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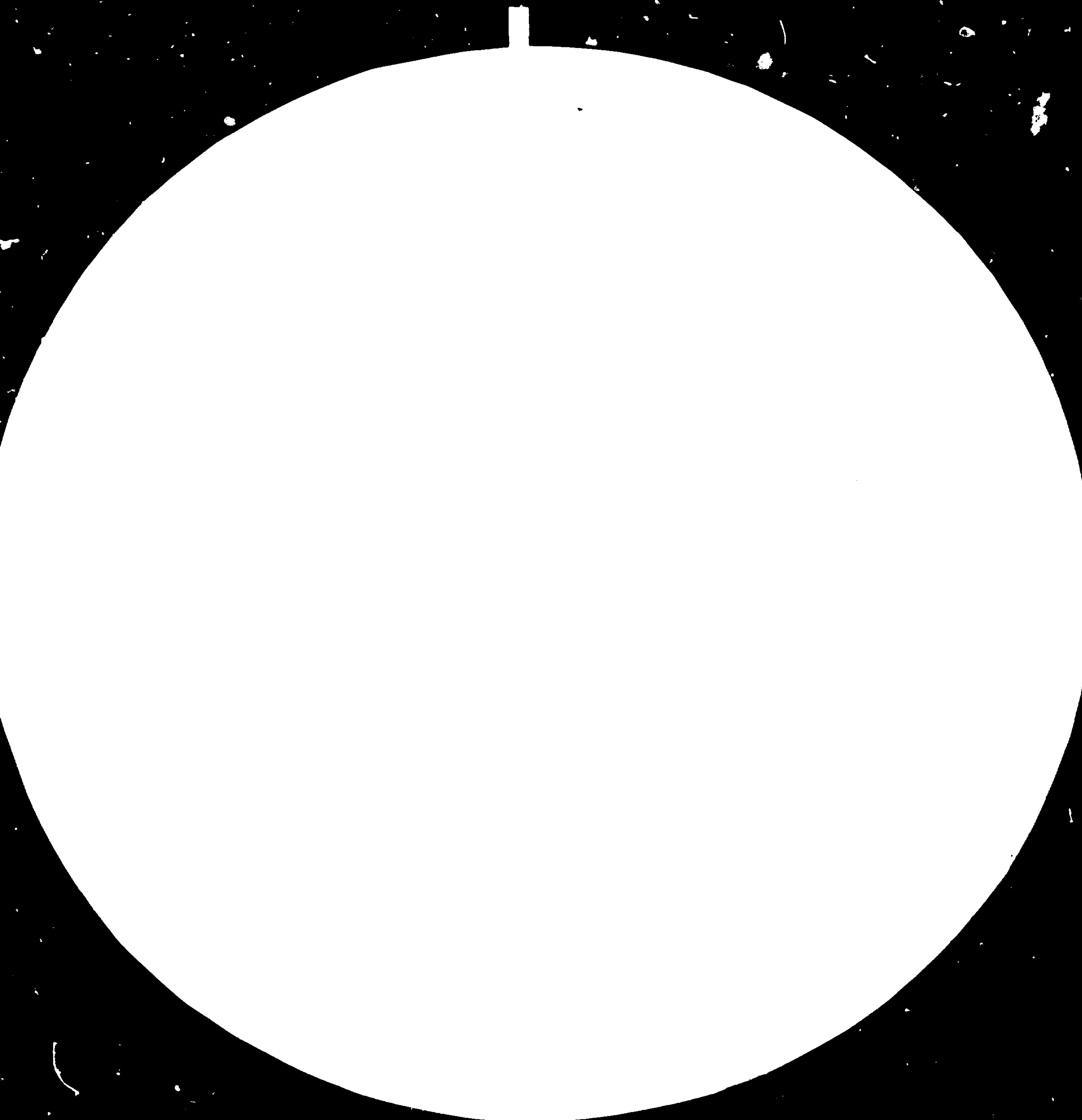

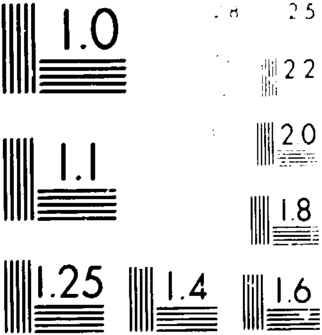
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THE PETROCHEMICAL AND POLYMER INDUSTRIES IN BOLIVIA*

by

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STUDY OF BOLIVIAN PETROCHEMICAL COMPLEX

INTRODUCTION

As a consequence of the Bolivian participation in the Petrochemical Program of the Andean Common Market, Bolivia received certain allocations of petrochemical products. For this situation it was necessary to study the feasibility of the installation of such allocations in Bolivia. YPFB the Bolivian Oil Company contracted the services of the consulting Company SRI International of United States to perform this study.

All the information presented in this paper are the results of said study.

SUMMARY

The study considers the following aspects:

- Market study
- Optimization
- Site selection
- Process and complex study
- Investment, production costs and profitability study

MARKET STUDY

In relation to this point it was necessary to perform a market analysis not only for the Bolivian market but for the surrowinding and Andean pact countries.

The results of the study say that the opportunities available to Bolivia in South American Markets for the products under study appear to justify a Petrochemical complex in Bolivia having order of magnitude capacities of 100.000 tons per year each of low density and high density polyethylene and 50.000 tons per year of polypropylene. Market opportunities for styrene monomer and polystyrene do not appear to be sufficiently large to justify an economically viable manufacturing facility for these products in Bolivia because of the small ANCOM market and competition from established and expected new producers elsewhere in South America and the world.

OPTIMIZATION

The objective of the optimization work was to determine the plant sizes for the products under consideration that will maximize the profitability of the complex within the constraints of the available markets. Several tasks had to be completed before undertaking the optimization work. These tasks are listed below and are discussed in the paragraphs which follow:

Process selection
Available markets
Raw material prices
Product prices and netbacks

PROCESS SELECTION

Information was solicited from licensors of processes for production of olefins and low density polyethylene, high density polyethylene, polypropylene and styrene. Of 40 licensors queried, 28 responded positively. The analysis of the information were weighted as follows:

	Weight
Quality of information	20%
Process economics	35%
Experience	20%
Comercial terms	25%

On the basis of the overall rating by the above weighting, we considered the following processes to be the top contenders for use in the complex:

Olefins: Braun, Linde, Lummus, Stone and Webster
HDPE: Montedison. Solvay.
LDPE (autoclave): ICI, National Distillers
LDPE (tubular): ANIC, Dart, Imhausen, Stamicarbon
PP: Dart, Hercules, Mitsui Toatsu, Montedison
Styrene: Mobil - Badger, Monsanto - Lummus

AVAILABLE MARKET

Phase I of the feasibility study established the markets for these products that might be available to Bolivia. The available markets were expressed in actual tons per year until 1988 and thereafter were given as growth rates. As part of the optimization study, SRI jointly with YPFB made assumptions as to what portion of the growth in demand in some of the countries might be available to Bolivian products.

Thousand Tons/Yera

	1986	1987	1988	2000
HDPE	110.5	135.9	63.1	205.7
LDPE	102.8	117.7	61.6	153.8
PP	55.8	62.0	30.0	100.8

RAW MATERIAL PRICES

The two principal raw materials for the petrochemical complex under consideration are ethane and propane. Their prices were derived from a natural gas price of US$ 2.23/million BTU which was the price Y.P.F.B. was receiving from Argentina for its natural gas. The price of ethane and propane was then calculated by developing the operating costs for a natural gas liquids extraction plant that would recover the amount of ethane and propane needed for the complex plus an allowance for a 10% return on investment.

NET BACKS

The netbacks are defined as the product revenue in US$ per ton received at the plant gate of the complex located in Santa Cruz.

As the example shows, we start out with the U.S. price of the product; then freight and insurance required to deliver the commodity from the Gulf Coast to a location are added to the U.S. price. On location closen, duties and miscellaneous charges are paid increasing the delivered price of the product.

It is assumed that the product made in Bolivia will sell for the price of the delivered product as estimated above.

To estimate the netback to the Bolivian producer, freight and insurance to the location chosen from the Bolivian site and miscellaneous charges are subtracted from the delivered price estimate previously.

SAMPLE NETBACK - HDPE FOR COLOMBIA

	From USA	From Bolivia
FOB Price US$	766	890.40 NetBack
Freight and insurance	126.50	222.30
CIF Value	892.50	1.112.70
Duty (30% of CIF)	267.75	-
Misc. charges (21.6% of CIF)	192.78	240.33
LANDED PRICE	1.353.03	1.353.03

OPTIMIZATION

We selected the box (complex algorithm) as the optimization. The box is a modified hill climbing procedure. It was selected because the optimization problem on hand is not suited to an analitical solution. The profitability indicators used in the optimization were the following:

Internal rate of return.
Net present worth at discounting rate of 20%.
Benefit/cost ratio at discounting rate of 20%.

The optimization parameters used were the following.

- Star up year.
- Project life.
- Income tax.
- Depreciation tax credit.
- Financing.
- Raw materials and product prices constant over project life.
- Prices in current dollars (inflation rates: 10%/Year in 1979, 7.5%/Year in 1980, 7%/Year thereafter).

The results showed that the production of styrene is detrimental to the profitability of the complex, we then redid the optimization for three products: LDPE, HDPE, and PP showing a relatively flat maximum for a complex consisting of the following units.

HDPE	90.000 ton/Year
LDPE	60.000 ton/Year
PP	40.000 ton/Year

In reviewing the results, the PP plant was sized according to the amount of the propylene that can be manufactured from the propane recovered along with the ethane in the natural gas liquids plant.

In this context a 27.000 tons/Year of PP was chosen for the complex.

SITE SELECTION

The selection of a site for the petrochemical complex in Bolivia required careful considerations of many factors as:

Availability of raw materials.
Markets to be supplied.
Availability of water and energy.
Availability of labor.
Adequate Infraestructure, for transportation, and housing and social services for workers.
Disposal of plant wastes.

In Bolivia, the source of raw material for the petrochemical complex is in the region of Santa Cruz or the Southeast region.

The markets within Bolivia are to small to justify a petrochemical complex solely for domestic markets at this time. The export market is therefore important in the site selection. The Andean

Common Market (ANCOM) will be the major market during the early years of the proposed project. Our market study points up the possibility of YPFB's supplying low density polyethylene to Brasil.

Of the many sites considered seven were only analized and from these contenders it was clear that Palmasola (near Santa Cruz) and Cochabamba were the leading contenders. Assuming that LDPE sales to Brasil are realized, Palmasola becomes the favored site.

PROCESS AND COMPLEX DESCRIPTION

The flow chart shows the overall plan and the overall material balance.

Natural gas is fed to an extraction plant, Natural Gas Liquids recovered from the gas are separated into ethane, propane, isobutane, butane and C + 5 gasoline.

The residue gas is available for sale to the complex and to others, for fuel. The ethane and propane are cracked in the olefins plant to produce ethylene and propylene. By-products are fuel gas and pyrolysis gasoline. The gasoline is sent to a nearby refinery and the fuel gas is available for use in the utility plant.

In the future a small phenol plant may be added.

In addition to the main units shown, a utilities center is included in the complex. Other facilities such as waste treatment, maintenance shops, office buildings et., are also part of the complex.

INVESTMENT COST

The investment cost of the complex was adjusted from the information on capital investments that was obtained from various licensors. The costs were provided on the basis of a U.S. Gulf Coast location or were adjusted to that location. The costs were finally adjusted to a Bolivian location by multiplying the U.S. Gulf Coast values by a factor of 1.30.

For the final evaluation, we updated costs to 1980 and made adjustments to match the feed and products conditions for the plants in the complex

The investments costs determined for the end of the year 1980 total about 390 million dollars, exclusive of inancing charges.

These costs are shown in the following table.

	Million US$
Olefins	130
H D P E	78
L D P E	71
P P	34
Utilities Center	27
Extraction unit	50
T o t a l	390

TIME SCHEDULE AND MANPOWER

The tentative time schedule shown in figure 2 for major activities from signing of the contracts to commercial operation indicates 46 months to complete the project.

Figure 3 shows a peak labor force of about 2000.

PRODUCTION COSTS

Production costs were calculated through conditions applied in Bo livia for example since electricity is produced within the comp'ex a trial and error calculation must be used. If the price of electricity is assumed, one can calculate the cost of producing raw water, cooling water, boiler feed water, and steam in that sequence.

Electricity will be produced along with steam in a combined cycle. The calculation of the total cost of producing electricity and steam is easy but the distribution of cost is dificult. We tried to balance the costs by considering relative energy costs in other countries and the price of purchased electricity in Bolivia. We finally settled on a price of 3.9 ₵/KWH for electricity.

We estimated the utility prices to be:

Electricity	3.9 ₵/Kwh.
Raw water	12.3 ₵/m3.
Cooling water	2.9 ₵/m3.
Process water/BFW	1.86 $/m3.
Steam	
At 46 Kg/cm2	15.20 $/Ton.
At 17.6 Kg/cm2	14.30 $/Ton.
At 3.5 Kg/cm2	12.30 $/Ton.
Nitrogen	9.9 ₵/Nm3.
Instrument air	1.3 ₵/Nm3.

The price of there utilities were calculated assuming a 10% return on investment and no income taxes.

After the utilities price are known, the price of ethylene and propylene can be calculated we assumed a depreciation of fixed capital of 10% /year, depreciation of preproduction expenses would be 20% /year, income tax would be 15% /year, and the discounted cash flow internal rate of return was to be 15%. From these figures, the price of the olefins was determined to be 458 US$/ton.

PROFITABILITY

On the basis of all the cata discussed above, we performed a discounted cash flow analysis using a 100% equity basis and 15 years of commercial operation for the term of analysis.

After the base case, we made runs to test the sensitivity of the internal rate of return to various factors. The results are shown in the following table.

For the case of 40% equity and for assumed inflation rates, the internal rate of return are considerably higher than for the base case.

	Olefins	HDPE	LDPE	PP
Base case	15%	26.1%	15.7	20.5%
40% equity	20%	39.1%	20.2	30.0
Inflation	18.1	37.4	28.8	31.9

As an example figure 4 shows the effect of changes on internal rate of return for HDPE.

From this figure it is apparent that the profitabilities of all products depend most strongly on sales revenues and least on utilities costs, sales volumens, raw materials and capital costs are of intermediate importance.

CONCLUSIONS

The oportunities available in South American Markets for Bolivia would justify a petrochemical complex in Bolivia, having order of magnitude capacities of 100.000 tons per year each of low density and high density polyethylene and 50.000 tons per year of polypropylene.

Figure No. 1
FLOW CHART FOR BOLIVIAN PETROCHEMICAL COMPLEX

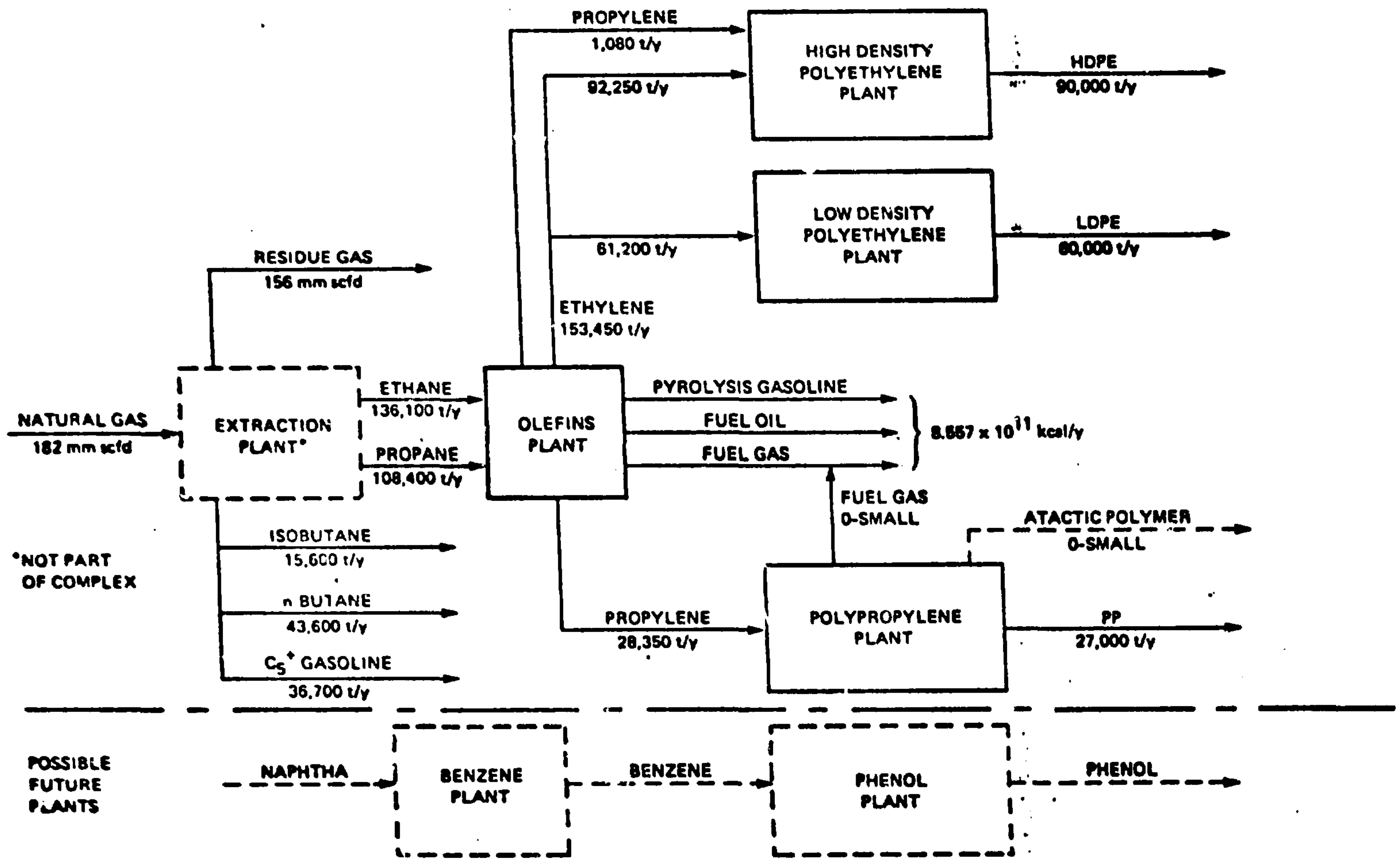
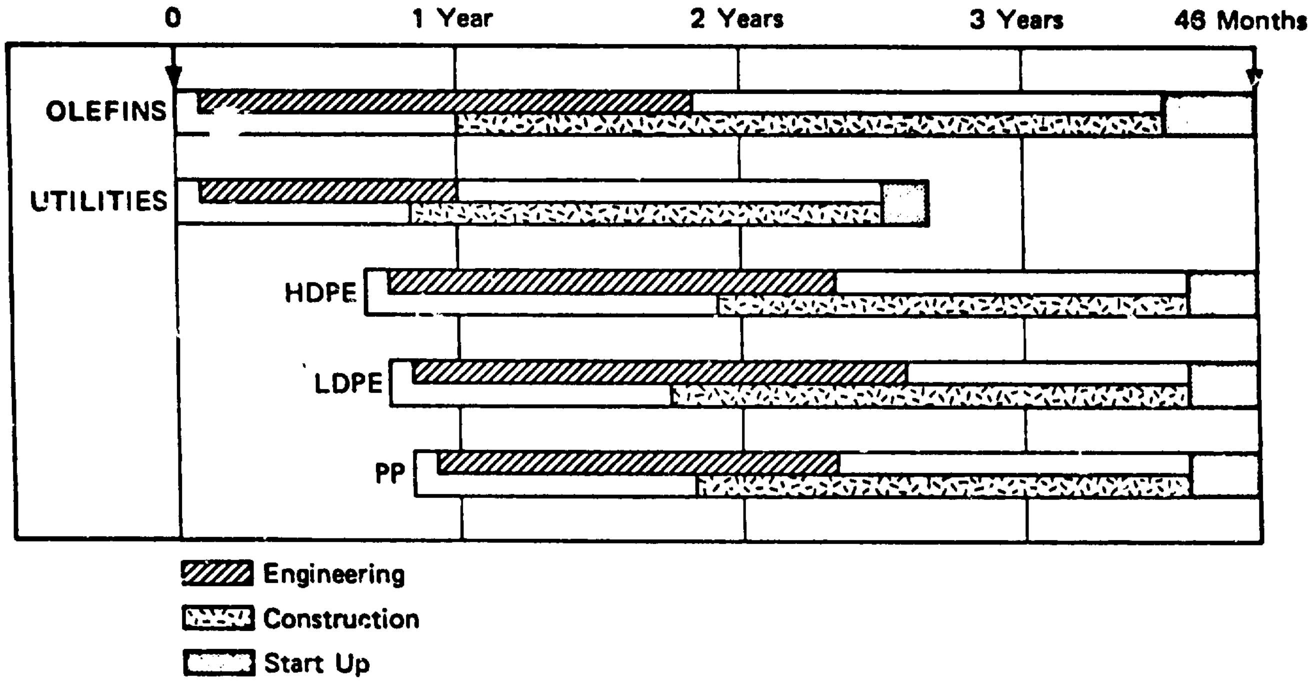


FIGURE No.2 TIME SCHEDULE FOR MAJOR ACTIVITIES



NOTE: Starting time for each plant is signing of contract.
Schedule shows activities up to start of commercial operations.

FIGURE No. 3 CONSTRUCTION MANPOWER FOR BOLIVIAN COMPLEX

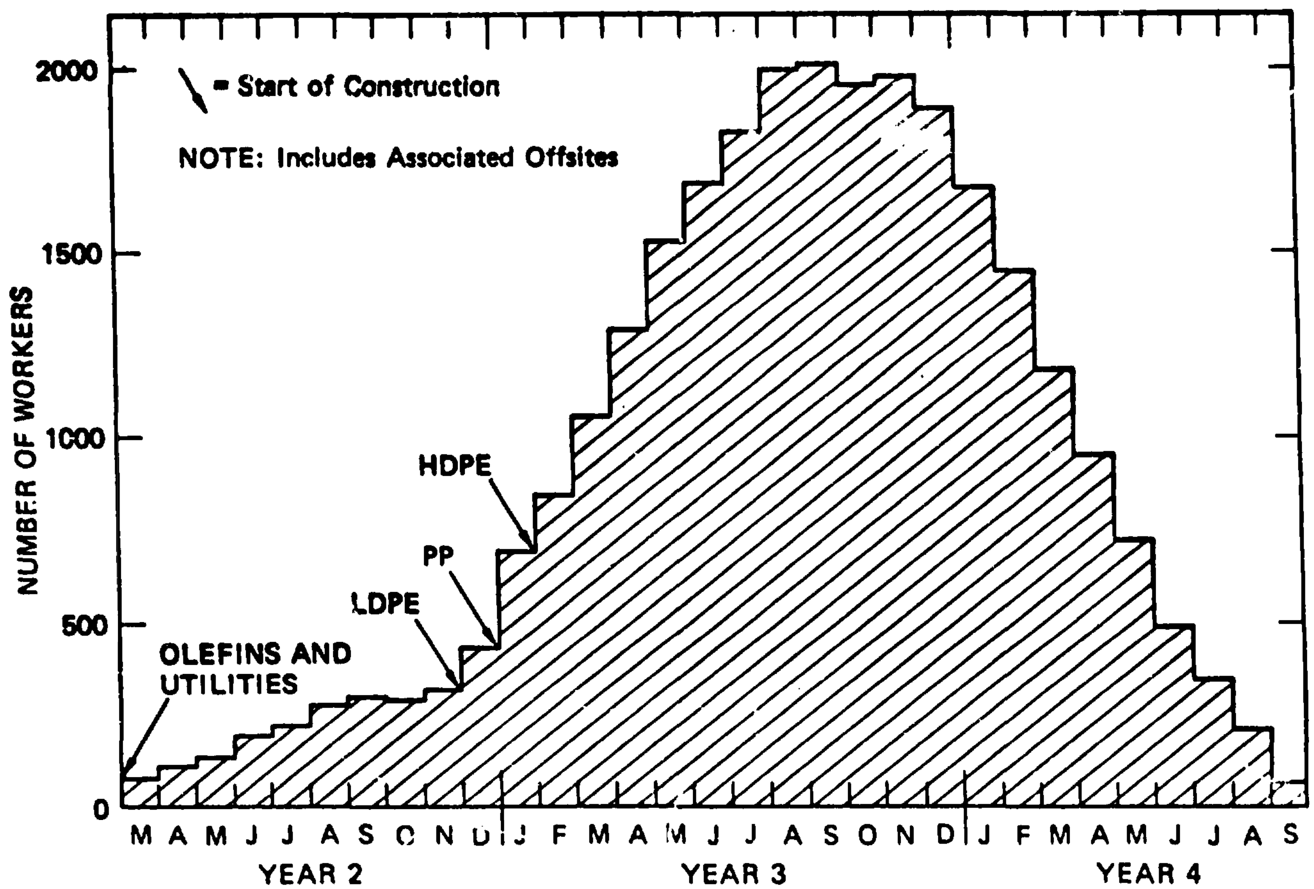


Figure No. 4
EFFECT OF CHANGES ON INTERNAL RATE OF RETURN: HDPE