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THE DEVELOPMENT OF THE PETROCHEMICAL INDUSTRY

IN PUERTO RICO^{1/}

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Introduction

During the past few years, a very substantial petroleum refining and petrochemical manufacturing industry has developed on the Caribbean Island of Puerto Rico. Its development was conceived in the mid-1950's by the Economic Development Administration (EDA) of the Commonwealth of Puerto Rico. Puerto Rico's basic industrial plan, as formulated by EDA, was to build a petroleum and petrochemical base under the already sizeable apparel, textile, and plastics industries.

The investment in plants actually operating is now approximately \$ 500 million. Completion of presently-approved projects within the next few years will increase the total Puerto Rican process industry investment to approximately \$ 1,100 million. In all, about 50 major petrochemical units are now on stream, under construction, or in engineering stages. Although most of this is in petrochemical facilities, conventional petroleum refineries (two in operation and a third being built) account for about one-fourth of the total investment. The Commonwealth Government foresees a \$ 2,000 million investment in petrochemical plants by 1975.

While Puerto Rico, as part of the United States, is not a developing country by United Nations' terminology, its economic problems have been quite similar to those confronting many developing countries today. The approach to solution of these problems with respect to fostering development of the process industries, and the substantial economic progress which has been achieved, should offer some guidance for other developing nations.

Background information

At this stage, it might be well to review the unique relationship which Puerto Rico has with the United States. The "Commonwealth" or "Associated Free State" status was devised in 1952 after the Island had been a U.S. possession for half a century. Puerto Ricans are citizens of the U.S. and have no restrictions on traveling or emigrating to the U.S. mainland. They are subject to U.S. laws, including military conscription, but they pay no income taxes to the Federal Government and cannot vote in national elections such as for the presidency of the U.S.

Puerto Rico has its own elected government and imposes its own taxes, including personal and corporate income taxes. The Commonwealth Government can also grant tax exemptions to new industries. Although Puerto Rico pays no taxes to the U.S. Treasury, most of the services and benefits provided by the Federal Government are available without restriction to firms and individuals on the island. Import duties collected by the U.S. Treasury on imports into Puerto Rico are remitted to the Treasury of Puerto Rico.

Tax incentives and regulations

An approved manufacturer can receive complete exemption from all Commonwealth taxes for 10 to 17 years, the actual time being dependent on his geographical location on the Island. Longer exemption periods are used as an incentive to encourage location in areas of greatest economic need. A manufacturer may also have the option of taking 50% tax exemption for twice the length of time of his allotted 100% exemption period.

A unique feature of Puerto Rico's laws allows very flexible depreciation for tax purposes. Firms allowed tax exemption privileges must take normal depreciation during tax-exempt years, and then the balance of the depreciation may be taken at any time. Other companies may depreciate equipment all in one year or take no depreciation at all in a given year. Most capital-intensive industries take the minimum depreciation allowed under U.S. law during their tax-exempt period, leaving the maximum depreciation possible for the post tax-exemption years. In addition, the cost of land may be depreciated under Puerto Rican tax laws.

Oil Import Practices

Since Puerto Rico is within the United States Customs Territory, its petrochemical manufacturers have direct duty-free access to the U.S. market for their products. The Island has no indigenous hydrocarbon raw materials. Thus, it must depend on imports of crude oil and other petroleum feedstocks from nearby oil-rich Venezuela or other producing countries.

Because of Puerto Rico's relationship to the United States, it must conform to U.S. policies with respect to oil imports. In 1959 the U.S. placed in effect a Mandatory Oil Import Control Program, the purpose of which was to en-

sure adequate supplies of crude oil and petroleum products in times of national emergency. This program restricts the volume of crude oil and petroleum products which may be imported from foreign sources in order to permit the continued growth and expansion of the U.S. domestic oil industry.

Notwithstanding these limitations placed on the U.S. petroleum refining industry in general, Puerto Rico has been able to obtain permission for the importation of plentiful petroleum feedstocks for the industry on the Island as long as the products are destined: (1) for use on the Island, or (2) for export to the international market. In addition, certain petrochemical materials such as benzene, toluene and xylene, which are not subject to the above controls, may be marketed in the Continental U.S. Moreover, some movement of the controlled petroleum products to the Continental U.S. has been permitted in order to provide an additional stimulus to the economy of Puerto Rico.

Location factors

A map of the Island showing the principal locations referred to in this paper is attached as Figure 1. Except for relatively flat plains around the coast, particularly on the south side, the entire Island is fairly mountainous.

Before development during the past two decades of new harbors specifically oriented to movement of petroleum and chemical products, principal shipping was through the natural harbor at San Juan on the north coast, and harbors at Ponce on the south coast and Mayaguez on the east coast. Protected natural harbors for shallow-draft vessels were also available on the south coast at Jobos and Guanica. The prevailing winds on the Island are from the north and northeast, with the result that the south coast locations are better protected than the exposed north coast. An excellent natural harbor was available at Guayanilla Bay but this had not been developed extensively until the advent of the petroleum refining industry.

In deciding on sites for plants and harbors, another factor of major import has been the need of various areas for economic assistance particularly in the form of more job opportunities.

Governmental assistance

Puerto Rico's Economic Development Administration (EDA) has played a major role in guiding the methodical step-by-step planning of a basic petroleum refining and petrochemical industry on the Island. Its well-organized and comprehensive effort has done much to attract qualified companies for this as well as other industries.

The services of EDA are available through offices in six key cities in the U.S. and one in Canada. An EDA Industrial Representative is assigned on a complimentary and confidential basis to any company interested in surveying Puerto Rico as a potential operating site. He draws on information from EDA's Office of Economic Research to supply all the many factors needed in the evaluation.

History of petrochemical development in Puerto Rico

Since the mid-1950's, Puerto Rico has planned industrial expansion and increased job opportunities around a well-organized and step-by-step establishment of a basic oil refining and petrochemical industry. After doing much research, the EDA felt that this was the only basic industry that could feasibly be established in Puerto Rico. It foresaw that this could accomplish two primary goals:

1. Provide cheaper fuel for generation of low-cost electric power, which could attract many types of industries.
2. Provide a low-cost domestic source of raw materials for the already-sizeable apparel and textile industries and other intermediate- and finished-goods industries that could be established.

Before the processing of petroleum was conceived as Puerto Rico's only feasible possibility for a basic industry, there was no internal impetus for an integrated manufacturing system of any kind. Manufacturers imported almost all of their raw materials and exported almost all of their products. Island consumption of local products was low because of high unemployment and an unusually low average per capita income of \$ 443 (1955). Fostering a basic metals industry was considered but was ruled out because of high costs of transporting

ore (Puerto Rico has no known metallic mineral resources except some copper ores), high electric power costs, and high cost of export shipment of large, heavy finished products.

The first petroleum processing units built were two oil refineries which began operation in 1955. With the cheaper fuel oil provided from this domestic source, the Puerto Rico Water Resources Authority generates dependable low-cost power for large-scale use. Fuel oil is supplied at a price as low as \$ 1.40 per barrel.

Low-cost electric power has attracted many energy-based heavy industries. For example, Pittsburgh Plate Glass Industries has recently decided to construct a large electrolytic caustic-chlorine plant; aluminum reduction, so dependent on a cheap source of power, is being strongly considered; and the metal fabricating industry is growing substantially. And, of course, this low-cost power has been basic for the needs of the expanding petrochemical industry.

Original establishment of an oil refining and petrochemical industry depended on strong export markets, and still does to a great extent. Quite a few plants processing petrochemical intermediates are in operation or are in the construction or engineering stages. But at present only the nylon plant of Fibers International is far enough down the line for integration into existing and potential future labor-intensive, consumer-goods operations. Fibers International is supplying, in part, two nylon tricot plants and six yarns texturers. In turn, these plants supply 13 plants producing hosiery, sweaters, swimwear, etc.

Puerto Rico's total employment in textiles and apparel now stands at approximately 46,000. With the scheduled tripling of nylon 66 capacity and construction of a carpet yarns plant, Fibers International will be able to support a major expansion in textile and apparel employment.

This, and information to follow, shows that Puerto Rico's overall plan for industrial development, with a petroleum processing industry as a basis, is making substantial progress.

Initial refining and petrochemical installations

The basis for Puerto Rico's start as a major petrochemical center was two modest petroleum refineries. The first to go on stream in 1955 was Caribbean Gulf Refining Corporation, which installed a plant in the San Juan harbor. The second was Commonwealth Oil Refining Company (CORCO) on the south coast at Guayanilla Bay just west of the port of Ponce. The CORCO plant began operating at the end of 1955. Both of these refineries were planned to charge Venezuelan crude oil, producing petroleum products for use on the Island. In order to effect better economy of scale, some capacity was also built in to produce additional refined products, such as gasoline and distillate fuel oils, for movement to the U.S. mainland. Initial installation of both these refineries was completed before the adoption of the Mandatory U.S. Oil Import Program. Thus, there was no initial limitation, other than economic factors, on the importation of Venezuelan crude and movement of refined products to the mainland.

Expansion in several stages has increased the charge capacity of these two refineries to current levels of approximately 40,000 B/D for the Gulf refinery and 115,000 B/D for CORCO. This latter figure is for the refinery proper and does not include the naphtha charged to the Commonwealth Petrochemicals, Inc., plant. In addition to producing local requirements of gasoline, LPG, diesel fuel, and other distillate petroleum products, both of these refineries supply heavy fuel oil for use by the Puerto Rico Water Resources Authority in generating electric power. The thermal power generating capacity of the Authority is largely concentrated in the San Juan and Guayanilla Bay areas, primarily to facilitate delivery of this heavy fuel to the generating plants by pipeline.

The availability of feedstock from CORCO's refinery attracted Union Carbide to Puerto Rico, and by June of 1959 the Island's first petrochemical plant went into production. Initially, this plant extracted ethylene from catalytic cracking unit residue gas purchased from CORCO and produced additional ethylene by steam cracking of ethane and propane extracted from this gas. The ethylene was converted into ethylene glycol, a chemical commodity in which Carbide has a substantial market position in many parts of the world. The product demand from this plant soon increased to the extent that feedstock requirements exceeded the

supply available from CORCO, and arrangements were then made to supplement the ethylene supply by steam cracking of light naphtha purchased from Caribbean refineries. The ethylene and glycol production capacities were expanded, and later facilities were installed to provide for recovery of butadiene and propylene and production of oxo alcohols. This first major expansion of the Carbide facility was completed early in 1965.

CORCO, too, decided to move into petrochemicals, and by 1965 had constructed the largest aromatics plant of its type in the world. This \$45 million project charges naphtha to catalytic reforming, and extracts and fractionates various aromatics. Although additional feedstock naphtha is brought into the refinery-petrochemical complex for charging to the petrochemical section, there is a substantial exchange of feedstock and by-products, such as the sulfolane raffinate, with the CORCO refinery. The initial feedstock requirements of the petrochemical facility were approximately 30,000 B/D, bringing the total charge to the CORCO refinery and petrochemical complex to approximately 145,000 B/D by 1966.

A major boost was given to development of the process industries in Puerto Rico in 1965 when Phillips Petroleum Company began construction of a petrochemical facility at Guayama. This plant produces basic aromatics by catalytic reforming of imported naphtha. The initial products included benzene, toluene, xylene, cyclohexane, ethylbenzene, orthoxylene, and paraxylene. Although the Phillips plant is basically an aromatics production facility, it also produces a substantial volume of co-product motor gasoline and by-product LPG and paraffinic naphtha.

The Phillips plant was the first major refining-petrochemical facility to be installed outside the Guayanilla Bay and San Juan harbor areas. A new port facility was dredged on the coast south of Guayama to accommodate tankers of up to 60,000 tons capacity. This made available an additional location at which crude oil and naphtha can be imported and liquid products shipped out. The harbor can be deepened by further dredging to handle larger tankers, if needed.

The most recent addition to the growing array of process industry installations is the refinery of Sun Oil Company at Yabucoa on the eastern end of the

Island. This facility involves an initial investment by Sun of approximately \$ 120 million, including \$ 45 million for a basic crude oil distillation refinery, \$ 63 million for downstream processing including a major lubricating oil manufacturing complex, and \$ 12 million for development of new port facilities. This plant is now under construction and is expected to be in full operation by 1972. The Sun Oil refinery will also supply Puerto Rico Water Resources Authority with 13,000 B/D of low-cost fuel oil, which will permit the Authority to build a thermal electric power generating plant in the area.

This year, CORCO put into operation a major expansion of the aromatics facilities, essentially duplicating the first aromatics installation. The total feedstock requirements for the refinery and the expanded aromatics plant are currently of the order of 170,000 B/D, and the volume of benzene (and cyclohexane), toluene, and xylenes produced totals approximately 300 million gallons per year.

The Carbide plant also is currently undergoing a major expansion, based on construction of a 1,000 million pound per year ethylene plant, and numerous downstream processing facilities for manufacture of aromatics, butadiene, polyolefins, and a host of other products. All of the facilities in the Carbide complex are wholly-owned installations of a subsidiary of Union Carbide Chemical Company.

As yet, no satellite facilities have developed around the Gulf Oil Company refinery. This plant is located in the San Juan harbor area, which is too congested for expansion into petrochemical manufacturing operations. At Guanica on the south coast, west of the Ponce-Juayanilla Bay area, W.R. Grace Company operates a fertilizer packaging and distribution plant. This installation, in fact, predated the petrochemical operations of Carbide and Commonwealth. Local interests installed this facility, which began operation in 1957, producing anhydrous ammonia, sulfuric acid, and ammonium sulfate for the local market. However, because of changing economic factors in the nitrogen fertilizer industry, basic manufacturing operations at this location have been discontinued. The Guanica plant is now used principally as a fertilizer terminalling and storage facility.

Evolution of the core petrochemical facilities concept

Puerto Rico's Economic Development Administration had the foresight to understand the potentialities of the petrochemical industry stemming from the sequential processing operations which transform petrochemical raw materials into consumer products. By encouraging the establishment of these petrochemical core industries, which could produce low-cost chemical raw materials or intermediates, the basis would be created for subsequent installation of various downstream processing facilities.

In negotiating with companies seeking to establish new core facilities, such as the Phillips and Sun installations, the Economic Development Administration imposed certain contractual obligations on the operating companies that would assure their fostering development of satellite plants or related operations. These include: (1) agreement to reinvest much of the profits from the core plant operations in downstream facilities for a period of several years, and (2) agreement to make available to local purchasers for further processing in Puerto Rico the necessary petrochemical feedstocks, such as aromatics and olefins. Moreover, the contracts negotiated between these operating companies and the Government generally spell out conditions for making such materials available at competitive prices, or even giving preference to local purchasers over export purchasers.

One feature in this respect concerns limitations imposed on the operating companies which prevent them from making long-term contracts for sale of their production for export off the island. In order to achieve economic viability for major projects such as the initial aromatics project of CORCO or the Phillips plant, it was necessary for these companies to make arrangements for sale of the products to export customers. However, these export sales were limited in duration and, wherever possible, arrangements were made so that benzene, xylenes, etc., could be withdrawn from the export sales on relatively short notice if customers were obtained who wished to install downstream processing facilities for utilization of these materials in Puerto Rico.

Summarizing the historical data discussed in the preceding section, Puerto Rico now has in operation, or under construction, five basic petroleum and/or petrochemical installations which manufacture a wide range of petroleum products

and petrochemical intermediates. Each of these could be the nucleus or "core" around which satellite facilities deriving their feedstocks from the core plant could be built.

As indicated previously, location of the Gulf refinery in the congested San Juan area probably precludes extensive satellite development around this core. A very extensive group of petrochemical facilities has already developed around the CORCO and Carbide cores and, to some extent, the Phillips plant. In the case of Carbide, all the downstream processing plants are owned by Carbide itself, which as yet has no joint-venture partners. Both CORCO and Phillips, however, have satellite processing plants in which some equity is owned by others. Also, at least one project taking feedstock from the CORCO plant is located in Puerto Rico at a substantial distance from the CORCO refinery and petrochemical plant. This is the phthalic anhydride plant of Puerto Rico Chemical Corporation, a subsidiary of Hooker Chemical Corporation, at Arecibo on the north coast. This plant produces phthalic anhydride from orthoxylene purchased from CORCO.

While no projects have yet been announced for satellite facilities to be built around the refinery of Sun Oil Company at Yabucoa (with the exception of the lubricating oil facilities being built by Sun itself as a part of the initial installation), it is anticipated that eventually other manufacturing operations utilizing feedstock from the Sun plant will be developed in this area.

The attached Table I lists pertinent data on capacity and cost of the refining and chemical facilities now in operation or firmly approved for installation on the Island.^{1/} Graphical presentation of the various plant installations, organized to show the geographical location and company ownership, is shown in Figure 2. By far, the most extensive group of satellite facilities has been developed around the CORCO refinery and aromatics plant. The aromatics products initially produced included benzene, toluene and xylene, and manufacture of orthoxylene. As shown in Figure 2, CORCO then formed a 50% joint-venture project with Shell (SACCI) to produce cyclohexane from a part of the benzene produced by the basic aromatics plant. In addition, CORCO established a 100% - owned

^{1/} Based in part on data contained in "The Petrochemical Opportunity in Puerto Rico", published by Continental Operations Branch of Economic Development Administration of Puerto Rico.

plant (STYROCHEM) to fractionate ethylbenzene from the ortho-depleted xylene product.

Another joint venture was formed by Hercules Chemical and CORCO to produce paraxylene from mixed xylenes from the CORCO aromatics plant. This plant is operated as the adjoining HERCOR facility.

The STYROCHEM, SACCI, and HERCOR satellites to the CORCO facility were all arranged concurrent with, or shortly after, installation of the initial aromatics plant. Subsequently, further joint ventures based on the CORCO facility have been announced, including OXOCHEM, an oxo-alcohol plant jointly owned by Grace and CORCO. Currently under construction is a major addition to the CORCO complex, including a 1,000 million pound per year ethylene plant jointly owned by CORCO and PPG Industries. At the same time, PPG Industries is installing a major caustic-chlorine-facility and vinyl chloride and ethylene glycol plants which will use ethylene from the CORCO-PPG olefin plant.

The Union Carbide Caribe plant is indicated as a single block in Figure 2, principally because all of the facilities in this complex are owned and operated by Carbide. A major expansion of this facility is now in progress based around a new 1,000 million pound per year ethylene plant, which will crack imported naphtha. At the same time, extensive aromatics, glycols, oxo-alcohols, butadiene, polyclefins and other units are being built, all based on the products from the new pyrolysis olefins plant.

Although numerous satellite facilities have been considered for the Phillips aromatics plant, only one has as yet been installed. This is the Fibers International nylon 66 fiber plant jointly owned by Phillips Petroleum and Rhone Poulenc, S.A. At present, this plant is being enlarged from an initial capacity of 40 million pounds per year of nylon fiber to 60 million pounds per year. The nylon 66 salt used by this fiber plant is imported from the U.S. mainland at present. However, it is planned that eventually adipic acid and hexamethylene diamine will be produced at the plant, using as the principal feedstock cyclohexane obtained from the Phillips PR Core, Inc., facility.

The above discussion has not necessarily defined the exact chronological sequence of all of these installations. However, this historical development indicates that in most instances the approach has been to justify and obtain financing for a petroleum refinery or petrochemical manufacturing facility largely on the basis of exporting products from Puerto Rico. Having thus established a source of relatively low-cost materials, subsequent installations were then made utilizing materials from the basic core facilities, with feedstocks being withdrawn from export sales. By striving to reserve maximum priority for local processing of these materials and fostering such down-stream processing by income tax exemption and other benefits, the Government of Puerto Rico hopes that ultimately very extensive processing will develop on the Island, with attendant increased employment opportunities for Puerto Rican citizens.

Consideration of advantages of stepwise petrochemical development

Nature of petrochemical industry with respect to sequence of processing

Petrochemical manufacturing operations usually consist of a number of processing steps in sequence. While two or more of the sequential operations may be performed in separate processing units located in the same petrochemical plant or complex, often intermediate materials are sold to other companies and transferred to other plant locations between successive processing steps. For example, the manufacture of nylon 6 yarn may be broken down into the following steps:

| <u>Step</u> | <u>Feedstock</u> | <u>Product</u> | <u>Type of Processing</u> |
|-------------|------------------|----------------|---|
| 1 | Crude oil | Light naphtha | Distillation |
| 2 | Light naphtha | Benzene | Catalytic reforming and solvent extraction |
| 3 | Benzene | Cyclohexane | Hydrogenation |
| 4 | Cyclohexane | Caprolactam | Complex-multistage chemical reactions |
| 5 | Caprolactam | Nylon 6 Chips | Polymerization |
| 6 | Nylon 6 Chips | Nylon 6 Yarn | Spinning, drawing, texturizing, twisting, winding |

In the above sequence of operations, the first two steps in which benzene is produced from crude oil might be carried out at a single plant or refinery. The benzene could be sold for shipment to another plant which could convert it to cyclohexane; the cyclohexane then sold to a caprolactam manufacturing plant; and so on throughout the sequence. Actually, Step No. 5 in this sequence involves, in itself, several different processing steps, but these are normally all conducted in an integrated plant converting cyclohexane to caprolactam. (There are several alternate processes).

It is noted that many of the intermediates in the above example (e.g. benzene and cyclohexane) have several alternate uses. A cyclohexane producer may have a caprolactam producer as one of a number of customers.

Other similar examples, some with less than six steps and others with even more, can be cited in the petrochemical industry. This situation is a somewhat unique characteristic of petrochemical operations. In the case of petroleum refining to produce normal petroleum fuel products such as gasoline and distillate fuel oil, sequential processing steps are also involved. However, in general, there is little sale and shipment of intermediate or unfinished oils between refineries at different locations. Crude oil is charged to a refinery, and the products, gasoline, fuel oil, kerosene, etc., are finished at the same refinery.

Because of the sequential nature of petrochemical operations, it is technically and economically feasible to build up a petrochemical manufacturing industry in a developing country by stepwise addition of the various processing steps. This approach may often be preferable to installing, from the very beginning, a complex combination of processing operations integrated all the way from the basic hydrocarbon raw materials to finished petrochemicals or consumer goods. In this manner, an economical scale of operations can be developed for each individual processing step.

The above discussion describes principally growth of the petrochemical industry by forward integration, beginning with basic refining of crude petroleum. However, this development may also occur by the alternate route of backward integration. A country may first install processing operations such as extrusion, molding or other fabrication facilities to make consumer goods from

imported plastics. When a sufficient market has developed, these plastics may then be produced in the developing country from imported monomers and other intermediates. Later, the monomers may be manufactured from more basic petrochemical intermediates. Ultimately the demand for petrochemical raw materials thus developed would contribute, along with conventional petroleum energy products, a sufficiently extensive market to justify the installation of a basic petroleum refinery.

The growth of the petrochemical industry in Puerto Rico provides a good illustration of the stepwise forward development of processing operations. As indicated above, the first plants were two petroleum refineries. These refineries made available on the Island finished petroleum products and hydrocarbon feedstocks such as naphtha for petrochemical operations. Later, plants were built to produce aromatics and olefins from the naphtha, including naphtha produced by the Puerto Rican refineries and supplemental naphtha purchased from other refineries in the Caribbean area. The basic refineries, aromatics plants, and olefins plants have been referred to as "core plants" because they may serve as a nucleus or core facility providing feedstocks upon which extensive petrochemical manufacturing operations could be based.

Schematic outlines of projects which may ultimately be developed based on the core facilities of CORCO and Phillips are presented in Figures 3 and 4, respectively.^{1/}

The CORCO complex, described in Figure 3, is coded to indicate plants which already are in operation, others which are definitely approved and are now being engineered or installed, and others on which planning and negotiations are underway. Naturally, there are many alternate potential customers or partners for the individual units in a complex array of possible plants such as this. Although CORCO has conducted negotiations with a great number of potential partners, some of these plans have not been carried forward to a successful conclusion. In other cases, certain satellite facilities have been planned or even formally announced

^{1/} Reference: "The Petrochemical Opportunity in Puerto Rico", published by Continental Operations Branch of Economic Development Administration of Puerto Rico.

but later delayed, or in some cases abandoned, because of deterioration of world market prices of certain products.

A similar presentation developed for the Phillips plant is shown in Figure 4. Since Phillips also makes aromatics, naturally the planned or studied downstream processing facilities are quite similar to those shown in Figure 3 for CORCO. Phillips has not yet developed an olefins manufacturing operation, which is needed to support many of the satellite operations. The paraffinic sulfonane raffinate from the aromatics extraction operation is available as olefin plant feedstock, along with PHG from the catalytic reforming operations. Phillips has made a sale of this raffinate to one of the other ethylene plants on the Island on an interim basis. (Also, naphtha to be produced from the Sun refinery will be sold to one of the other ethylene cracking facilities, at least until such time as Sun may develop other requirements for it).

In late 1967, Phillips announced plants for production of both polyethylene and polypropylene at the Guayama plant. At that time, it was planned to purchase ethylene and propylene from the proposed BORCO-PFG ethylene plant. This would be delivered from Guayanilla to Guayama by pipeline. Later, however, due in part to delays of actual installation of the CORCO-PFG olefins plant, Phillips decided to hold up the installation of the polyolefin facilities at Guayama. This matter is still in abeyance (July 1969) and ultimately Phillips or others may build polyolefin facilities at Guayama.

As can be seen in Figures 3 and 4, the various processing operations fall in logical sequence. Economic justification of one downstream processing facility will, in many cases, ultimately lead to other facilities. For example, now that vinyl chloride monomer (VCM) is definitely to be produced in Puerto Rico, it is likely that a plant will ultimately be built to produce polyvinyl chloride (PVC). Then facilities will probably be installed for manufacture of consumer articles from the PVC. In 1967, Esso Chemical planned a PVC polymerization plant, and went quite far in setting up an organization and facility to implement this plan. However, the plan was later abandoned, presumably because of adverse cost factors, including the major problems of having to import monomer from the U.S. mainland and to ship, at least initially, much of the polymer from Puerto Rico. However, with monomer becoming available locally, installation of polymerization facilities

is anticipated.

There are, of course, some instances in which the development of a sequence of plants cannot be taken in totally independent single steps. For example, Carbide had to build ethylene-consuming units along with its ethylene manufacturing facility. Also, the CORCO-PPG ethylene plant could not be built until such time as firm commitments could be arranged for sufficient volume of the ethylene and propylene products to justify the installation. One of the principal outlets for the CORCO-PPG ethylene is the vinyl chloride monomer plant of PPG Industries. Installation of this plant was, in turn, dependent on the availability of both ethylenes and chlorine. It would be technically feasible to import both chlorine and ethylene from the U.S. mainland or other sources, using cryogenic (or pressure) ships and barges. However, both these materials, as well as vinyl chloride, are highly competitive commodities, and dependence on one or both feedstocks from outside Puerto Rico would have a major adverse effect on the vinyl chloride monomer plant economics. As a result, the rather difficult step of simultaneous justification and installation of the olefin plant, caustic-chlorine plant, and the vinyl chloride monomer plant, was a major obstacle which has now been surmounted.

In summary, the sequential development of most of these various plants in Puerto Rico has followed a pattern of stepwise installations, with separate justification for each step, to a much greater extent than is attempted in some developing economy situations.

Economic factors involved in justifying various processing steps

Each of the individual projects installed in Puerto Rico has had to pass the test of economic viability to the satisfaction of the operating company. Admittedly, the economic outlook of most of these projects has benefited substantially from the tax exemption program and other aids provided by the Government of Puerto Rico and the Government of the United States. In each case, however, granting of tax exemption and other incentives has been contingent on the particular project's ability to demonstrate that it would provide adequate benefits to Puerto Rico in terms of the opportunity to generate ancillary industries and increased employment on the Island.

The very large aromatics producing plants of both CORCO and Phillips probably would not have been built if it had been necessary to provide markets on the Island for the aromatic products in the initial step. The plants were justified and built with export markets arranged but with provision for withdrawing these products from export sales at such time as local customers could be developed. As discussed under the history of the CORCO complex, satellite facilities consuming substantial volumes of the aromatics from the initial plant have been developed. Although some of the benzene is still being exported, CORCO has been able to develop satellite markets for all the xylene output from the initial aromatics plant, and has, in fact, local use for most of the xylene products from the recent expansion.

Perhaps the principal economic advantage of the stepwise or sequential building of petrochemical manufacturing plants is that this technique enables construction of large-scale, low-cost manufacturing facilities at each particular step without completely unmanageable financing and marketing requirements for any individual project. Of particular importance in developing this approach was the insistence of the Economic Development Administration on assurances for preferential treatment of satellite customers on the Island for supplies of raw material. While much of the core plants' output and some downstream products are still being exported, continued effort is being applied to expand the downstream processing on the Island, ultimately leading to high labor-intensive consumer-goods manufacturing operations. At the same time, operations such as molding of plastic products are being carried out to some extent with plastics imported from the mainland. Availability of locally-produced feedstocks for these fabricating operations will make a substantial cost reduction in this highly-competitive industry, and should lead to substantial growth of the consumer goods manufacturing plants in the future.

Conclusions and recommendations

Puerto Rico's fortuitous situation of having a competitively priced source of raw materials within close reach, a strong export market on the U.S. mainland, and an established and growing local consumer-goods market is rarely enjoyed by developing countries. It is suggested, however, that pooling of markets on a regional basis could be employed in some cases to permit installation of petrochemical facilities of economic size. The advantages to be gained by avoiding duplication or construction of several small units are obvious. Admittedly, the consent of different nations to pooling of their markets for this purpose would probably have to be contingent on simultaneous pooling of resources and other interests. Each country which provides some controlled market to support a petrochemical project must have various incentives to participate in such a regional cooperative effort.

Generally, developing countries which have major reserves of oil and gas move first to install basic refining facilities within the producing country. Primary petrochemical manufacturing, such as facilities for production of aromatics or olefins, may also be built adjoining the refineries with some advantage. However, naphtha and heavier feedstocks for these primary petrochemical units may be easily transported to other locations as may crude oil and finished petroleum products. In fact, the aromatics and olefins-producing plants in Puerto Rico obtain additional naphtha feedstocks from several other Caribbean area refineries to supplement the supplies available from the Puerto Rican refineries.

For further forward integration, benzene and other aromatics, as well as propylene, butadiene, and other primary petrochemicals, can be conveniently shipped by conventional transportation facilities. Ethylene has in the past normally been used as feed to processing units located near the ethylene plant, with the product moved by relatively short pipelines. Recently, however, the transportation of ethylene by cryogenic ships and barges has been demonstrated commercially. A single large ethylene plant could distribute ethylene to several relatively small polyethylene, alcohol, or other ethylene-consuming units, achieving a delivered cost much lower than the cost of ethylene produced in smaller-scale pyrolysis units at each consuming location.

To achieve full forward integration on a regional basis of a petrochemical complex such as the schemes shown in Figures 3 and 4, co-operative agreements should be made to disperse the downstream processing steps and permit installation of some of the facilities in various countries of the cooperating group. Each country cooperating in the regional effort would expect to enjoy the benefit of some of the manufacturing installations, in return for which it would make available on a preferential basis its internal market for the higher-valued downstream products, such as plastics and synthetic fibers, and to some extent for the ultimate consumer goods manufactured from the petrochemical materials.

In a cooperative effort such as described above, it is likely that the stronger national economic interests in a common market type of grouping of developing countries would be the first to build the basic refining and petrochemical core facilities. However, as the complex integrates forward, downstream units should then be built in the other cooperating countries. Some export markets outside the "region" will have to be sought initially until such time as "regional" downstream processing facilities could be justified for all the core products. Therefore, as a practical means of accomplishing any such regional cooperative program, it would be necessary for a detailed long-range development plan to be agreed upon initially by the cooperating member countries, and for such agreements to be honored rigorously as implementation of the scheme progresses.

Although the above-described cooperative type of venture between different developing countries would necessarily require extensive involvement by governments in negotiation, this need not necessarily preclude ownership of the manufacturing facilities in the private sector or some appropriate combination of joint ownership of the private and public sectors. Individual entrepreneurs in the cooperating countries would be required to cooperate with their respective governments in arranging for allocation of the individual plants between countries on a basis which would fit the available product and intermediate chemical markets, the availability of required skilled labor, infrastructure, etc. Also, in the capital-intensive refining and petrochemical industries, collaboration of financial sources in the private sector would be required from the onset and throughout the formulation of such petrochemical installations.

It is perhaps opportune at this juncture to point out that the United Nations Industrial Development Organization, who is the sponsor of this meeting, has been active in making available to developing countries technical assistance for their petrochemical industry sector. For reasons which are easily understood, UNIDO has not had any part to play with regard to the petrochemical industry in Puerto Rico. However, some of the technical assistance made available through UNIDO has similarity to the petrochemical industry activities fostered in Puerto Rico. These UNIDO activities include:

- 1.. Operational technical assistance in the planning and programming for the petrochemical industry sector in the developing countries,
2. Evaluation of petrochemical industry projects,
3. Investment promotion for petrochemical projects, and
4. Preparation of feasibility studies and detailed engineering reports for petrochemical projects in the developing countries which, in many instances, may serve as loan-request documents by the authorities of the developing countries when attempting to arrange financing of such projects.

It is our understanding that the technical assistance in petrochemicals available through UNIDO is also designed to provide experts equipped to handle problems on the plant level, whether in day-to-day operations, in repair and maintenance of petrochemical machinery, or any other aspects of improving petrochemical processing technology, as may arise during startup of a new petrochemical plant in the developing country or the reorganization of an existing production facility.

Last, but not least, we have seen examples where UNIDO offers technical assistance to the developing countries in establishing the proper institutional framework necessary for the development of the petrochemical industry sector. This may be in the form of assistance to an existing planning commission, industrial studies institute or an industrial development corporation, whether similar in structure to the EDA or otherwise, as best suited to the particular conditions of the developing country concerned.

The authors of this paper are members of the staff of Purvin & Gertz, Inc., consulting engineers of Dallas, Houston, and London. This international consulting group provides technical management, and financial consulting assistance to private companies and various government agencies in all phases of petroleum and natural gas processing, transportation and marketing, as well as petrochemical manufacturing and marketing operations. Purvin & Gertz, Inc. has been particularly active in Puerto Rico for the past 12 years, carrying out assignments in various capacities for operating companies on the Island as well as several agencies of the Government of the Commonwealth. The firm is retained on a regular basis by Economic Development Administration and Puerto Rico Industrial Development Company for a wide range of assignments in connection with the developing petrochemical industry on the Island.

Acknowledgements

Grateful acknowledgement is hereby given to Economic Development Administration for permission to make extensive use in this report of data from the publication "The Petrochemical Opportunity in Puerto Rico" 1968, including data recently assembled for a forthcoming revision of the booklet. Acknowledgment is also made of permission granted by Commonwealth Oil Refining Company for reproduction of Figure 3, and by Phillips Petroleum Company for use of Figure 4.

TABLE I

PETROCHEMICAL AND RELATED OPERATIONS IN PUERTO RICO

| <u>Company - Location</u> | <u>* Total Investment</u> | <u>Product</u> | <u>Capacity</u> | <u>Status</u> |
|--|----------------------------|---|---|---|
| <u>REFINERIES</u> | | | | |
| Caribbean Gulf Refining Corp. (Gulf Oil Corp.) - Bayamon | \$27 Million | Petroleum Products | 40,000 Bbls./Day | On Stream |
| Commonwealth Oil Refining Co., Inc. (CORCO) - Penuelas | \$145 Million | Petroleum Products | 115,000 Bbls./Day | On Stream |
| Puerto Rico Sun Oil (Sun Oil Co.) - Yabucoa | \$120 Million | Petroleum Products (Including Lubs Oils) | 66,000 Bbls./Day | 1971 |
| <u>CORE PETROCHEMICAL FACILITIES</u> | | | | |
| <u>OLEFINS</u> | | | | |
| Commonwealth Oil Refining Co., Inc., and PPG Industries - Penuelas | \$85 Million | Ethylene Propylene Butadiene | 1 Billion Lbs./Year 650 Million Lbs./Year 300 Million Lbs./Year | Late 1970 Late 1970 Late 1970 |
| Union Carbide Caribe (Union Carbide Corp.) - Penuelas | \$80 Million | Ethylene/Propylene | 380 Million Lbs./Year Expansion to: 775 Million Lbs./Year Ethylene and 500 Million Lbs./Year Propylene | On Stream Late 1971 On Stream |
| | \$9 Million | Butadiene | 20 Million Lbs./Year Expansion to: 120 Million Lbs./Year | Late 1971 |
| <u>AROMATICS</u> | | | | |
| Commonwealth Oil Refining Co., - Penuelas | \$42 Million | Benzene Toluene Xylenes Orthoxylene Aromatic Solvents | 100 Million Gals./Year 10 Million Gals./Year 48 Million Gals./Year 10 Million Gals./Year 10 Million Gals./Year | On Stream On Stream On Stream On Stream On Stream |
| | Expansion: \$47 Million | Benzene Xylenes Orthoxylene | 60 Million Gals./Year 37 Million Gals./Year 9 Million Gals./Year | Mid-1969 Mid-1969 Mid-1969 |
| Phillips Puerto Rico Core, Inc. (Phillips Petroleum Company) - Guayama | \$67 Million | Benzene Cyclohexane Toluene Mixed Xylenes Paraffinic Stock Paraxylene Orthoxylene | 111 Million Gals./Year 46 Million Gals./Year 91 Million Gals./Year 100 Million Gals./Year 117 Million Gals./Year 74 Million Lbs./Year 130 Million Lbs./Year | On Stream On Stream On Stream On Stream On Stream On Stream On Stream |
| Union Carbide Caribe (Union Carbide Corp.) - Penuelas | \$10 Million | Crude Aromatics | 80 Million Gals./Year | Late 1971 |

Source: Commonwealth of Puerto Rico, Initial Submission to
Cabinet Task Force on Oil Import Control, July 15, 1969.

TABLE I (CONT.)

PETROCHEMICAL AND RELATED OPERATIONS IN PUERTO RICO

| <u>Company - Location</u> | <u>Total Investment</u> | <u>Product</u> | <u>Capacity</u> | <u>Status</u> |
|---|--|--|---|--|
| <u>CHEMICAL PLANTS</u> | | | | |
| Air Products Corp. (Catalytic Construction Co.) - Guayanilla | \$10 Million | Oxygen Nitrogen | 400,000 Tons/Year 300,000 Tons/Year | March 1970 March 1970 |
| PPG Industries - Guayanilla | \$78.5 Million | Chlorine Caustic Soda Vinyl Chloride Monomer Ethylene Glycols, Oxides & Derivatives | 200,000 Tons/Year 500 Million Lbs./Year 400 Million Lbs./Year | Late 1970 Late 1970 Late 1970 |
| Oxchem Enterprise (Commonwealth Oil Refining Co., Inc., and W. R. Grace & Co.) - Penuelas | \$32 Million \$8 Million | Oxo-Alcohols Phthalic Anhydride | 250 Million Lbs./Year 60 Million Lbs./Year | 1970 1971 |
| Royal Dutch-Shell Group and Commonwealth Oil Refining Co., Inc. - Penuelas | \$4 Million | Cyclohexane | 30 Million Gals./Year | On Stream |
| Styrochem Corporation (Sub. of Commonwealth Oil Refining Co., Inc.) - Penuelas | \$5 Million | Ethylbenzene | 12 Million Gals./Year | On Stream |
| Hercor Chemical Corp. (Hercules Inc. and Commonwealth Oil Refining Co., Inc.) - Penuelas | \$13 Million Expansion: \$7 Million | Paraxylene Paraxylene | 140 Million Lbs./Year 100 Million Lbs./Year | On Stream 1969 |
| Fibers International Corp. (Phillips Petroleum Co. and Rhone-Poulenc, S.A.) - Guayama | \$46 Million \$45 Million | Nylon 66 | 20 Million Lbs./Year Expansion to: 40 Million Lbs./Year | On Stream 1971 |
| Puerto Rico Chemical Co. (Hooker Chemical Co.) - Arecibo | \$11 Million | Phthalic Anhydride | 90 Million Lbs./Year | On Stream |
| Placco Co. of Puerto Rico (Shell Petroleum Co., Ltd. England) - Guaynabo | \$8 Million | Epoxy Enamels & Adhesives Asphalt Emulsions Road & Roofing Asphalts | Not Available | On Stream |
| Pearless Petrochemical Co. - Guayanilla | \$2 Million Expansion: \$1 Million | Aliphatic Solvents Not Available | 5,000 Bbls./Day Not Available | On Stream Not Avail. |
| Reichhold Chemical del Caribe (Reichhold Chemical Co., Inc.) - Rio Piedras | \$650,000 | Plasticizers | 10 Million Lbs./Year | On Stream |
| Union Carbide Caribe (Union Carbide Corp.) - Penuelas | \$75 Million \$35 Million \$18 Million | Ethylene Glycols Ethylene Glycols 2-Ethylhexanol | 200 Million Lbs./Year 460 Million Lbs./Year Addition: 100 Million Lbs./Year Increase to: 130 Million Lbs./Year | On Stream Late 1971 On Stream By 1970 |
| | \$40 Million | Low-Density Polyethylene | 100 Million Lbs./Year | Mid-1972 |
| | \$35 Million | Polyethylene | 300 Million Lbs./Year | Mid-1972 |
| | \$5 Million | Di-2-Ethylhexyl Phthalate | 50 Million Lbs./Year | Mid-1971 |
| | \$10 Million | Bis Phenol A | 35 Million Lbs./Year | Late 1972 |
| | \$10 Million | Glycol Ethers | 240 Million Lbs./Year | Mid-1972 |
| | \$15 Million | Cumene | 545 Million Lbs./Year | Late 1971 |
| | \$10 Million | Acetone | 120 Million Lbs./Year | Mid-1972 |
| | \$20 Million | Phenol | 200 Million Lbs./Year | Mid-1972 |

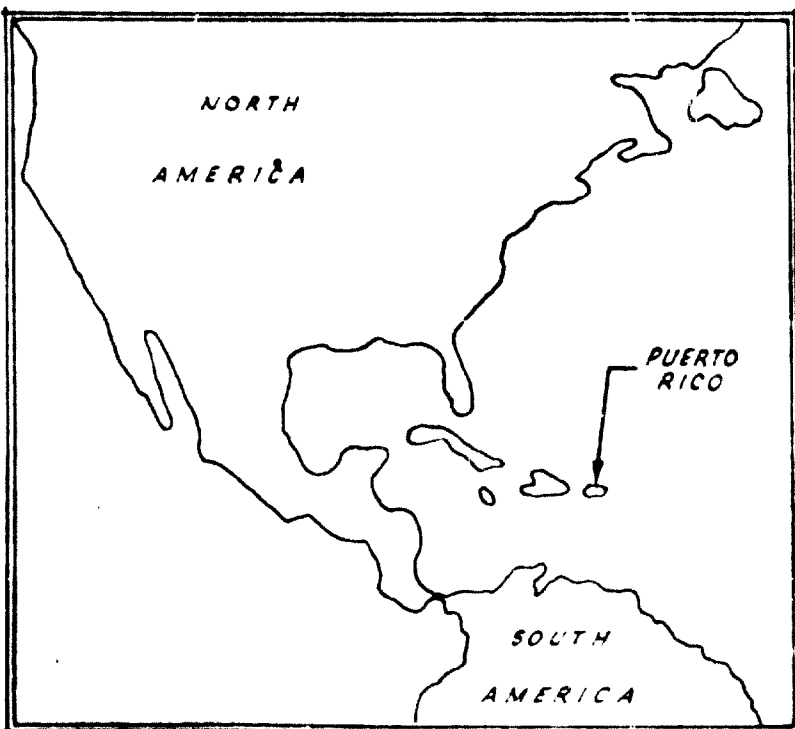
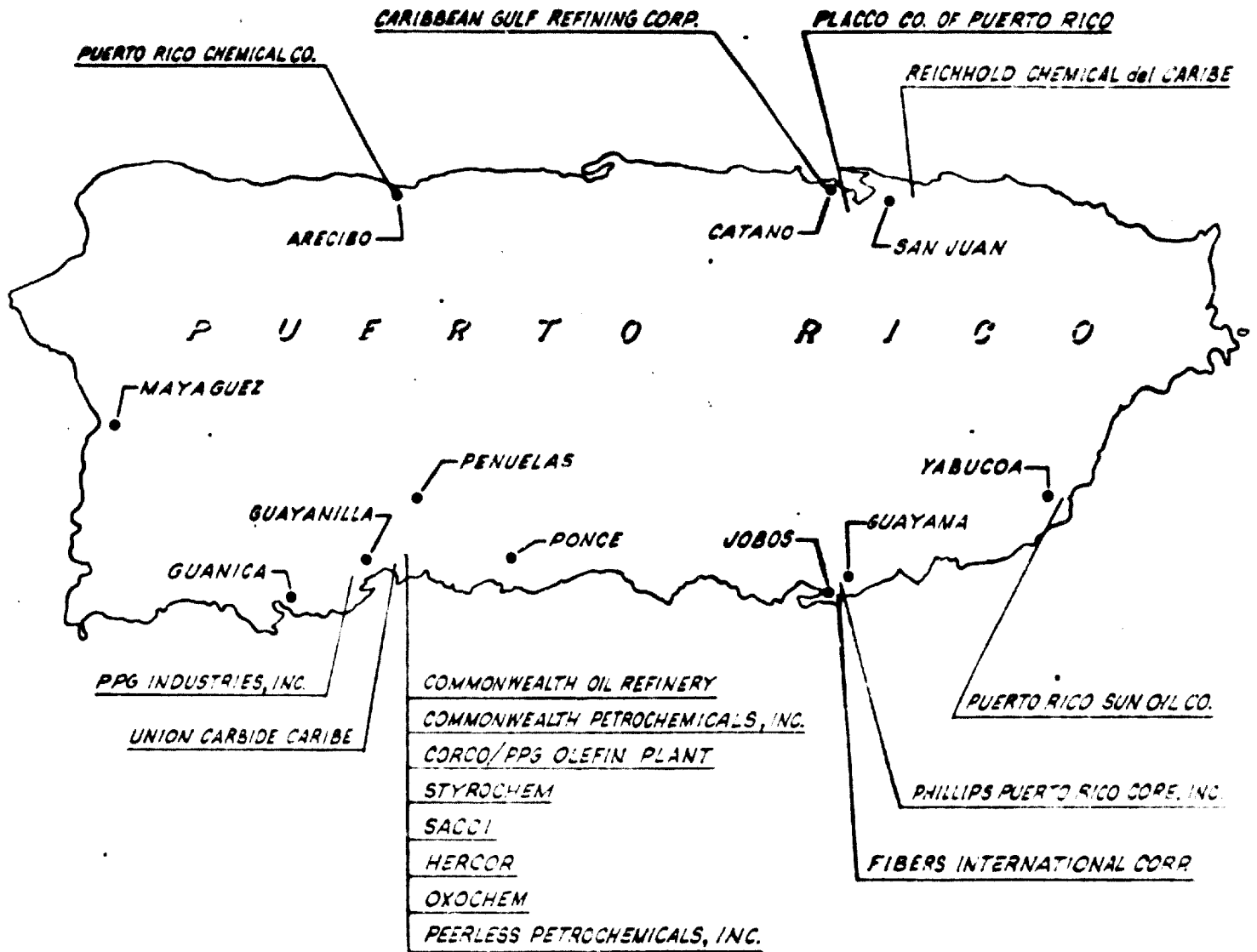
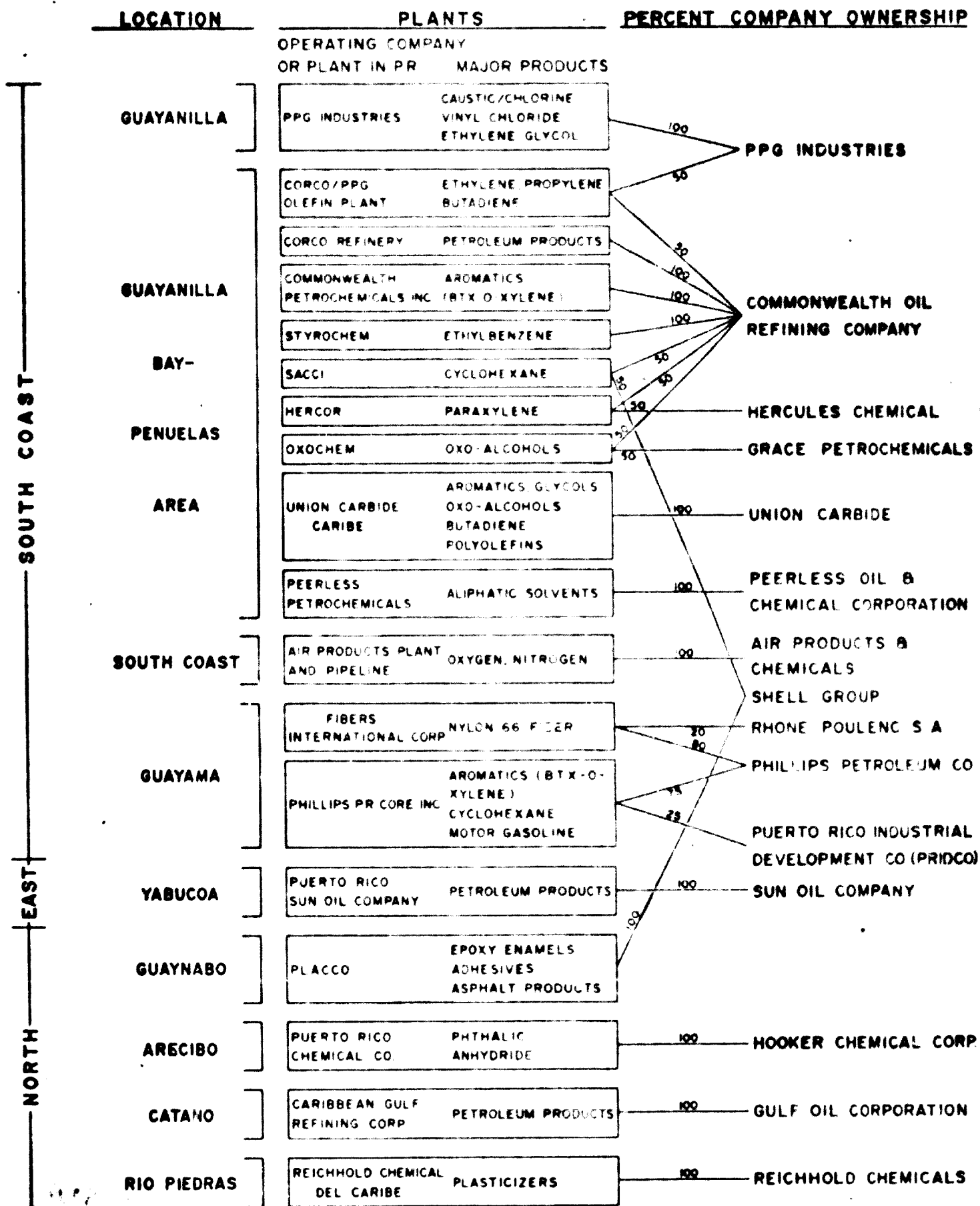


FIGURE 1

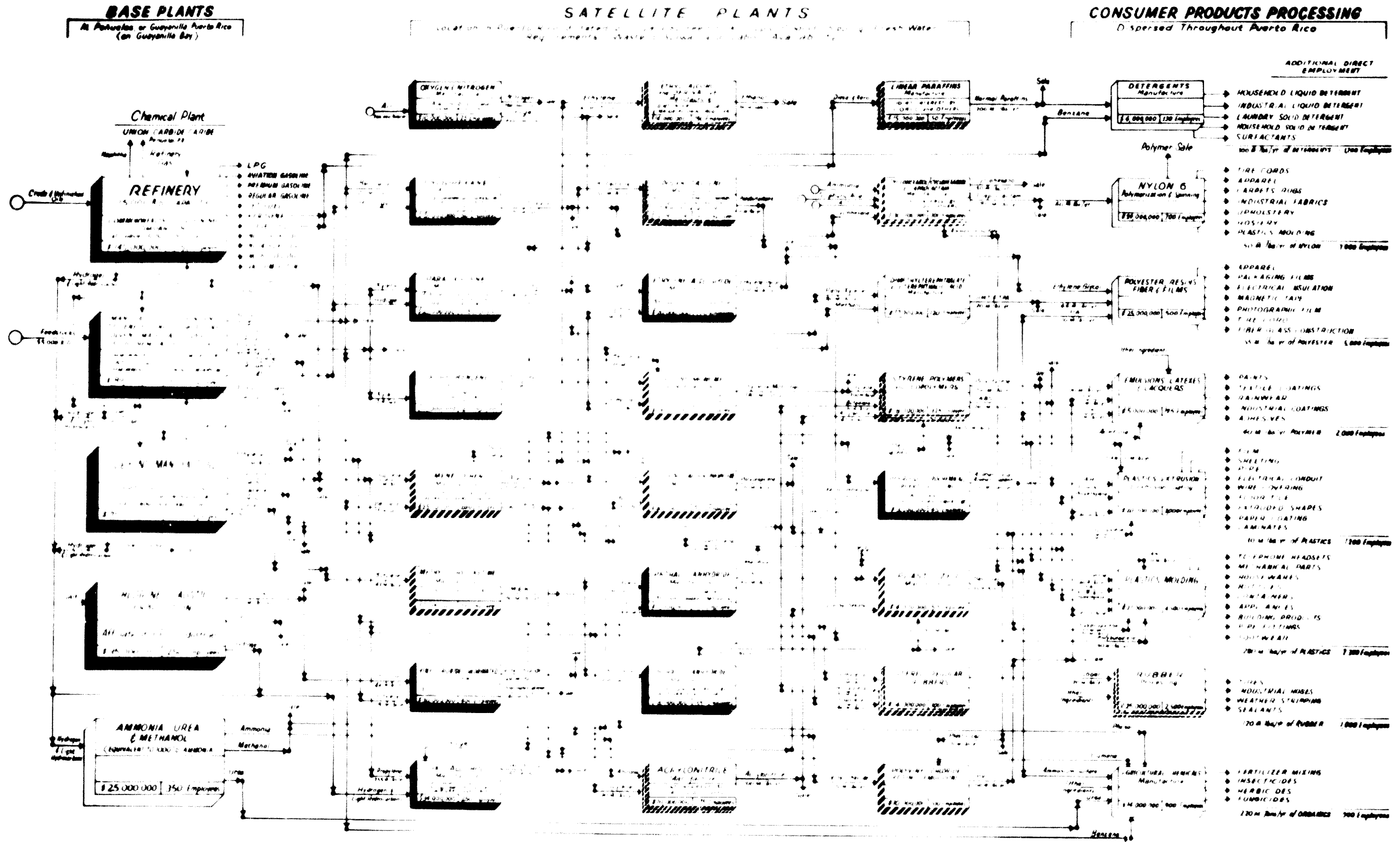
PETROCHEMICAL OPERATIONS
IN PRODUCTION OR UNDER CONSTRUCTION
IN PUERTO RICO

**FIGURE 2
PUERTO RICO PETROCHEMICAL PLANTS**



CORCO COMMONWEALTH OIL REFINING COMPANY, INC.

PROJECTS AND PLANS FOR DEVELOPMENT OF CHEMICAL PROCESS INDUSTRY IN PUERTO RICO

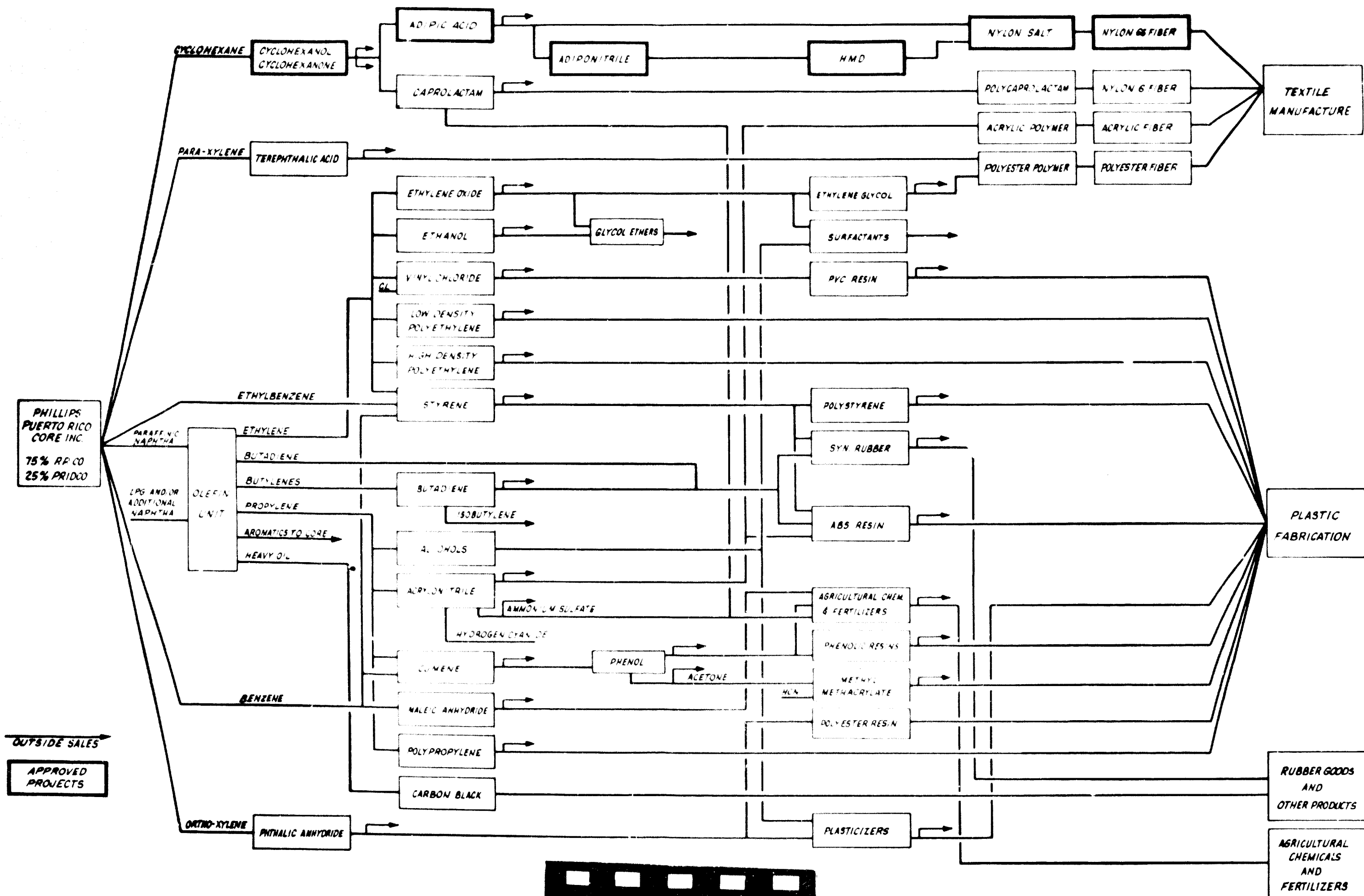


| TOTAL | | EMPLOYEES | | EMPLOYEES | | EMPLOYEES | | EMPLOYEES | | EMPLOYEES | |
|-------------|-------------|-------------|-------|-------------|-------|-------------|-------|-------------|--------|-------------|--------|
| COLUMBS | ACROSS | \$ | | \$ | | \$ | | \$ | | \$ | |
| 379,000,000 | 379,000,000 | 739,500,000 | 1,170 | 140,300,000 | 1,795 | 108,000,000 | 1,290 | 764,000,000 | 6,405 | 764,000,000 | 18,355 |
| | | 578,500,000 | 1,720 | 658,800,000 | 5,115 | 764,800,000 | 6,405 | 908,000,000 | 18,760 | 908,000,000 | 18,760 |

PLANTS IN OPERATION BEING CONSTRUCTED OR ANNOUNCED APRIL 1969 (CAPACITIES ARE FOR EXPANSION PLANS)
 DEFINITIVE ENGINEERING UNDERWAY
 PROJECT PLANNING

DEPENDENT ON EXTENT OF CONSUMER PRODUCT PROCESSING ON ISLAND
21,700
34,080

FIGURE 4
PHILLIPS PETROLEUM COMPANY
PROJECTED PLANS FOR CHEMICAL AND CONSUMER PRODUCT INDUSTRY
IN PUERTO RICO





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