78,750
Fuel oil	m^3	55.24	0.08	4.42	198,900
4 - OTHERS					
5 - BYPRODUCTS CREDIT					
Hydrogen	t	163.00 (*)	0,045	(7.34)	(330,300)
Ethyl Acetate	t	766.00 (**)	0,035	(26.81)	(1.206,450)
Acetic Acid	t	690.00 (*)	0.018	(12.42)	(558,900)
TOTAL VARIABLE COSTS				203.58	9,161,100

FIXED MANUFACTURING COSTS	EVALUATION BASIS	COST PER UNIT (US$/ton prod)	ANNUAL COST (US$)
1 - LABOUR	OPERATION, MAINTENANCE AND PROCESS PERSONNEL	14.20	639,000
2 - MAINTENANCE	3% OF ISBL	5.13	231,000
3 - DEPRECIATION	10 % OF ISBL + 5 % OF OSBL	20.56	925,000
4 - INSURE AND TAXES	2 % OF ISBL	3.42	154,000
5 - PLANT OVERHEAD	200 % OF LABOUR	30.00	1,350,000
TOTAL FIXED COSTS		73.31	3,299,000
TOTAL MANUFACTURING COSTS		276.89	12,460,100
RETURN ON INVESTMENT BEFORE TAX	25% OF TOTAL INVESTMENT	71.11	3,200,000
TRANSFER PRICE		348.00	15,660,100

N.A. not available (*) Fuel Value (**) Brazilian market (***) non-subsidized ethanol price

TABLE - IX

PROCESS ECONOMICAL EVALUATION

PRODUCT: Acetaldehyde
PROCESS: Wacker, 2 stages
CAPACITY: 45,000 Mt/y
LOCATION: Brazil
DATE: 1st trim. 1979

ESTIMATED INVESTIMENT

ITEM	VALUE (US$)
BATTERY LIMITS CAPITAL COST (ISBL)	10,500,000
OFFSITES CAPITAL COST (OSBL)	4,200,000
TOTAL FIXED CAPITAL	14,700,000
WORKING CAPITAL	2,800,000
TOTAL INVESTMENT	17,500,000

ESTIMATED MANUFACTURING COSTS AND TRANSFER PRICE

MANUFACTURING COSTS	UNIT	UNIT COST (US$/UNIT)	UNIT CONSUMPTION (UNIT/t prod)	COST PER UNIT (US$/t prod)	ANNUAL COST (US$)
1 - RAW MATERIALS					
Ethylene	t	393.00 (*)	0.68	267.24	12,025,800
HCl (100%)	kg	0.084	23.00	1.93	86,850
2 - CATALYSIS AND CHEMICALS					
Catalyst	liter	12.00	0.51	6.12	275,400
3 - UTILITIES					
Cooling Water	m^3	0.06	172.40	10.34	465,300
Process Water	m^3	0.88	0.2631	0.23	10,350
Steam	t	5.50	0.9124	5.02	225,900
Electricity	kwh	0.025	519.10	12.98	584,100
Inert gas	Nm^3	0.040	7.761	0.31	13,950
4 - OTHERS					
5 - BYPRODUCTS CREDIT					
TOTAL VARIABLE COSTS				304.17	13,687,650

FIXED MANUFACTURING COSTS	EVALUATION BASIS	COST PER UNIT (US$/t prod)	ANNUAL COST (US$)
1 - LABOUR	OPERATION, MAINTENANCE AND PROCESS PERSONNEL	14.20	639,000
2 - MAINTENANCE	3% OF ISBL	7.00	315,000
3 - DEPRECIATION	10 % OF ISBL 4.5% OF OSBL	28.00	1,260,000
4 - INSURE AND TAXES	2 % OF ISBL	4.67	210,150
5 - PLANT OVERHEAD	200 % OF LABOUR	29.00	1,305,000
TOTAL FIXED COSTS		82.87	3,729,150
TOTAL MANUFACTURING COSTS		387.04	17,416,800
RETURN ON INVESTMENT BEFORE TAX	25% OF TOTAL INVESTMENT	97.22	4,374,900
TRANSFER PRICE		484.26	21,791,700

(*) Brazilian market price of Petrochemical Ethylene

TABLE - X

PROCESS ECONOMICAL EVALUATION

PRODUCT Acetic Acid
PROCESS Air Oxidation
CAPACITY 60,000 MTY
LOCATION Brazil
DATE 1st trim. 1979

ESTIMATED INVESTIMENT

ITEM	VALUE (US$)
BATTERY UNITS CAPITAL COST (ISBL)	9,000,000
OFFSITES CAPITAL COST (OSBL)	3,600,000
TOTAL FIXED CAPITAL	12,600,000
WORKING CAPITAL	5,600,000
TOTAL INVESTMENT	18,200,000

ESTIMATED MANUFACTURING COSTS AND TRANSFER PRICE

MANUFACTURING COSTS	UNIT	UNIT COST (US$/UNIT)	UNIT CONSUMPTION (UNIT / ton prod)	COST PER UNIT (US$/ton prod)	ANNUAL COST (US$)
1 - RAW MATERIALS					
Acetaldehyde	t	495,000(*)	0.78	386.10	23,166,000
2 - CATALYSTS AND CHEMICALS					
Mn Acetate	kg	4.40	0.20	0.88	52,800
3 - UTILITIES					
Cooling Water	m^3	0.06	280.00	16.8	1,008,000
Process Water	m^3	0.88	8.00	7.04	422,400
Steam	t	5.50	3.60	19.80	1,188,000
Electricity	kwh	0.025	293.00	7.33	439,800
Instrument Air	Nm^3	0.04	2.50	0.10	6,000
4 - OTHERS					
5 - BYPRODUCTS CREDIT					
TOTAL VARIABLE COSTS				438.05	26,283,000

FIXED MANUFACTURING COSTS	EVALUATION BASIS	COST PER UNIT (US$/ton prod)	ANNUAL COST (US$)
1 - LABOUR	OPERATION, MAINTENANCE AND PROCESS PERSONNEL	11.52	691,200
2 - MAINTENANCE	3% OF ISBL	4.50	270,000
3 - DEPRECIATION	10 % OF ISBL + 5 % OF OSBL	18.00	1,080,000
4 - INSURE AND TAXES	2 % OF ISBL	3.00	180,000
5 - PLANT OVERHEAD	200 % OF LABOUR	24.00	1,440,000
TOTAL FIXED COSTS		61.02	3,661,200
TOTAL MANUFACTURING COSTS		499.07	29,944,200
RETURN ON INVESTMENT BEFORE TAX	25% OF TOTAL INVESTMENT	75.83	4,549,800
TRANSFER PRICE		574.90	34,494,000

(*) Transfer Price of Acetaldehyde from non-subsidized ethanol.

TABLE – XI

PROCESS ECONOMICAL EVALUATION

PRODUCT	Acetic Acid
PROCESS	Air Oxidation
CAPACITY	60,000 MTY
LOCATION	Brazil
DATE	1st trim. 1979

ESTIMATED INVESTIMENT

I T E M	V A L U E (US$)
BATTERY LIMITS CAPITAL COST (ISBL)	9,000,000
OFFSITES CAPITAL COST (OSBL)	3,600,000
TOTAL FIXED CAPITAL	12,600,000
WORKING CAPITAL	3,700,000
TOTAL INVESTMENT	16,600,000

ESTIMATED MANUFACTURING COSTS AND TRANSFER PRICE

MANUFACTURING COSTS	UNIT	UNIT COST (US$/UNIT)	UNIT CONSUMPTION (UNIT / ton prod)	COST PER UNIT (US$/ton prod)	ANNUAL COST (US$)
1 – RAW MATERIALS					
Acetaldehyde	t	348,00 (*)	0,78	271.44	16,286,400
2 – CATALYSTS AND CHEMICALS					
Mn Acetate	kg	4.40	0.20	0.88	52,800
3 – UTILITIES					
Cooling Water	m^3	0.06	280.00	16.8	1,008,000
Process Water	m^3	0.88	8.00	7.04	422,400
Steam	t	5.50	3.60	19.80	1,188,000
Electricity	kwh	0.025	293.00	7.33	439,800
Instrument Air	Nm3	0.04	2.50	0.10	6,000
4 – OTHERS					
5 – BYPRODUCTS CREDIT					
TOTAL VARIABLE COSTS				323.39	19,403,400

FIXED MANUFACTURING COSTS	EVALUATION BASIS	COST PER UNIT (US$/ton prod)	ANNUAL COST (US$)
1 – LABOUR	OPERATION, MAINTENANCE AND PROCESS PERSONNEL	11.52	691,200
2 – MAINTENANCE	3% OF ISBL	4.50	270,000
3 – DEPRECIATION	10 % OF ISBL + 5 % OF OSBL	18.00	1,080,000
4 – INSURE AND TAXES	2 % OF ISBL	3.00	180,000
5 – PLANT OVERHEAD	200 % OF LABOUR	24.00	1,440,000
TOTAL FIXED COSTS		61.02	3,661,200
TOTAL MANUFACTURING COSTS		384.41	23,064,600
RETURN ON INVESTMENT BEFORE TAX	25% OF TOTAL INVESTMENT	69.16	4,150,000
TRANSFER PRICE		453.57	27,214,600

(*) Transfer Price of Acetaldehyde from subsidized ethanol

TABLE - XII

PROCESS ECONOMICAL EVALUATION

PRODUCT	Acetic Acid
PROCESS	Air Oxidation
CAPACITY	60,000 MTY
LOCATION	Brazil
DATE	1st trim. 1979

ESTIMATED INVESTIMENT

I T E M	V A L U E (US$)
BATTERY UNITS CAPITAL COST (ISBL)	9,000,000
OFFSITES CAPITAL COST (OSBL)	3,600,000
TOTAL FIXED CAPITAL	12,600,000
WORKING CAPITAL	4,700,000
TOTAL INVESTMENT	17,300,000

ESTIMATED MANUFACTURING COSTS AND TRANSFER PRICE

MANUFACTURING COSTS	UNIT	UNIT COST (US$/UNIT)	UNIT CONSUMPTION (UNIT / ton prod)	COST PER UNIT (US$/ton prod)	ANNUAL COST (US$)
1 - RAW MATERIALS					
Acetaldehyde	t	484.00 (*)	0.78	377.52	22,651,200
2 - CATALYSTS AND CHEMICALS					
Mn Acetate	kg	4.40	0.20	0.88	52,800
3 - UTILITIES					
Cooling Water	m^3	0.06	280.00	16.80	1,008,000
Process Water	m^3	0.88	8.00	7.04	422,400
Steam	t	5.50	3.60	19.80	1,188,000
Electricity	kwh	0.025	293.00	7.33	439,800
Instrument Air	Nm^3	0.040	2.50	0.10	6,000
4 - OTHERS					
5 - BYPRODUCTS CREDIT					
TOTAL VARIABLE COSTS				429.47	25,768,200

FIXED MANUFACTURING COSTS	EVALUATION BASIS	COST PER UNIT (US$/ton prod)	ANNUAL COST (US$)
1 - LABOUR	OPERATION, MAINTENANCE AND PROCESS PERSONNEL	11.52	691,200
2 - MAINTENANCE	3% OF ISBL	4.50	270,000
3 - DEPRECIATION	10 % OF ISBL + 5 % OF OSBL	18.00	1,080,000
4 - INSURE AND TAXES	2 % OF ISBL	3.00	180,000
5 - PLANT OVERHEAD	200 % OF LABOUR	24.00	1,440,000
TOTAL FIXED COSTS		61.02	3,661,200
TOTAL MANUFACTURING COSTS		490.48	29,429,400
RETURN ON INVESTMENT BEFORE TAX	25% OF TOTAL INVESTMENT	72.08	4,324,800
TRANSFER PRICE		562.57	33,754,200

(*) Transfer Price of Acetaldehyde from Petrochemical Ethylene

TABLE - XIII

PROCESS ECONOMICAL EVALUATION

PRODUCT	2-ethylhexanol
PROCESS	From ethanol
CAPACITY	20,000 MTY
LOCATION	Brazil
DATE	1st trim. 1979

ESTIMATED INVESTIMENT

ITEM	VALUE (US$)
BATTERY UNITS CAPITAL COST (ISBL)	15,500,000
OFFSITES CAPITAL COST (OSBL)	4,500,000
TOTAL FIXED CAPITAL	20,000,000
WORKING CAPITAL	4,000,000
TOTAL INVESTMENT	24,000,000

ESTIMATED MANUFACTURING COSTS AND TRANSFER PRICE

MANUFACTURING COSTS	UNIT	UNIT COST (US$/UNIT)	UNIT CONSUMPTION (UNIT / ton prod)	COST PER UNIT (US$/ton prod)	ANNUAL COST (US$)
1 - RAW MATERIALS					
Ethanol (100%)	t	293.00 (**)	2,45	717.85	14,357,000
Hydrogen (pure)	t	700.00	0.09	63.00	1,260,000
2 - CATALYSTS AND CHEMICALS					
Catalyst	kg	5.00	2.00	10.00	200,000
UTILITIES					
Cooling Water	m^3	0.06	115.00	6.90	138,000
Process Water	m^3	0.88	0.70	0.62	12,400
Steam	t	5.50	28.00	154.00	3,080,000
Electricity	kwh	0.025	2,000.00	50.00	1,000,000
Nitrogen	Nm^3	0.076	390.00	29.64	592,800
4 - OTHERS					
5 - BYPRODUCTS CREDIT					
n-butanol	t	1,057.00(*)	0.044	(46.51)	(930,200)
Acetic Acid	t	690.00(*)	0.10	(69.00)	(1,380,[illegible])
Ethyl Acetate	t	766.00(*)	0.033	(25.28)	([illegible],600)
TOTAL VARIABLE COSTS				891.22	17,824,400

FIXED MANUFACTURING COSTS	EVALUATION BASIS	COST PER UNIT (US$/ton prod)	ANNUAL COST (US$)
1 - LABOUR	OPERATION, MAINTENANCE AND PROCESS PERSONNEL	42.62	852,400
2 - MAINTENANCE	3% OF ISBL	23.25	465 000
DEPRECIATION	10% OF ISBL + 5% OF OSBL	88.75	1,775,000
4 - INSURE AND TAXES	2% OF ISBL	15.50	310,000
5 - PLANT OVERHEAD	200% OF LABOUR	84.00	1,680,000
TOTAL FIXED COSTS		254.12	5,082,400
TOTAL MANUFACTURING COSTS		1145.34	22,906,800
RETURN ON INVESTMENT BEFORE TAX	25% OF TOTAL INVESTMENT	300.00	6,000,000
TRANSFER PRICE		1445.34	28,906,[illegible]

(*) Brasilian Market Price (**) Nonsubsidized Ethanol Price

TABLE - XIV

PROCESS ECONOMICAL EVALUATION

PRODUCT 2-ethylhexanol
PROCESS From ethanol
CAPACITY 20,000 MTY
LOCATION Brazil
DATE 1^{st} trim. 1979

ESTIMATED INVESTIMENT

I T E M	V A L U E (US$)
BATTERY LIMITS CAPITAL COST (ISBL)	15,500,000
OFFSITES CAPITAL COST (OSBL)	4,500,000
TOTAL FIXED CAPITAL	20,000,000
WORKING CAPITAL	3,600,000
TOTAL INVESTIMENT	23,600,000

ESTIMATED MANUFACTURING COSTS AND TRANSFER PRICE

MANUFACTURING COSTS	UNIT	UNIT COST (US$/UNIT)	UNIT CONSUMPTION (UNIT / ton prod)	COST PER UNIT (US$/ton prod)	ANNUAL COST (US$)
1 - RAW MATERIALS					
Ethanol (100%)	t	170.00 (**)	2.45	416.50	8,330,000
Hydrogen (pure)	t	700.00	0.90	63.00	1,260,000
2 - CATALYSTS AND CHEMICALS					
Catalyst	kg	5.00	2.00	10.00	200,000
3 - UTILITIES					
Cooling Water	m^3	0.06	115.00	6.90	138,000
Process Water	m^3	0.88	0.70	0.62	12,400
Steam	t	5.50	28.00	154.00	3,080,000
Electricity	kwh	0.025	2,000.00	50.00	1,000,000
Nitrogen	Nm^3	0.076	390.00	29.64	592,800
4 - OTHERS					
5 - BYPRODUCTS CREDIT					
n-butanol	t	1,057.00 (*)	0.044	(46.51)	(930,200)
Acetic Acid	t	690.00 (*)	0.10	(69.00)	(1,380,000)
Ethyl Acetate	t	766.00 (*)	0.033	(25.28)	(505,600)
TOTAL VARIABLE COSTS				589.87	11,797,400

FIXED MANUFACTURING COSTS	EVALUATION BASIS	COST PER UNIT (US$/ton prod)	ANNUAL COST (US$)
1 - LABOUR	OPERATION, MAINTENANCE AND PROCESS PERSONNEL	42.62	852,400
2 - MAINTENANCE	3% OF ISBL	23.25	465,000
3 - DEPRECIATION	10 % OF ISBL + 5 % OF OSBL	88.75	1,775,000
4 - INSURE AND TAXES	2 % OF ISBL	15.50	310,000
5 - PLANT OVERHEAD	200 % OF LABOUR	84.00	1,680,000
TOTAL FIXED COSTS		254.12	5,082,400
TOTAL MANUFACTURING COSTS		843.99	16,879,800
RETURN ON INVESTMENT BEFORE TAX	25% OF TOTAL INVESTMENT	295.00	5,900,000
TRANSFER PRICE		1,138.99	22,779,800

(*) Brazilian Market Price (**) Subsidized ethanol price

TABLE - XV

PROCESS ECONOMICAL EVALUATION

PRODUCT	Butadiene
PROCESS	From Ethanol
CAPACITY	30,000 MTY
LOCATION	Brazil
DATE	1st trim. 1979

ESTIMATED INVESTIMENT

I T E M	V A L U E (US$)
BATTERY UNITS CAPITAL COST (ISBL)	20,000,000
OFFSITES CAPITAL COST (OSBL)	6,000,000
TOTAL FIXED CAPITAL	26,000,000
WORKING CAPITAL	4,000,000
TOTAL INVESTMENT	30,000,000

ESTIMATED MANUFACTURING COSTS AND TRANSFER PRICE

MANUFACTURING COSTS	UNIT	UNIT COST (US$ /UNIT)	UNIT CONSUMPTION (UNIT / ton prod)	COST PER UNIT (US$/ton prod)	ANNUAL COST (US$)
1 - RAW MATERIALS					
Ethanol (100%)	t	293.00(***)	2.47	723.71	21,711,[illegible]
2 - CATALYSTS AND CHEMICALS					
Catalyst	kg	5.00	5.00	25.00	750,00[illegible]
3 - UTILITIES					
Cooling Water	m^3	0.06	500.00	30.00	900,00[illegible]
Steam	t	5.50	5.00	27.50	825,0[illegible]
Electricity	KWH	0.025	900.00	22.50	675,000
Nitrogen	Nm^3	0.076	50.00	3.80	114,000
4 - OTHERS					
5 - BYPRODUCTS CREDIT					
Ethyl Ether	t	975.00 (*)	0.137	(133.50)	(4,007,400
Hydrogen (100%)	t	163.00 (**)	0.026	(4.24)	(127,2[illegible]
TOTAL VARIABLE COSTS				694.69	20,840,700

FIXED MANUFACTURING COSTS	EVALUATION BASIS	COST PER UNIT (US$/ton prod)	ANNUAL COST (US$)
1 - LABOUR	OPERATION, MAINTENANCE AND PROCESS PERSONNEL	42.62	1,278,6[illegible]
2 - MAINTENANCE	3% OF ISBL	20.00	600,00[illegible]
3 - DEPRECIATION	10 % OF ISBL + 5% OF OSBL	76.67	2,300,10[illegible]
4 - INSURANCE AND TAXES	2 % OF ISBL	13.33	399,90[illegible]
5 - PLANT OVERHEAD	200 % OF LABOUR	84.00	2,520,00[illegible]
TOTAL FIXED COSTS		236.62	7,098,60[illegible]
TOTAL MANUFACTURING COSTS		931.31	27,239,30[illegible]
RETURN ON INVESTMENT BEFORE TAX	25% OF TOTAL INVESTMENT	250.00	7,500,00[illegible]
TRANSFER PRICE		1181.31	35,439,30[illegible]

(*) Brazilian Market (**) Fuel value (***)Nonsubsidized ethanol price

TABLE - XVI

PROCESS ECONOMICAL EVALUATION

PRODUCT	Butadiene
PROCESS	From Ethanol
CAPACITY	30,000 MTY
LOCATION	Brazil
DATE	1st trim. 1979

ESTIMATED INVESTIMENT

ITEM	VALUE (US$)
BATTERY UMITS CAPITAL COST (ISBL)	20,000,000
OFFSITES CAPITAL COST (OSBL)	6,000,000
TOTAL FIXED CAPITAL	26,000,000
WORKING CAPITAL	3,200,000
TOTAL INVESTMENT	29,200,000

ESTIMATED MANUFACTURING COSTS AND TRANSFER PRICE

MANUFACTURING COSTS	UNIT	UNIT COST (US$/UNIT)	UNIT CONSUMPTION (UNIT / ton prod)	COST PER UNIT (US$/ton prod)	ANNUAL COST (US$)
1-RAW MATERIAIS					
Ethanol (100%)	t	170.00(***)	2.47	419.90	12,597,000
2-CATALYSTS AND CHEMICALS					
Catalyst	kg	5.00	5.00	25.00	750,[illegible]
3-UTILITIES					
Cooling Water	m^3	0.06	500.00	30.00	900,000
Steam	t	5.50	5.00	27.50	825,000
Electricity	kwh	0.025	900.00	22.50	675,000
Nitrogen	Nm^3	0.076	50.00	3.80	114,000
4-OTHERS					
5-BYPRODUCTS CREDIT					
Ethyl Ether	t	975.00(*)	0.137	(133.58)	(4.007,400)
Hydrogen (100%)	t	163.00(**)	0.026	(4.24)	(127,200)
TOTAL VARIABLE COSTS				390.86	11,726,400
FIXED MANUFACTURING COSTS	**EVALUATION BASIS**				
1-LABOUR	OPERATION, MAINTENANCE AND PROCESS PERSONNEL			42.62	1,278,600
2-MAINTENANCE	3% OF ISBL			20.00	600,000
3-DEPRECIATION	10% OF ISBL + 5% OF OSBL			76.67	2,300,100
4-INSURE AND TAXES	2% OF ISBL			13.33	399,900
5-PLANT OVERHEAD	200% OF LABOUR			84.00	2,520,000
TOTAL FIXED COSTS				236.62	7,098,600
TOTAL MANUFACTURING COSTS				627.50	18,825,000
RETURN ON INVESTMENT BEFORE TAX	25% OF TOTAL INVESTMENT			243.33	7,300,000
TRANSFER PRICE				870.83	26,125,000

(*) Brazilian market price (**) Fuel Price (***)Non-subsidized ethanol price

TABLE XVII

PRICES OF CHEMICALS OBTAINED FROM ETHANOL AND PETROCHEMICAL FEEDSTOCK

BRAZILIAN CONDITIONS - 1st QUARTER 1979

PRODUCT	PRICES (US$/t)		
	INDUSTRIAL ALCOHOL	SUBSIDISED ALCOHOL	PETROCHEMICAL
Ethylene	702	484	393 *
Acetaldehyde	495	348	484 **
Acetic Acid	575	454	563 **
Octanol (2-ethyl hexanol)	1,445	1,139	1,204 **
Butadiene	1,181	871	563 *

* Brazilian market price

** Estimated transfer price according to the economical evaluation charged) in the country for the petrochemical originated product.

Such data indicate that, at the level of capacity taken into consideration, ethanol-chemical processes to manufacture acetaldehyde and acetic acid — widely used in the country — are competitive as compared to alternative petrochemical routes, even if considering ethanol at current market prices.

On the other hand, the saving with the production of octhanol from ethyl alcohol is highly dependent on the cost of raw material and, therefore, the use of a subsidised price for the alcohol seems to be essential to ensure competitiveness of such process.

As regards ethylene, the subsidy taken as reference in the economic evaluation seems insufficient to render the price in the process from alcohol equivalent to that of the petrochemical product. By reviewin the text of the National Alcohol Plan it appears to be possible to apply for a larger subsidy, which, to reach the intended equivalence, would, in this instance, be on the basis of 25% of present petrochemical ethylene prices.

Where butadiene is concerned, results obtained indicate that its production by ethanol-chemical route is far from being competitive as compared to the processes to obtain this basic product in naphtha pyrolysis complexes.

6. CONCLUSIONS

Petroleum supply difficulties bring back the ethanol-chemical industry as a sound technological alternative to obtain certain products, nowadays predominantly petrochemical.

Brazil's tendency toward the use of that productive route is maybe unparalleled in the world, in view of its territorial extent and propitious conditions for the culture of sugar cane, manioc and other agricultural products applicable in alcoholic fermentation.

On the other hand, the National Alcohol Plan has created favorable conditions to strengthen such activity in the country, amongst which should be pointed out the assurance of a regular supply of raw material, at a reasonable price, and encouragement to development of technology in the agricultural and industrial sectors.

Thus, the experience in manufacturing ethanol-chemical derivatives,acquired throughout many years by the producing companies, permits to consider its technology fully absorbed in Brazil.

Such experience is now being utilized, in the scope of companies and research centers, to modernize manufacturing processes, with a view to its prompt use in larger and more economical units.

Moreover, in view of the present stage of the art - whether agricultural, or industrial - of manufacturing ethyl alcohol, it may be anticipated that, shortly, this raw material will continue to be produced in the country at high costs. Therefore, the subsidy instituted by the Government should continue for some years, in order to ensure competitiveness of ethanol-chemical processes when compared to the petrochemical industry processes.

At medium and long term, as a result of

PROALCOOL efforts and the technological development programs under way, which lead to higher agricultural productivity indices and more competitive industrial processes, it is expected that ethanol-chemical industry in Brazil will at last reach its maturity, becoming self-sufficient.

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