STUDY OF DOMESTIC SOCIAL AND ECONOMIC IMPACTS OF
OCEAN THERMAL ENERGY CONVERSION (OTEC) COMMERCIAL DEVELOPMENT

Volume II
INDUSTRY PROFILES

MASTER

Submitted to:
DEPARTMENT OF ENERGY
OFFICE OF CONSERVATION AND RENEWABLE ENERGY
DIVISION OF OCEAN SYSTEMS
WASHINGTON, D.C.

Under Contract DE-AC01-80CS-80002

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December 22, 1981

Submitted by:
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INTRODUCTION

This volume contains economic profiles of the industries most affected by the construction, deployment, and operation of Ocean Thermal Energy Conversion (OTEC) powerplants. Six industries which will contribute materials and/or components to the construction of OTEC plants have been identified and are profiled here. These industries are:

- Steel industry
- Concrete industry
- Titanium metal industry
- Fabricated structural metals industry
- Fiber glass-reinforced plastics industry
- Electrical transmission cable industry

The economic profiles for these industries detail the industry's history, its financial and economic characteristics, its technological and production traits, resource constraints that might impede its operation, and its relation to OTEC. Some of the historical data collected and described in the profile include output, value of shipments, number of firms, prices, employment, imports and exports, and supply-demand forecasts. For most of the profiled industries, data from 1958 through 1980 were examined.

In addition, profiles are included on the sectors of the economy which will actually construct, deploy, and supply the OTEC platforms. The sector which will be responsible for construction of the OTEC plant is the shipbuilding industry. The shipbuilding industry profile differs from the others in that the emphasis is on the capacity of shipyards to construct OTEC plants rather than on an examination of historical data on the shipbuilding industry. This same approach was used in examining the offshore support services industry, which will be responsible for deployment of the OTEC platforms and for resupply of the platforms.

The actual operation of OTEC plants may affect two additional industries, the primary aluminum industry and the ammonia industry. The production of aluminum and ammonia is energy intensive, and it is expected that OTEC-generated power will be used in the production process of each of these products. The information included in the profiles of these two industries is similar to the information contained in the profiles of the six industries which will contribute materials and components to the construction of OTEC plants.

EXECUTIVE SUMMARY

Steel Industry

Steel, one of the materials which will be used to construct OTEC hulls, is the most important engineering material; its major uses are in transportation, construction, and machinery. According to the Department of the Interior, the domestic steel industry is composed of about 180 companies, including 80 with their own steelmaking furnaces, which produce a wide range of steel mill products. In 1980, 82 million tons of steel mill products, valued at \$49 billion, were produced. This represents an 18 percent decline from 1979, when 100 million tons of steel mill products, valued at \$48 billion, were produced. Imports in 1980 were 16.8 million tons, down slightly from the 19.5 million tons imported in 1979. Exports in 1980 were 4.6 million tons, compared to 3.5 million tons in 1979.

Inadequate domestic steel capacity in the future is a distinct possibility. Since 1959, the United States has been a net importer of steel, and since 1977 net imports have averaged about 15 million tons per year. The modernization and expansion program for the 1979-88 period proposed by the industry assumes a very low rate of increasing domestic demand for steel (1.5 % per year). Should that projection be too low, the capacity planned for would be inadequate, and imports could rise to 20 percent of domestic consumption.

The major problems facing the steel industry are the need to modernize in order to remain competitive with foreign producers, the imposition of stricter pollution control requirements, the rising cost of energy, and a relatively low profit rate. In addition, decreased demand in the automotive and construction industries in 1980 led to a decline of 18 percent in steel consumption, causing plant shutdowns and layoffs.

One estimate of the amount of steel required to construct an OTEC hull is 107,000 tons. Under the 25 plant scenario, it is possible that as many as nine plants could be under construction simultaneously, and that construction would take three years per plant. If all these plants used steel hulls, approximately 321,000 tons per year of steel could be required to meet OTEC construction needs. This amount of steel represents only about .30 percent of domestic steel mill product capacity. However, it represents approximately 3.0 percent of the average annual steel mill products used for construction. This may not be significant, though, in view of the fluctuation in recent years in steel

used for construction. For example, steel used for construction increased from 12.4 million tons in 1972 to 15.6 million tons in 1973, and from 10.9 million tons in 1977 to 12.1 million tons in 1978. The increases during these periods represent much more than the 321,000 tons that may be required annually by OTEC.

Concrete Industry

Depending on the design selected for an OTEC plant, concrete may be used to construct the graving dock, hull, or cold water pipe, or all three. The amount of concrete required to construct one OTEC plant could be as much as 150,000 to 200,000 cubic yards. This is about one percent of U.S. total annual production, and is two to three times the amount produced annually by one average-sized company. According to Mr. John Marlarky, of the National Ready Mixed Concrete Association, it would be difficult for the existing ready-mixed concrete industry to supply the large amounts of concrete required to construct an OTEC plant, since most concrete firms are relatively small and lack the capital to quickly increase production. Consequently, it may be necessary to establish a temporary, or portable, concrete plant. This is the type of plant used on large highway and airport paving jobs. Used and new plant equipment is readily available.

Other industry spokesmen indicate that the larger ready-mixed concrete firms would have no trouble supplying the amount of concrete required for OTEC plants. Furthermore, these spokesmen claim that quality control would be better at an existing ready-mixed plant than at a temporary plant, thus resulting in less waste due to "bad batches."

Mr. Marlarky has indicated that, for projects such as OTEC, the availability of the materials required to make concrete (cement, sand and gravel, and crushed stone) presents more of a problem than the availability of concrete itself. Currently, there is a general shortage of sand, stone, and gravel — known as concrete aggregates — in the Gulf Coast region. Regional shortages of cement have occurred each of the last four years, particularly in the west and southwest.

Accordingly, only a brief profile of the concrete industry has been included, with a more in-depth look at the cement industry, the sand and gravel industry, and the crushed stone industry. These profiles are summarized below.

Cement

Portland cement comprises more than 95 percent of the U.S. cement output; 97 percent of Portland cement production is used to make concrete. The ready-mixed concrete industry accounts for almost two-thirds of total cement shipments. Portland cement production peaked at 83.6 million tons in 1973. Production fell during the recession of 1974-75, and has fluctuated since then, following the fluctuations in construction activity. Production in 1980 has been estimated at 73.7 million tons. Shortages of Portland cement in the Southwestern States in 1977 spread to most of the western half of the country and parts of the south in 1978. Cement supplies remained tight in some areas of the country in 1979, but shortage situations tended to be less serious and widespread than in 1978. Regional shortages result from insufficient regional capacity and from high transportation costs.

There are 48 companies operating 159 portland cement plants in 40 states, with the 10 largest producers representing about 50 percent of capacity. Twenty-eight firms, with 78 percent of the capacity, are divisions or subsidiaries of diversified companies. Total U.S. capacity is about 100 million tons.

Several major problems with important implications for future supply availability and pricing face the industry. These are air-pollution requirements, increasing energy prices requiring energy conservation and conversion to less-scarce fuels, and the need to expand capacity in many market areas. Capital needed to accomplish these requirements will be great, and in light of the high and rising costs of construction, cement prices will continue to rise in coming years.

Sand and Gravel

About 33 percent of sand and gravel production is used as concrete aggregate in the construction of buildings and engineered construction projects such as highways, dams, and bridges. Another 15 percent is used as asphaltic concrete aggregate for highway construction, while nine percent is used for concrete products such as cement blocks, bricks, and pipes.

There are about 7600 sand and gravel deposits and 6000 processing plants in the United States. Sand and gravel are important construction materials, and their availability and cost have a disproportionately strong influence on the general economy. For example,

although the number of people employed in the sand and gravel industry is relatively small compared with employment in other parts of the construction industry, products made with sand and gravel have a major impact on total employment in the construction industry. Employees of construction contractors, cement manufacturers, and the concrete industry are affected by the availability of sand and gravel.

During the seventies, production of sand and gravel fluctuated along with other construction-related industries. In 1970, 915 million tons were produced, more than in any previous year. Production decreased slightly the following two years, and then increased to 955 million tons in 1973. During the 1974-75 recession, production fell sharply, dropping to 762 million tons in 1975, the lowest level since 1962. Following the recession, production increased annually through 1978, when a new high of 966 million tons of sand and gravel were produced. Production decreased slightly in 1979, and dropped to an estimated 800 million tons in 1980.

Despite the rising costs of labor, the higher land values, and the added costs of pollution control, selling prices of sand and gravel have risen rather slowly. Automation and increased operating efficiency have helped to limit price increases. The competitive nature of the sand and gravel industry, which is one of the most competitive of all industries, has also kept prices low.

Crushed Stone

The crushed stone industry is the largest nonfuel, nonmetallic mineral industry in the United States. Output of crushed stone in 1980 was approximately 978 million tons. Of the total production, 74 percent was limestone, 11 percent was granite, and 8 percent was traprock. About 11 percent of crushed stone is used to make cement and 13 percent is used as aggregate to make concrete. Thus, nearly one-fourth of all crushed stone is used to make concrete.

During the period 1958 to 1973, annual production increased steadily from 533 million tons to 1059 million tons. Following 1973, production decreased due to the recession, falling to 900 million tons per year in 1975 and 1976. During the period from 1977 to 1979, the stone industry resumed its normal growth pattern, with production reaching 1.1 billion tons in 1979. Industry growth was again interrupted in 1980, as production dropped to an estimated 978 million tons.

The crushed stone industry is probably second only to sand and gravel with respect to land-use conflicts and environmental problems. The problems are mainly due to the necessity for locating crushed stone aggregate supply sources near consumers, which are for the most part in areas of rapidly expanding urban growth. The production sites must be located near the consumers because of the low-cost, high-weight of crushed stone. Otherwise, transportation costs can very quickly price stone out of competition or at least greatly increase construction costs.

The use of increasingly efficient production equipment and methods has resulted in a downward trend in constant dollar prices for crushed stone. This downward trend is expected, however, to reverse itself in the early 1980s as a result of increasing costs of pollution control, land rehabilitation, and transportation.

Titanium

Titanium is critical to the proposed OTEC plants because it is a leading candidate metal for the heat exchangers. Its advantages over other proposed metals, such as stainless steel and aluminum, are its resistance to corrosion and biofouling, and its light weight. It is estimated that a single OTEC plant could require 10,000 tons of titanium metal, or approximately 36 percent of all titanium mill products produced in 1980.

Domestic production of titanium sponge metal has fluctuated in the past decade. Production increased from 9,260 tons in 1972 to 19,933 tons in 1974. From 1975 to 1977, production averaged 12,941 tons; and from 1978 to 1980, production averaged 20,792 tons. Domestic production in 1980 was at an all-time high of 22,500 tons. Production of titanium mill products has averaged 15,853 tons since 1966, with a low of 11,241 tons in 1971 and a high of 27,637 tons in 1980.

Prices remained steady at \$1.32 per pound from 1964 to 1973. Thereafter, prices increased gradually, reaching \$3.98 per pound in 1979, before jumping to \$7.02 per pound in 1980. The Producer Price Index went from 95.5 in 1972 to 521.3 in March 1980.

Titanium ingot is produced by eight firms, including the three producers of sponge. Titanium mill products are produced by about 20 firms. There is easy movement in and out of this production step because titanium mill products can be fabricated in stainless steel or speciality steel plants.

Sponge metal capacity was about 23,000 tons in 1979. Four companies have planned capacity increases totaling 8,700 tons by the mid-1980s. These capacity increases are the first to be announced since 1967.

The Federal strategic minerals stockpile goal for titanium sponge metal was raised in 1980 from 131,503 tons to 195,000 tons. Stockpile purchases, however, have not yet been authorized. In 1980, there were approximately 32,000 tons of sponge in the stockpile.

With regard to the OTEC program, titanium manufacturers can be expected to be reluctant to expand capacity to produce for a market subject to governmental cutback. One possible scenario is for the Federal government to agree to purchase for the stockpile any titanium produced or planned specifically for OTEC, but not used due to cancellation or postponement of OTEC projects.

Fabricated Structural Metals Industry

The fabricated structural metals industry group (SIC 344) is composed of firms that cut, bend, weld, drill, and otherwise convert mill shapes, primarily steel, into a variety of products, including: structural metal for buildings, bridges and ships; metal doors and trim; heat exchangers, condensers, boilers, and tanks; pipes, roofing, siding, and other sheet metal products; architectural and ornamental metalwork; prefabricated metal buildings; and miscellaneous metal work, including concrete reinforcing bars. The total value of shipments for the industry for 1978 was \$25.93 billion. The individual industries within the structural metals industry group to be examined in this paper, with 1978 value of shipments in parentheses, are:

- Fabricated structural metal (\$5.34 billion)
- Fabricated plate work (\$7.27 billion)
- Miscellaneous metal work (\$1.46 billion)

The total value of shipments for these three segments for 1978 was \$14.07 billion, representing 54 percent of the value of shipments for the entire industry group.

Fabricated Structural Metal

Fabricated structural metal (SIC 3441) includes columns, joists, and tresses, which are used to build frameworks for buildings and bridges. This industry also provides products to the shipbuilding industry, and would be a source of materials used in constructing an OTEC hull. As of 1977, there were 2,139 firms classified as structural metal fabricators. These firms owned 2,462 establishments, 1,074 of which had 20 or more employees.

The value of shipments for the fabricated structural metal industry increased from \$1.60 billion in 1958 to an estimated \$6.80 billion in 1980. Much of this increase has been due to inflation and, in recent years, output has actually declined. Output was 3.98 million tons in 1959 and increased continuously until 1973, when it peaked at 7.04 million tons. Output has been depressed since 1973, averaging 5.93 million tons for the years 1974 to 1978.

The capacity utilization in the structural metal industry has been low throughout the 1970s. The average from 1973 to 1978 was 68 percent, with a low of 60 percent in 1975 and a high of 72 percent in 1978. This excess capacity is the result of decreased demand which began with the 1974-75 recession.

Fabricated Plate Work

Fabricated plate work (SIC 3443) includes heat exchangers, boilers, condensers, and metal tanks. This industry could be expected to fabricate the titanium heat exchangers, as well as the condensers, for OTEC. In 1977, 1,683 companies, operating 1,864 establishments, were classified as plate work fabricators. About half of these establishments had 20 or more employees. There were 102 establishments primarily producing heat exchangers and steam condensers, not including those used in nuclear applications.

The value of shipments for the fabricated plate work industry tripled between 1967 and 1977, increasing from \$2.59 billion to \$7.43 billion. About half of this increase was due to inflation and half due to increased production. During this same period, the value of shipments for heat exchangers and condensers also tripled, rising from \$345.5 million in 1967 to \$1.1 billion in 1976 before dropping to \$900.5 million in 1977. Capacity utilization in the fabricated plate work industry, as well as the heat exchanger industry, has been low in recent years, averaging about 80 percent and 70 percent, respectively.

Miscellaneous Metal Work

Miscellaneous metal work (SIC 3449) includes concrete reinforcing bars (SIC 34494), which will be used if the OTEC hull is constructed of concrete. In 1972, the miscellaneous metal work industry was composed of 336 companies operating 418 establishments, 220 of which had 20 or more employees. By 1977, the number of companies had decreased slightly to 308, while the number of establishments decreased to 412. The number of establishments with 20 or more employees showed a proportionately greater decrease, falling to 185.

From 1972 to 1977, shipments of miscellaneous metal work averaged \$1,376 million, with a low of \$994.6 million in 1972 and a high of \$1,734 million in 1974. During this same period, shipments of concrete reinforcing bars averaged \$868 million, with a low of \$583.3 million in 1972 and a high of \$1,156.6 million in 1974. In 1977, total value of shipments of miscellaneous metal work was \$1,332.9 million, \$900.1 million of which was accounted for by concrete reinforcing bars.

Fiber Glass-Reinforced Plastics

Specific qualities are required for the OTEC cold water pipe, which may be up to 3,000 feet in length and 100 feet in diameter, and have to withstand the deteriorating effects of the constant wave movements and corrosive effects of the ocean. Several proposed configurations make use of fiber glass-reinforced plastic.

The production of fiber glass-reinforced plastic cold water pipes is affected by the availability of certain materials. The main components are: 1) glass sand, with sodium compounds and limestone to produce the glass fibers; 2) the fiber glass filaments used to strengthen the plastic pipes; and 3) petroleum and natural gas and the thermosetting resins, epoxies and polyesters, which coat the glass fibers to enable molding the shape of the plastic pipes. These materials, which are classified in the following categories by Standard Industrial Classification Codes (SICs) and product codes, will be discussed separately as stages of production for the fiber glass-reinforced plastic pipes. They are:

- Industrial sand — SIC 1446; Glass sand — product code 14461;
- Pressed and blown glass, n.e.c. — SIC 3229; Glass fiber, textile type — product code 32293;
- Plastics materials and resins — SIC 2821; Thermosetting resins and plastics materials — product code 28214; and
- Miscellaneous plastics products — SIC 3079; Construction plastics products — product code 30796.

Glass Sand

In 1980, the glass sand industry was composed of approximately 30 companies operating 45 establishments. About 15 million tons of glass sand, valued at \$126.2 million, was produced in 1980. The price for ground fiber glass increased drastically from 1978 to 1979, rising from \$8.67 per ton to \$14.72 per ton.

Although glass sand production shows an increasing trend and is in abundant supply, producers are faced with several problems which may curtail production and, therefore, severely impact the OTEC fiber glass-reinforced plastic cold water pipe program. Problems relating to government environmental control regarding excessive noise, wastewater discharge, washing down truck loads of sand and gravel to prevent additional air pollution from dust particles, as well as concerns over reclamation of mine sites (especially open pit mines) are causing mine owners to experience much

higher operating costs. Decisions such as building fences around an unsightly mine area, or creating a park over a previous mine site, could discourage potential mine owners as well as cause active producers to close their mines when their operations become uneconomical. In addition, mine owners may have increased costs because of more frequent repair or replacement of equipment due to excessive wear from constant use created by the huge increase in demand for glass sand for the OTEC project.

Despite these problems, according to representatives of the industrial sand and gravel industry, the increased demand for silica sand will not be a hardship for producers. For each cold water pipe of 100 feet inside diameter, 3000 feet long, and 4 inches thick, they estimate approximately 100,000 tons of silica sand is needed. Since the industrial sand and gravel industry produced 32 million short tons of silica sand by 140 establishments in 1980 (for the foundries as well as for the glass industries), an additional demand of approximately 5 million tons for 50 cold water pipes over a 10 year period would present no difficulty to the industry.

Glass Fiber

In 1979, only eight companies with 15 establishments comprised the fiber glass industry (SIC 32293), which produced 986 million pounds of fiber glass valued at \$528.7 million. This represents more than a tripling of production since 1967, when 291 million pounds were produced. From 1963 through 1975, the price per pound of textile type fiber glass remained fairly stable, fluctuating slightly over time from 47.5 cents per pound in 1963 to 49.3 cents per pound in 1974. After 1974, prices rose to 66.8 cents per pound for 1978, indicating a 35 percent increase from 1974 to 1978.

Despite a drop in demand in early 1980 (from the construction industry), followed by a drop in output by some of the smaller fiber glass establishments, the larger fiber glass manufacturers (who experienced an increasing trend in production) appear very optimistic about the future of fiber glass. This optimism is not surprising, since they are developing a higher capability of substituting fiber glass for other elements, thereby enlarging the market. Another important fact is that most of the required materials for producing fiber glass are relatively inexpensive and available. Meanwhile, production capacities are being expanded in the larger firms in this highly concentrated industry through new technologies utilizing highly automated machinery and improved techniques to produce more output in less time.

As with the glass sand industry, the fiber glass industry will require higher costs for repairing machinery and equipment when processing much larger amounts of materials for OTEC than what ordinary wear and tear would require. One example would be that melting glass at high temperatures is very corrosive to glass furnace linings; thus, more frequent periodic repairs should probably be expected. However, industry representatives are reassured by the expansion of production capacities and indicate that a projected increase in demand for fiber glass (to be used in the fiber glass-reinforced plastic cold water pipes for OTEC power plants) would be warmly received and would be met easily and successfully.

Plastics Materials and Resins

In 1977, the plastics materials and resins industry (SIC 2821) was composed of 221 companies operating 397 establishments, which reported shipments values at \$10.8 billion. The thermosetting resins and plastics materials industry (SIC 28214) was made up of 119 establishments reporting shipments valued at \$1.5 million. Resin prices rose sharply in recent years, increasing 18.2 percent in 1979 and 39 percent in 1980.

Despite concern over the threatened shortages of petroleum and natural gas, the general outlook for plastics (according to representatives of the larger companies) is good due to increasing demand, improved technology and increasing capacity in the near future. However, since resins have become so important to our economy and are used in so many industries, shortages in the supplies of petroleum and natural gas should not be overlooked. According to one company official, the industry probably has sufficient resins (which are produced from chemical compounds or hydrocarbons obtained from petroleum and natural gas) to last for two years, but one huge order for resins for OTEC cold water pipes would exhaust these resin supplies.

Construction Plastics Products

In 1977, the construction plastics products industry (SIC 30796), composed of 574 establishments, reported shipments valued at \$2.8 billion. Shipments in 1972 were valued at \$1.1 billion. The Producer Price Index increased from 100.0 in December 1975, used as the base, to 127.3 in 1980.

Although processors in the resins and plastics industries showed concern early in 1980 over threatened shortages and increased costs of resins, current indications project an increasing trend in sales for the next few years. From the suppliers of the basic raw materials to the manufacturers of the finished fiber glass-reinforced plastic products, every effort is made to keep materials moving steadily and to assure sufficient output to meet the increasing demand.

Because of the concerted effort by these industries to ensure continued production and demand, industry representatives have a bright outlook for the resins and plastics industries (especially the pipe and conduit industries) which are recovering from the 1980 slump and which are expected to have an increasing growth rate through the next few years. Finally, due to better availability of material supplies, and to the many advantages in the required characteristics and properties of the OTEC cold water pipe configuration, the choice of using fiber glass-reinforced plastic pipes seems to merit a high rank.

Cable Industry

Two types of high voltage electrical transmission cables are required for OTEC: riser cables, which will extend from the OTEC plant to the ocean floor; and long distance power cables, which will connect the riser cable to on-shore facilities. None of the normal means of transmitting high voltage power is immediately applicable to OTEC. Existing cable plants would not have the capabilities required to produce the very long lengths of OTEC power cables. It has been estimated that a dedicated plant for production of such cables would cost about \$22 million (1976 dollars).

Riser cable suitable for OTEC has not yet been developed. Simplex Wire and Cable Company is currently engaged in research and development of riser cables. Recently awarded a \$1.5 million contract by the Department of Energy, Simplex has received a total of \$4 million since 1977 for R&D of a high voltage OTEC undersea power transmission cable. Simplex has already manufactured several full scale prototype cables, and plans to devote its efforts to further mechanical and electrical testing.

Shipbuilding Industry

To be capable of constructing OTEC plants, shipyards must have graving dock facilities in excess of 475 feet in length and of sufficient beam, and must have skilled personnel and support shops available. Qualified shipyards must also be located reasonably close to the intended OTEC operating sites. Of the 28 major U.S. shipyards examined, 10 emerged as prime candidates for OTEC construction.

Four shipyards located on the Great Lakes were eliminated because of limited access to the Atlantic Ocean. Two shipyards were eliminated due to closure. Twelve additional shipyards were eliminated for a variety of reasons, including lack of suitable access channels to deep water, lack of engineering and skilled labor forces, lack of complex construction experience, and/or lack of financial capabilities to undertake a project the size of OTEC.

The 10 shipyards considered suitable for OTEC construction are:

- General Dynamics - Quincy, Massachusetts
- Bethlehem - Sparrows Point, Maryland
- Newport News - Newport News, Virginia
- Tampa Ship Repair - Tampa, Florida
- Ingalls, Litton - Pascagoula, Mississippi
- Avondale Shipyards - New Orleans, Louisiana
- National Steel - San Diego, California
- Triple A Machine Shop - San Francisco, California
- Bethlehem - San Francisco, California
- Lockheed - Seattle, Washington

Offshore Support Industry

Available data is not sufficient to provide an accurate forecast of the number of offshore personnel necessary for OTEC vessel deployment and CWP attachment operations. However, it is safe to make some general statements and assumptions.

First, because of the size of a 400 MW OTEC facility, the largest offshore support vessels, the 1,000 ton tug and derrick barge with a lifting capacity of 600 tons, would be employed during the towing of the OTEC facility from the shipyard to its operating site and during the CWP placement operation. Currently, there are five such 1,000 ton tugs in the U.S. offshore fleet, all operating out of the Gulf of Mexico. Whether new tugs of this size would be necessary cannot be determined at this time. Also, qualified personnel with unlimited licenses may not be available in sufficient numbers in view of current industry shortages.

Second, smaller support craft would also be utilized in the deployment operation. Submergence vehicles and divers would be necessary for the CWP attachment and final OTEC fitting operation. Helicopters would be required to perform resupply and transport functions during the entire operation.

Third, although the offshore support industry, servicing the East Coast, Caribbean and Gulf Coast market, is well established, it may have problems servicing OTEC plants under the 50 plant scenario. The OTEC Commercialization Scenario for 25 OTEC plants postulates that 20 of the 25 operating OTECs would be located in Atlantic and Gulf Coast waters, while in the 50 OTEC scenario, 44 OTECs would be in operation in this area. The deployment of 20 OTEC plants in this area would tax the existing large support craft availability and increase the demand for qualified personnel. However, with careful scheduling and no rise in other offshore operations, it could be workable. In the case of the 50 OTEC scenario with 44 OTECs being deployed in the Atlantic and Gulf Coast, the offshore support industry would not be able to handle this workload based on the projected growth rate. The increased demand for highly qualified personnel would cause the existing shortage to increase irrespective of measures taken under P.L. 96-378 ("Small Vessel Inspection and Manning Act," which was designed to ease the projected shortage of small vessel personnel).

When an offshore industry spokesperson was questioned concerning this shortage issue and the possibility of deployment of a large number of OTEC vessels, he agreed that present growth projections would not be sufficient. Nevertheless, he believes that the leadtime associated with the construction of 44 OTEC facilities would be sufficient to allow the industry to plan for the additional demands.

Fourth, in the case of the OTEC plants producing electricity cabled to shore, a definite problem arises. To date, the U.S. Naval Sea Lift Command is the only group allowed by law to lay electrical cable offshore in U.S. waters. This requirement would have to be relaxed if the construction of a significant number of OTEC plants producing electricity cabled to shore were a foreseeable reality.

The OTEC crew rotation and resupply function would be an ongoing process starting from the beginning of OTEC deployment operation and continuing throughout the operational life of the OTEC vessel. Smaller support crafts and helicopters would perform these functions. It is projected that these functions would be performed from land bases close to the operating OTEC plant. A light support craft center is already well established for the Gulf Coast, and new centers of light support would develop in Puerto Rico and Hawaii. It is probable that the related personnel would relocate their families to these new centers of job opportunity, thus stimulating the land based economies of the associated areas.

Aluminum Industry

Several organizations, including APL and TRW, have considered conceptual designs for OTEC plant ships which would reduce alumina to aluminum metal on board. This process is attractive for OTEC application because aluminum production is energy intensive, because the alumina is already imported over long distances, and because the OTEC alumina reduction plants could be located near alumina shipping routes. Aluminum also appears to be an attractive initial product for the OTEC island energy complex concept, i.e., use of OTEC plants off Puerto Rico, Hawaii, or other tropical islands to supply electricity by cable to onshore industrial complexes.

Aluminum is the most abundant structural metal element in the earth's crust. It is important in virtually all segments of the world economy, but principal uses have been developed in six major industries: transportation, construction, electrical, containers and packaging, consumer durables, and mechanical equipment.

For many years demand has grown at a faster rate than the growth rate of other major metals, and measured either in quantity or value, the use of aluminum now exceeds that

of any other metal except iron. Smaller but important industrial uses also have been developed for nonmetal forms of aluminum.

Since the early 1970s there has been a substantial increase in the cost of producing aluminum in the U.S. due to the increase in the cost of fuels and electric energy, the increase in bauxite mining taxes and levies, and increases in the cost of other raw materials such as caustic and fluorine. Bureau of Mines' estimates of the operating cost per ton of primary aluminum ranged from \$300 to \$600 in 1974 and from \$500 to \$800 in 1977. The average price per pound of aluminum ingot increased from 25.3 cents in 1973 to 59.4 cents in 1979. Because of the large use of electrical energy for primary aluminum metal production, national and regional policy decisions will play an increasingly important role in locating future production facilities.

The domestic primary aluminum industry is composed of 12 companies operating 33 plants with an employment of 29,000. The "Big Three" producers (Alcoa, Reynolds, and Kaiser), operate 20 plants and account for about 64 percent of domestic production.

Production of primary aluminum has increased annually since the 1940s, except for 1975 when production suffered a sharp decline. Production nearly tripled between 1950 and 1960, increasing from 0.7 million tons to 2.0 million tons. From 1960 to 1970, production doubled, as 4.0 million tons of primary aluminum were produced in 1970. By 1974, production had reached 4.9 million tons. Production decreased to 3.8 million tons in the recession year of 1975. There has been an increase in production each year since 1975, with a record 5.0 million tons being produced in 1979.

The historical price stability of aluminum has been an important factor in the high rate of growth of the industry relative to other metal-producing industries. Since 1973, however, aluminum prices have been increasing sharply, rising from 25.3 cents/lb. in 1973 to 59.4 cents/lb. in 1979. During this same period, the PPI rose from 101.3 to 278.4.

Although 90 percent of the domestic supply of aluminum raw materials is imported, most of the domestic demand for primary aluminum metal is met by U.S. producers. During the 1968-1979 period, the U.S. produced an annual average of 94 percent of the

primary aluminum metal it consumed. Although the U.S. is expected to continue producing a major part of the metal it consumes because of the relatively high handling and transport costs of the metal, an increasing proportion of domestic demand will probably be met by imports from countries with low-cost electricity. The Bureau of Mines estimates that U.S. production of primary aluminum metal in 1985 and 2000 will comprise 85 and 80 percent, respectively, of probable U.S. demand. Such predictions favor the production of aluminum on OTEC plants.

Ammonia Industry

The energy produced by an OTEC plant may be used for the production of ammonia, which presently requires large amounts of natural gas as a feedstock. Ammonia could be manufactured aboard an OTEC plant from nitrogen, which can be extracted from the air, and hydrogen, which is made by electrolysis of seawater. Ammonia is formed in an equilibrium process with little evolution of heat so that it efficiently transforms electrical energy into storable chemical energy. It is easily liquefied, stored, and transported.

Historically, about 75 percent of the U.S. annual ammonia production (19 million tons in 1980), has been used as fertilizer, 25 percent applied directly to the soil, and 50 percent used as a basic material in the production of other fertilizers. The remaining ammonia is used to make nitric acid, sodium carbonate, vitamins, cleaning agents, and other chemicals. It is also used as a refrigerant.

When ammonia is used to produce derivative products, it is often part of a continuous production process. That is, it is produced and consumed at the same site. For example, urea plants are located adjacent to ammonia plants which provide both feedstocks necessary for urea production — ammonia and carbon dioxide. In such cases, it would be difficult to replace the ammonia feedstock with ammonia produced at another site, such as an OTEC plant.

In 1978, ammonia production consumed about 630 billion cubic feet of natural gas, the oil equivalent of 1.46 million barrels per day. It has been estimated by Johns Hopkins

Applied Physics Laboratory that the substitution of OTEC ammonia for ammonia made from natural gas could conserve natural gas in an amount equivalent to 500,000 barrels per day of oil by 1999.

Anhydrous ammonia (NH_3) is the nitrogenous material most commonly produced for use as fertilizer. Although current U.S. ammonia capacity (about 21 million tons/year) is sufficient for the next few years, little additional capacity is scheduled beyond 1980, and there is the possibility of domestic nitrogen deficits by the early 1980s unless older plants are replaced as they close down. Recently, the FAU/UNIDO/World Bank Fertilizer Working group forecast a North American nitrogen fertilizer deficit of 430,000 tons for 1984/85.

Production of anhydrous ammonia nearly tripled between 1960 and 1970, increasing from 4.8 million tons to 13.1 million tons. Production continued to increase steadily after 1970, reaching 18.9 million tons by 1980. Production of other ammonia compounds also increased during this period, though not as rapidly as production of anhydrous ammonia. Between 1960 and 1967, production of ammonium nitrate increased from 3.1 million tons to 7.2 million tons; production of ammonium sulfate increased from 0.9 million tons to 2.2 million tons; production of nitric acid increased from 3.3 million tons to 7.9 million tons.

The industry appears to be subject to major fluctuations which directly affect fertilizer prices, supplies, and industry profits. In the 1960s, demand grew at a steady rate, but growth in demand was outweighed by large increases in productive capacity. As a result, prices fell. By 1971, the growth of productive capacity almost stopped because of unprofitability, and several firms left the industry. Fertilizer prices increased nearly 150 percent between 1971 and 1975. At the same time, however, production costs increased greatly because of greater capital and energy costs. Prices decreased from 1975 through 1978. Although prices have increased since 1978, they have not reached the 1975 level.

Ammonia producers have operated at 90 percent capacity in recent years. Despite high fertilizer prices, producers are unlikely to expand capacity significantly because increasing costs of natural gas feedstocks are expected to offset rises in fertilizer prices. Between 1977 and 1979, 29 plants with 4 million tons of capacity closed down. This was a result of overcapacity, high imports, and the increasing cost of natural gas.

The ammonia market reflects many of the fluctuations that plague agriculture in general. There has been a mismatching of supply and demand, with a supply glut in the 1960s followed by shortages in the early 1970s. This has led to erratic prices and profits. Producers appear reluctant to commit capital in an industry with a record of such ups and downs. It seems unlikely that firms that have never operated in the fertilizer industry will attempt to enter the industry in the future. The increasing costs of construction, production, and marketing, as well as uncertain prices and availability of natural gas, have raised substantial barriers to entry. The industry is characterized by increasing concentration and vertical and horizontal integration.

INDUSTRY PROFILES

STEEL INDUSTRY

Uses of Steel

The primary uses of steel fall into three categories: structural members, coverings and containers, and mechanical elements. Structural members, which include framing for buildings, bridges, rail and highway structures and industrial equipment, as well as the supporting members of land vehicles and ships, comprise the largest use of steel. Its use in machine elements probably ranks second, closely followed by its use as a covering or in containers in which its strength is inherent in the skin or shell.

Steel is used as the frame and as reinforcing for the concrete in buildings, bridges, and docks. It is used by building contractors in structural shapes, sheet piling, pipe, rods, and bars. In the automotive industry, iron and steel comprise most of the weight of the mobile equipment produced—in the frame, a structural member; in the body, a covering; and in the engine and drive train, mechanical elements.

Product Classifications

In the Standard Industrial Classification (SIC) system, steel is found at the 3-digit level, SIC Code 331 (Blast Furnaces, Steel Works, and Rolling and Finishing Mills). At the 4-digit level, SIC Code 3312 (Blast Furnaces, Steel Works, and Rolling Mills) accounts for about 83 percent of the total value of shipments under SIC 331. The other 4-digit product classifications for steel, and their percentage share of the total value of shipments, are:

- SIC 3313 - Electrometallurgical Products (2%)
- SIC 3315 - Steel Wire Drawing and Steel Nails and Spikes (5%)
- SIC 3316 - Cold Rolled Steel Sheet, Strip, and Bars (5%)
- SIC 3317 - Steel Pipe and Tubes (5%).

The companies classified in SIC 3312 produce raw steel and a wide variety of steel mill products and basic shapes, such as plates, sheets, strips, rods, bars, and tubing. The companies included in the other 4-digit classifications purchase these basic shapes and convert them into consumer goods. SIC Code 3312 represents that part of the steel industry which will be examined in this profile, since this is the part of the industry that accounts for steel production.

Number of Firms, Concentration

The domestic steel industry is composed of approximately 180 firms which produce a wide range of steel mill products. In 1980, 76 of these firms produced raw steel in their own furnaces at 153 plants. This represents a slight decrease from the early 1970s, when 90 firms operated furnances at 175 plants. The firms without steelmaking furnaces purchase semifinished steel for fabrication into consumer goods.

About 20 firms are fully integrated, operating blast furnaces, steelmaking furnaces, and finishing mills, while 40 companies operate minimills (an electric arc furnace steel-making plant which produces less than 600,000 tons of raw steel annually).

The iron and steel industry is divided into four principal branches—iron ore mining, pig-iron production, steel making, and steel rolling. Depending on the function performed, the individual companies composing the industry are classified as integrated, semi-integrated, and nonintegrated. Integrated companies are those which operate in all four of the industry's branches. Semiintegrated concerns do not make their own pig-iron, but purchase it to make steel and rolled products. Nonintegrated producers either make pig-iron exclusively (these are the so-called merchant blast furnaces) or buy ingots or semifinished steel for rolling and further processing.

The steel industry today is—structurally speaking—an oligopoly and is dominated by a relatively few, large, integrated producers. These, taken together, own or control about three-quarters of the nation's ore reserves, blast furnace capacity, ingot and "steel for casting" capacity, and finished hot-rolled capacity. Both horizontally and vertically, therefore, steel is a highly concentrated industry.

The concentration ratios for the steel industry have remained virtually unchanged for more than a decade. This is not surprising considering that very little new capacity has been added during this period. The 4-firm concentration was 54 percent in 1968, and remained at 54 percent in 1980. The 8-firm concentration was about 75 percent each year. In 1968, the top 4-firms were United States Steel (24.7%), Bethlehem Steel (15.5%), Republic Steel (7.5%), and National Steel (6.5%). In 1978, these same four-firms were in the same order among the top five, with LTV Corporation taking over the number three spot. As LTV became one of the top producers, the market shares of both U.S. Steel and Bethlehem declined to 22 percent and 14 percent, respectively.

Most of the steel industry in the United States is located in the industrial complex surrounding the lower Great Lakes ports in Pennsylvania, Ohio, Indiana, Illinois, and Michigan. These five states account for about 70 percent of domestic steel production. There are large integrated steel mills in northern New York, eastern Maryland, and Alabama, and relatively small integrated steelmaking plants in Texas, Colorado, Utah, and California.

Integration and Diversification

Three factors can cause confusion in an analysis of the U.S. steel industry:

- There are a great number of companies involved in ferrous materials that are best not considered as part of the domestic steel industry,
- The domestic steel industry is not homogeneous.
- Some companies usually treated as steelmakers have diversified out of steel and are continuing to do so.

Companies not considered part of the domestic steel industry in this analysis include: foundries, ferroalloy producers, steel distribution companies, steel fabricating companies, companies producing or processing raw materials only (e.g., coal, iron ore, scrap, coke), and the design, construction, consulting, and equipment companies that serve steelmakers. In this analysis, the U.S. steel industry includes only those firms that at one point in their production sequence make molten steel and subsequently sell mill forms and perhaps some primary product.

Because the steel industry is not homogeneous, it is convenient to break it down into three major segments:

- Integrated steelmakers, those that convert iron ore to molten iron and then convert the molten iron to commodity carbon steels.
- Nonintegrated steel makers, those that do not have ore conversion facilities, but depend mainly on ferrous scrap to feed electric arc furnaces and produce a relatively small range of low-price carbon steels.
- Alloy and speciality steelmakers, those that use a variety of processes to produce higher priced, higher performance steel than those produced in the other segments.

The forward integration by the major producers has been a factor in strengthening the steel oligopoly. Since 1939, large steel producers have integrated forward, large steel consumers have integrated backwards, and independents have been subjected to periodic vertical price squeezes.

Recent technological changes have substantially reduced the barriers to entry and deprived the integrated producers of their dominant position vis-a-vis the potential newcomer. As long as the open hearth was the work horse of raw steel production, companies which owned extensive ore reserves, coke ovens, efficient blast furnaces (to make pig iron), and large open hearths (to make steel) had a decisive advantage deriving from size and vertical integration. The capital investment required by new facilities made entry by small producers virtually impossible.

In the last 30 years, however, the introduction of the basic oxygen furnace and the adaptation of the electric furnace to the production of carbon steel substantially reduced the cost of entry. The electric furnace, especially, has made it possible to construct mini-mills without the necessity of integrating backward into iron ore, coke ovens, and blast furnaces.

Capacity and Capacity Utilization

By the end of World War II, the U.S. steel industry had a raw steel capacity of approximately 100 million tons. Capacity was expanded significantly in the 1950s,

increasing to over 130 million tons. Since 1959, when the United States became a net importer of steel, domestic steelmaking capacity has grown very little. In the 1960s there was an increase in capacity of only 6 million tons, and in the 1970s the net increase was only 5 million tons. Today, gross steelmaking capacity is about 142 million tons. This is equivalent to a capacity of approximately 106 million tons of steel mill products.

Since 1973, capacity utilization has averaged about 86 percent. A high of 97 percent was achieved in 1973, while a low of 76 percent was reached in 1975. While capacity utilization figures are not yet available for 1980, the very low production for that year indicates that 1980 capacity utilization was significantly below the 1979 rate of 88 percent.

Annual investments in new domestic steelmaking capacity and modernization of existing plants during the past decade have only been about half the estimated future need level. However, the steel industry has continued to invest significant amounts of money in non-steel businesses. The basic investment situation is not expected to change unless the prospects for greater profit margins in steelmaking improve. An extension of existing trends indicates that the domestic capacity expansion required to avert forecasted supply and price problems may not take place.

Production and Prices

From 1965 to 1972, production was fairly constant, ranging from 84 million tons in 1967 to 94 million tons in 1969, while averaging 90 million tons. From 1973 to 1980, production was erratic, ranging from a low of 80 million tons in 1975 to a high of 110 million tons in 1973 and 1974. The average during this period was 96 million tons. Following the 1975 recession, production increased annually until 1979, when it reached 100 million tons. In 1980, low demand from key markets, such as the automotive and construction industries, led to an 18 percent decrease as production fell to 82 million tons.

The actual composite price for all steel mill products rose very slowly from 1958 to 1968, increasing from 6.06 cents per pound to 6.60 cents per pound. From 1968 to 1973, prices rose more rapidly, climbing from 6.60 cents to 9.38 cents per pound. Since 1973, the price rise has been dramatic, as composite prices for steel mill products reached 21.7 cents per pound in 1980.

The Producer Price Index (1967 = 100) for steel has risen more rapidly than for industrial commodities. The PPI for steel in 1978 was 254.5 compared to 209.3 for all industrial commodities. This comparatively rapid increase is due to the rapidly rising price of energy and, to a lesser extent, labor. From 1962 to 1972, when the exchange rate favored imports, foreign competition held prices down. When the dollar was devalued, price controls, in the early 1970s, prevented prices from rising. When price controls were removed, in April 1974, prices immediately increased. Prices have continued to increase, relative to other industrial commodities, due to the steel industry's large requirements for energy and labor.

Steel is a concentrated industry and its behavior conforms closely to the oligopoly pattern. Price uniformity is assured through price leadership. Price stability is attained, often at the expense of extreme fluctuations in production and employment. Price levels are geared to a break-even point of 50 percent or less of capacity. The industry leader sets prices like a public utility, aiming for a predetermined profit target, and the other firms usually follow.

Production Process

There are three commercially feasible methods of producing steel:

- A hot metal method using the blast furnace for ironmaking and basic oxygen or open hearth steelmaking furnaces.
- Direct reduction ironmaking furnaces linked with electric steel furnaces.
- Cold metal/scrap based steelmaking in electric furnaces.

The hot metal method is used in integrated steel plants. In this process, metallurgical-grade coal is baked to produce coke for the blast furnace operation. "Sintering" operations reclaims fine iron ore particles resulting from various mill operations. Iron ore, limestone, and coke are converted into molten iron in the blast furnace. The molten iron is then taken directly to the steelmaking furnace where it is converted to steel.

Direct reduction of iron ore eliminates blast furnaces and coke ovens. Instead, it produces highly concentrated iron pellets that can be substituted for scrap in a steelmaking furnace. Its development was described as an evolution in the industry which promises to reduce new plant capital costs and pollution. At present, though, adoption of direct reduction in the U.S. seems hindered because its cost is not yet competitive with scrap, and the best direct reduction processes require expensive natural gas.

The final alternative for producing steel is a "cold metal" route, whereby recycled scrap or direct reduced iron is refined into steel via electric arc furnaces. This process does not require iron ore or equipment such as coke ovens, sintering plants, or blast furnaces to refine it. Consequently, capital investment needs are greatly reduced. Electric arc furnaces are often used to turn scrap into a narrow range of low value products in so-called mini-mills. In 1978, however, a third of the Nation's electric furnaces were operated by fully integrated steel firms.

Regardless of what method is used to produce it, at this state the molten steel must be solidified before further processing steps can take place. Traditionally, the molten steel is captured in large ladles and poured into ingot molds, where the steel is moved and allowed to cool and solidify. The steel ingots can then be removed from the mold, reheated, and rolled into semifinishing shapes in a primary rolling mill. These shapes are then converted to finished products by further processing.

Technological Change

The creation and adoption of new technology are hampered by a number of factors, the most important of which are inadequate capital formation, inadequate R&D, high regulatory compliance costs, and the threat of unfairly traded imports. The most important technological change for integrated steel makers during the next 10 years will be greater adoption of continuous casting. Continuous casting is a growing technology that provides dramatic energy and labor savings and increases yield. Instead of reheating ingots, continuous-casting machines receive molten steel and solidify it in a continuous, water-cooled molding process into semifinished shapes. The main benefits of continuous casting are lower energy requirements, lower capital costs per ton, higher labor productivity, better steel quality, and reduced pollution.

Another important new steel technology is direct reduction (DR) of iron ore. DR refers to a number of processes that are alternatives to the blast furnace and coke oven for the production of iron. These processes operate at lower temperatures than blast furnaces and they convert iron ore to iron without melting. DR is compatible with other new technological developments, and direct reduced iron can also be used as a substitute for scrap in the nonintegrated steel sector.

Barriers to Entry

The primary barrier to entry is the substantial investment required to construct an integrated steelmaking plant. A GAO report published in January 1981 indicated that a new integrated plant would cost from one to four billion dollars, depending on size (about \$1,000 per ton of capacity). The GAO analysis shows that such a plant, employing the latest technology, could earn a 10 percent real return on equity after taxes. Actual operating profits for the industry averaged 9.2 percent from 1975 to 1978. Nevertheless, investors may hesitate to commit such funds in view of the delays and risks associated with such a large project.

An investor interested in entering the steel industry may prefer the nonintegrated mini-mill sector. This is so because of the lower entry costs (\$50 to \$100 million). Furthermore, the mini-mill sector has shown higher earnings recently than has the integrated sector. Other advantages of the nonintegrated compared to the integrated plants include a shorter construction period and lower energy costs per ton of steel produced. Nevertheless, further expansion of mini-mill production may be hindered by future scrap shortages with attendant high prices.

Cost of Production

Unusually large cost increases for raw materials were responsible for most of the 133 percent increase in domestic steel production costs during the 1970's. Although hourly employment costs are higher than the all-manufacturing average and recent increases have been considerable, the relative significance of unit labor cost is declining as a result of skyrocketing raw material costs, particularly for energy. During the past decade, raw materials (including energy) were responsible for almost 60 percent of the total costs of producing a ton of steel in the United States; labor, for slightly more than 30 percent; and financial costs, for about 9 percent.

Compared to other basic industries, steel is faced with a major environmental cost burden. This may be attributed in part to the fact that most steelmaking processes were developed (and most facilities constructed) during a time when environmental considerations were an insignificant factor in equipment design. There has been little recent construction, which might allow the incorporation of environmental technology, and the industry has been forced to follow the less efficient retrofit approach.

The steel industry has reported environmental equipment expenditures from 1969 to 1978 averaging \$280 million per year, or about 13 percent of annual capital investments. Future regulatory investments will increase to between \$550 million and \$800 million annually, according to Federal and industry estimates, respectively. In addition, the industry will incur substantial costs in operating and maintaining environmental control equipment, particularly for increased energy use. Steelmakers have estimated that future environmental costs will be about 20 percent of the industry's total capital investments per year.

The Occupation Safety and Health Administration (OSHA) was established by Congress in 1970, but thus far OSHA regulatory costs have been rather limited. They are the steel industry's greatest regulatory uncertainty: the costs to industry of OSHA regulations are not well understood, and information on future costs is speculative. As enforcement activities gain momentum and regulatory costs increase during the next several years, more detailed reporting systems and analyses will probably be developed.

The industry reported OSHA-related expenditures of about \$41 million for 1977. Expenditures in 1978 and 1979 are estimated to have totaled about \$80 million. When judicial challenges are settled, and the Agency begins actively enforcing major regulations affecting the steel industry, these expenditures may increase considerably. In a number of cases, however, environmental and occupational regulations overlap, so that combined regulatory costs will be less than those for EPA and OSHA evaluated separately and summed. Cokemaking will remain the industry's main occupational health hazard for the foreseeable future. Thus, integrated producers, especially the older and smaller ones, will be affected more severely than others in the near future. However, anticipated revisions in noise and metalics standards could have a substantial impact on all industry segments.

Employment

Total employment in the steel industry in 1980 was 429,000, of which 333,000 were production workers and 86,000 were technical workers and management personnel. Employment in the steel industry has decreased since 1974, when it stood at 518,000. Production per employee has increased fairly consistently from 117 tons per year in 1958 to 191 tons per year in 1980. Production per employee peaked in 1974 at 212 tons.

There are several causes for the downward trend in employment. A positive factor is increased labor productivity, which has enabled the steel industry to meet a generally increasing demand with less workers. A negative factor, however, is the growth of steel imports. It is estimated that every million tons of imports displace 4,000 to 5,000 domestic steel industry employees. On this basis, the current level of imports has displaced approximately 100,000 steel company employees over the past 20 years.

A technical manpower shortage is now developing in a few areas in the steel industry, and it could become more serious if the industry were to begin vigorous modernization, R&D, and innovative programs. Only about 18 percent of all steel industry salaried technical personnel are now engaged in engineering R&D, and even smaller numbers in steelmaking R&D. This is partly because considerable research manpower is absorbed in environmental R&D. Research personnel are primarily engaged in market-oriented research leading to evolutionary changes in process and product, rather than in fundamental research that might produce radical changes.

The training, skills, and performance of steel production workers have not impeded the development and use of new technologies. When new equipment has been introduced, steelworkers have generally been cooperative. Prevailing manpower use patterns reflect the industry's concern with production capability rather than an emphasis on changing and improving technology. National union leadership is concerned with technological displacement, but does not resist the introduction of new technology.

Imports and Exports

The United States has been a net importer of steel mill products since 1959. During the 1960s, net imports averaged 5.9 million tons annually, or about 12 percent of domestic

consumption. During the 1970s, net imports increased to 12.7 million tons annually. In 1980, exports were 16.6 million tons and imports were 5.0 million tons. Steel imports are expected to increase slightly in 1981 while steel exports will probably decline.

Domestic steel consumers purchase steel from foreign producers for a variety of reasons, including:

- **Price** - For example, as of late 1979, even after adoption of the trigger pricing mechanism, Japanese steel cost approximately \$30 per ton less than competing domestic steel on the West Coast. Differences in the ordering price are not the whole story, however. Foreign firms usually guarantee their quoted prices to delivery, while American firms charge the price in effect at the time of delivery. Furthermore, buyers criticize U.S. mills for following suit each time a major steel mill publishes a new price list.
- **Quality** - Buyers often feel that more modern facilities outside the United States permit foreign steel mills to market products of superior quality. Foreign steel is often superior in gauge control, consistency, fabrication, and processing.
- **Supply Protection** — Many consumers buy foreign steel because certain steel mill products are unavailable domestically or because domestic producers are slow to make deliveries. This problem was aggravated when, in 1974, domestic steel companies operated near 100 percent capacity, yet 17 million tons of steel mill products were imported. Furthermore, West Coast companies have found that it is cheaper to import steel mill products not available on the West Coast than to pay shipping costs for eastern steel mill products.

Profits

Throughout the past two decades, except for 1974, the steel industry's profits after taxes, as a percent of stockholder's equity, were substantially below the average for all

manufacturing. Since 1960, the average after-tax profit rate for steel companies was 7.5 percent, compared to 12.8 percent for all manufacturing.

The nonintegrated and speciality producers have markedly better profits than integrated companies. For example, in 1978 the average return on investment for 12 integrated companies (accounting for 63 percent of domestic shipments) was 6.2 percent; for 6 nonintegrated producers (accounting for 61 percent of their segment's shipments) the average was 12.3 percent; and for 9 of the major speciality companies the average was 11.1 percent.

The financial data for the integrated companies are somewhat misleading because substantial nonsteel business is generally included. Without nonsteel profits, financial results for integrated companies would be substantially worse; indeed, for some companies steelmaking itself generally loses money. In contrast, the best performing of the nonintegrated and alloy/specialty companies have profit rates considerably above the averages for their segment and are often considered growth companies. These are precisely the companies that use the latest technology.

Domestic Supply-Demand Forecast

There are many uncertainties in supply-demand forecasting for a commodity such as steel, which is very sensitive to general domestic economic conditions and world supply factors. Nevertheless, relatively good agreement exists among various steel demand forecasts. For 1985, the demand forecasts vary from a low of 114.7 million tons by the industry itself (American Iron and Steel Institute), to a high of 133.4 million tons (Tribendis and Clark). For 1990, the industry projects domestic demand at 125.0 million tons while Chase Econometrics projects demand at 137.3 million tons. The only steel demand projection for 2000 forecasts steel demand in the U.S. at 151.1 million tons (U.S. Bureau of Mines).

The low projections of AISI are based on a low growth rate in steel demand of 1.5 percent annually. The high projection of Tribendis and Clark was based on a growth rate in steel demand of 1.9 percent annually. (From 1950 to 1975, steel consumption increased 2.0 percent per year.) The Bureau of Mines used a curvilinear regression of demand on population, beginning in 1915. The demand projections for 2000 were based on Bureau of the Census population projections.

Assuming an adequate supply of raw materials and energy, the domestic supply of steel is dependent upon the capacity of the U.S. steel mills, and, to some extent, on the availability of steel products on the world market. There are, however, few reliable projections of domestic steel production capacity. Such projections involve major uncertainties, including the extent of import penetration and the extent of investment, modernization, and expansion in domestic capacity. Chase Econometrics estimates that capacity will be 129.6 million tons in 1990, while the steel industry forecasts 1990 steel capacity at 109.7 million tons.

To compare the capacity and demand projections, it is necessary to assume an operating rate. A 90 percent operating rate yields a realistic production level. Using an average of the Chase Econometrics and steel industry forecasts for 1990 yields a demand of about 131 million tons and a domestic supply of about 107 million tons (.9 x 119 million tons). Thus, there is a projected shortfall of 24 million tons, or 18 percent of total demand, in 1990. This shortfall will have to be met by imports. Since net imports have averaged about 12 percent of domestic consumption for the past decade, it is projected that imports will increase significantly over the next decade.

The amount of steel imported into the United States depends on several economic and political factors, including the relative cost of steel production in the United States and abroad, whether a worldwide shortage or oversupply of steel exists, the imposition of tariffs, quotas or "antidumping" restrictions by the Government, or voluntary restraint agreements or orderly marketing agreements between the United States and other countries. Under normal conditions, and when there is a worldwide oversupply, imported steel is priced somewhat below domestic steel, but in times of shortage this may be reversed.

Although the Free World currently has abundant steel to meet demand, many analysts (Fordham University's Industrial Economics Research Institute, Chase Econometrics, and others) forecast shortages of capacity by 1990. Therefore, if U.S. steel capacity is not increased, domestic steel consumers will have a difficult time in procuring steel, and will have to pay extremely high prices for imported steel in the late 1980s and early 1990s.

The Steel Industry and OTEC

Depending on the configuration of an OTEC plant, steel may be used to construct the hull or, alternatively, as reinforcing bars in a concrete hull. Steel has also been discussed as a cold-water pipe material, but it is more probable that concrete or fiber-reinforced plastic will be used instead.

One estimate of the amount of steel required to construct an OTEC hull is 107,000 tons. Under the 25 plant scenario, it is possible that as many as 9 plants could be under construction simultaneously, and that construction would take three years. If all these plants used steel hulls, approximately 321,000 tons per year of steel could be required to meet OTEC construction needs. This amount of steel represents only about .30 percent of domestic steel mill product capacity. However, it represents approximately 3 percent of the average annual steel mill products used for construction. This may not be significant, though, in view of the fluctuation in recent years in steel used for construction. For example, steel used for construction increased from 12.4 million tons in 1972 to 15.6 million tons in 1973, and from 10.9 million tons in 1977 to 12.1 million tons in 1978. The increases during these periods represent much more than the 321,000 tons that may be required by OTEC.

CONCRETE INDUSTRY

Introduction

Products, Markets, and Shipments

The ready-mixed concrete industry consists of companies manufacturing a concrete batch and delivering it to the user in a plastic (unhardened) state. Purchasers of ready-mixed concrete favor the product because: it reduces the investment they would otherwise have to make in mixing and batching equipment; it eliminates the need to set aside valuable space at the construction site for such mixing; it adds convenience to the construction process, because the product can be ordered and received when needed without operating a mixing plant only part of the time; and it allows for mobile delivery to the exact point of use at the project without double handling. None of these reasons, however, are particularly applicable to the construction of an OTEC plant.

The physical distribution of ready-mixed concrete is severely limited both by its short hardening time and its high weight-to-value ratio. These limits provide strong reasons for setting up a concrete plant at the OTEC construction site. In some cases the construction sites suitable for OTEC, such as shipyards, already have facilities available for producing the required amounts of concrete.

The value of shipments of ready-mixed concrete by all manufacturing establishments, as reported by the Bureau of Census, increased from \$1.5 billion in 1958 to an estimated \$7.7 billion in 1980. After 1972, however, the increase in value of shipments was due to increased prices rather than increased quantity. From 1958 to 1972, quantity consumed increased from 113 to 208 million cubic yards (MCY). In 1973, consumption decreased slightly to 195 MCY. The 1974-75 recession had a severe effect on the concrete industry, as consumption fell to 150 MCY in 1975. Consumption of cement increased annually from 1976 through 1978, and then decreased again in 1979 and 1980. According to Mr. Malarky, about 200 MCY were produced and consumed in 1980. This is still slightly below the peak year of 1972.

The long-term forecast for this industry is a 2.1 percent compound annual increase in volume of shipments through 1984. This represents a slightly larger growth rate than the two percent estimated for construction activity but is somewhat less than the 2.3 percent for cement. These projections are from the U.S. Industrial Outlook, 1980.

Industry Structure

According to the National Ready Mixed Concrete Association, there are about 5,000 companies operating more than 8,000 plants, with total employment of approximately 80,000. Most of the companies are relatively small. It is believed that 50 percent of the plants produce less than 25,000 cubic yards per year, and 50% of the companies produce less than 75,000 cubic yards per year. Few companies operate in more than one or two geographic regions and there are no national chains. About half of the total volume of ready-mixed concrete is produced by 10 percent of the largest companies.

The typical firm supplying ready-mixed concrete will be a proprietorship operating one or more plants and a number of mixer trucks in an urban or metropolitan market. The firms range in size up to multi-million dollar operations and more than a few are part of widely diversified national corporations. While the level of integration is limited —only 280 of the 4,915 establishments are associated with a mine or quarry — the level of diversification can be fairly broad for those public companies. For example, some of the largest companies may operate stone quarries and sand and gravel pits, manufacture concrete block or precast units or even supply asphaltic concretes.

Prices of ready-mixed concrete are quoted on a delivered basis and the cost and time of delivery from the producing plant to the construction site are significant factors in the service performance and competitiveness of the supplier. Thus, although each supplier attempts to achieve at least a target margin, price competition on a job-by-job basis frequently exists. However, this competition is somewhat lessened by the frequent personal supplier-purchaser relationships that are important in doing business in this industry. The Producer Price Index for concrete in 1979 was 249.6, while for concrete ingredients it was 244.0.

The major concerns facing the concrete industry are:

- The availability of cement and aggregate;
- The rising cost of fuel for the large fleets of ready mix trucks; and
- Environmental problems, including air, water, and noise pollution.

Concrete Ingredients

Concrete is a mixture of portland cement, fine and coarse aggregate, water, and sometimes admixtures. Chemical action between the cement and the water results in the crystallization of hydrous calcium aluminum silicates, which causes the mixture to bind and set together with the aggregates and admixtures into concrete. Almost half of the water normally used in mixing ceases to exist as a liquid and becomes part of the solid substance. The remainder evaporates.

Portland cement is an extremely complex material, composed primarily of limestone with smaller amounts of gypsum, clay, shale, and other chemical compounds. The American Society for Testing Materials specifies standards for eight types of portland cement. These eight types exhibit different properties concerning strength, heat of hydration, and resistance to sulfate action.

Aggregates are the inert materials used as filler in the cement paste. Natural sand is the most commonly used fine aggregate, while coarse aggregates are usually composed of gravel and/or crushed stone. Sand and gravel occur naturally and may also be obtained from crushed stone, iron or steel slag, fly ash, bottom ash, broken glass or crushed concrete. Crushed stone is primarily limestone, granite, or traprock. Aggregate must be free from clay, organic matter, and chemical salts, and is sized and graded to strict specifications.

Admixtures are added to the concrete immediately before or during its mixing, and are used to modify the properties of concrete so that it will be more suitable for particular work. Admixtures are used to accelerate or retard hardening, improve resistance to freezing and thawing, and improve workability of the mixture.

The proportioning of a concrete mixture consists of determining the most economical combination of cement, aggregates, and water (and in some cases an admixture) that will produce concrete of the required placeability, durability, and strength. Many of the factors that influence these properties can be controlled by proper selection and proportioning of available materials, by subsequent control of the mix, and by proper curing and protection of the concrete after it is placed. A representative mixture required to produce one cubic yard of concrete, and one OTEC plant, is:

	<u>Pounds</u>	<u>Cubic Feet</u>	<u>Tons Per OTEC Plant</u>
Cement	564	2.87	42,300
Sand	1300	7.95	97,500
Stone	1806	10.80	135,450
Water	<u>333</u>	<u>5.34</u>	<u>24,975</u>
	4003	26.96	300,225

Industrial profiles of the cement, sand and gravel, and crushed stone industries follow.

Cement Industry

Uses of Cement

Over 95 percent of the cement produced in the United States is hydraulic portland cement. Hydraulic cements are those that have the property of hardening under water and are the chief binding agents for concrete. About 97 percent of portland cement production is used to make concrete. The U.S. demand pattern for cement in 1977 was: ready-mixed concrete, 64.9 percent; concrete product manufacturers, 13.6 percent; highway contractors, 5.8percent; building material dealers, 7.5 percent; other contractors, 4.2 percent; other, 4.0 percent. The biggest change in recent years has been decreased demand by highway contractors, who were consuming over 9.0 percent of total portland cement production in 1971. The amount of cement consumed by this sector decreased from 7.4 to 4.6 million tons from 1971 to 1977.

As an intermediate product, the output of cement depends upon the final demand for concrete. In turn, the demand for concrete varies directly with construction spending.

The residential, industrial, and commercial building sectors are the largest users of concrete. However, the largest concrete using projects — dams, highways, and other public works projects — are found in the nonbuilding and transportation sectors. With larger but relatively fewer projects, these sectors will show a greater absolute variability in concrete (cement) consumption over time than will other sectors. A decision to proceed with or to postpone only a few projects will make a substantial difference in the amount of concrete or cement purchased in any one year. Given the regional nature of the cement industry, large projects such as OTEC may have a significant impact on the cement industry.

Number of Firms, Concentration

The cement industry is made up of a relatively small number of firms, which varies slightly from year to year. The number of firms declined from 52 in 1975 to 48 in 1979. The number of plants in operation during this period declined from 174 to 159. Air pollution standards imposed recently led to the closing of older and less efficient plants. These would have required large expenditures of funds for pollution control equipment.

The level of concentration is moderate, with no single firm accounting for more than eight percent of total production capacity. The 10 largest firms represent about 50 percent of capacity. As demonstrated by the concentration ratios in the chart below, the trend since 1950 has been toward decreasing concentration.

Year	4-Firm	8-Firm	20-Firm
1950	33.5	48.2	NA
1964	29.6	50.2	83.3
1974	24.5	42.5	NA
1975	22.1	39.3	73.0

These concentration ratios do not, however, adequately reflect the structure of the cement industry. Since cement is a high weight/low value product, it is not economical to ship it long distances. Therefore, the relevant competitive market is regional, rather than national. The concentration of shipments in regional markets is high enough for these markets to be considered oligopolies.

Capacity and Capacity Utilization

The annual capacity of the portland cement industry increased from 50 million tons in 1950 to 95 million tons in 1967. The decade of the 1960s was one of excess capacity, with capacity utilization below 80 percent. From 1967 to 1973, total capacity decreased to about 85 million tons while capacity utilization increased, reaching 90 percent in 1973. During the 1974-75 recession, capacity utilization dropped to about 70 percent.

By the late 1970s, total capacity reached 100 million tons, with capacity utilization of 75 percent to 85 percent. Capacity utilization varies for several reasons, including:

- Variations in demand due to fluctuations in construction activity;
- Unscheduled kiln shutdowns due to technical problems; and
- Production stoppages due to labor problems.

The industry attributes the relatively low levels of capacity expansion in recent years to low profit levels in the 1970s. In addition, the huge cost of building a new energy-efficient plant which meets air pollution standards has prevented many firms from adding to capacity. Air pollution standards have contributed to decisions to close older and generally less efficient plants that would have required large expenditures of funds for pollution control equipment. Furthermore, large capital expenditures to retrofit other existing plants with such equipment has drained off funds that normally might have been devoted to capacity expansion. The costs of converting the less scarce fuels and installing energy conservation equipment have also reduced the amount of capital available for expansion.

While plans for considerable new capacity additions have recently been announced, it might take several years to get all the required approvals to build a plant, plan and build the facility, and get it into operation. Consequently, much of the new capacity announced in the last two or three years will not be in operation until the early or mid-1980s.

Production and Prices

Portland cement production increased erratically between 1958 (56.6 million tons) and 1973 (83.6 million tons). The cement industry was seriously affected by the recession in 1974 and lagged behind other industries during the recovery. Production fell to 79 million tons in 1974 and less than 67 million tons in 1975, the lowest output since 1963. Following the recession, output increased annually until 1978, when it reached a level of 80.7 million tons. Due to a general decline in construction activity, output decreased in 1979 and 1980, falling to an estimated 73.7 million tons in 1980.

Prices increased moderately from 1958 to 1969. During this period, the Producer Price Index (PPI) rose only eight points, from 97.4 to 105.6. By 1973, the PPI increased to 137.2. Following decontrol of prices in 1973, the PPI shot up suddenly, reaching 161.9 in 1974, and climbing to over 300 in 1980. As a point of comparison, the PPI for all construction materials in 1980 was about 265.

Cement price patterns are very complex, and the PPI may not be an entirely accurate depiction of cement prices. Discounts for cash and large orders, freight absorptions, and bagging and palleting costs vary with local markets. The Bureau of Mines publishes the mill value of cement, which is the actual value of sales to customers, F.O.B. plant, less all discounts and allowances, freight charges, costs of operating terminals, and costs of paper bags and pallets. Mill value of portland cement rose from about \$15 per ton in 1954 to about \$50 per ton in 1980. Most of this increase, however, took place since 1973, when the mill value was less than \$22. (In constant 1977 dollars, the value varied only slightly, and reached its lowest level in the early 1970s. Not until 1976 did the constant dollar value return to and slightly exceed the 1954 value.)

Overcapacity was responsible for the moderate increases in mill value from 1954 to 1970. Government price controls initiated in 1971 restrained price increases through 1973. Following decontrol in 1974, mill value increased each year to reach the \$50 per-ton level of 1980. However, companies maintained that the new price gains do not offset the increased costs of fuel, power, labor, and transportation.

Price movements in cement are likely to be influenced strongly in the future by large increases in energy costs, transportation costs, and the need to generate profits which can provide the capital for energy conservation, the meeting of environmental regulations, and for capacity expansion.

Integration and Diversification

All cement firms are vertically integrated backwards via raw material ownership. Cement plants are located at the source of the principal raw material, limestone. A number of cement-producing companies are now mining their own coal properties or are seeking to obtain coal-mining operations.

An attempt at forward vertical integration was made in the early 1960s when some cement manufacturers, reacting to the slowdown in the growth of final demand, tried to capture some cement markets by purchasing ready-mix concrete manufacturers. This practice was effectively stopped by the Federal Trade Commission, and most cement manufacturers today are not heavily involved in the concrete industry. About 20 percent of cement capacity is owned by cement firms that also produce concrete.

Most cement capacity belongs to diversified firms producing cement on a division or subsidiary basis. Many of these firms are in markets related to construction. Of the 48 companies operating cement plants, 28 firms, with 78 percent of total capacity, are divisions or subsidiaries of diversified companies. Eleven companies, with 13 percent of total capacity, make only cement.

Barriers to Entry

In 1964, there were five firms among the top ten that were not present in 1950. Industry growth slowed in the 1960s and only one new firm entered the top ten between 1964 and 1975. All of the firms that have dropped out of the top since 1950 are still producing cement and are all ranked among the top 20. The firms that fell out of the top 10 did so because of the growth of smaller firms, not because of the entry of newer firms.

This stability highlights the substantial barriers to entry which have arisen in the cement industry. The large capital expenditures necessary for the production of cement and the established distribution networks of the current firms are likely to discourage potential new competitors. In addition, the cost of constructing a cement plant present a formidable barrier to entry. Recent estimates place construction costs at over \$100 per ton of annual production, meaning that a medium size plant would cost more than \$100 million to build. Most entry since 1964 has been by acquisition rather than by new firms building new plants.

Production Process

Portland cement is composed primarily of limestone, clay or shale, and gypsum. The relative abundance of limestone, shale, and clay narrows the prospecting and exploration work mostly to delineating the size and chemical uniformity of the deposits. Although a few limestone and gypsum deposits are mined underground, most raw materials for the cement industry are quarried using surface mining methods.

Principal steps in manufacturing portland cement consist of crushing, grinding, mixing, and burning raw materials to produce a substance called clinker, and cooling and grinding the clinker. Burning is the most important operation because fuel consumption is the major expense in the process, capacity of a plant is measured by kiln output, and strength and other properties of cement depend on the quality of clinker produced. The clinker is finely ground and mixed with gypsum to form cement.

Employment

The number of employees in the cement industry has declined steadily during the past two decades. From 1958 to 1976, the number of total employees declined from 41,100 to 28,100, while the number of production workers declined from 34,800 to 22,300. During this same period total wages increased from \$214 million to \$445 million, while value added increased from \$725 million to \$1461 million.

During the period 1958 to 1976, labor productivity nearly doubled. The industry took advantage of economies of scale, as plant size and kiln size increased. The trend toward greater labor productivity will continue, as many new plants are using computers to increase the degree of automation.

Imports and Exports

Imports have increased from 1.8 million tons in 1969 to 9.4 million tons in 1979, when, for the first time, they represented more than 10 percent of U.S. consumption. Many companies with distribution facilities on waterways import large quantities of cement to supplement plant production. Imports help to alleviate local shortages, especially on the west coast, gulf coast, and Florida. Exports have been insignificant, representing less than one percent of U.S. production.

Profits

Profits in the cement industry have been cyclical. In the strong growth years of the 1950s cement was a highly profitable industry. The composite industry return on sales exceeded 15 percent in 1956, and new entrants were attracted. This margin on sales fell steadily throughout the slow growth period of the 1960s, reaching a low of 4.2 percent in 1970. Returns to net worth and stockholders equity show the same pattern. As the utilization of capacity began to increase in 1971 and 1972, profits followed, rising to 5.5 percent of net sales in 1972. Had it not been for the imposition of wage and price controls in August 1971, profits would have risen even more. It was during this period that production facilities were being used at their highest level ever and product shortages were beginning to occur. Price controls were removed in November 1973, concurrent with the collapse of the demand for cement. The low operating rates of 1974 and 1975 led to low profit margins of 4.3 percent and 3.0 percent, respectively, for these years.

During the past five years demand has improved over that of 1975, and was particularly strong in 1978. However, demand has again declined in each of the last two years and manufacturers are reluctant to build new capacity, claiming profits are inadequate to provide capital or attract new capital for investment in additional production capacity. For this reason, some companies have invested in foreign cement-manufacturing ventures with anticipated higher returns, while others have diversified.

Crushed Stone Industry

The crushed stone industry is the largest nonfuel, nonmetallic mineral industry in the United States. Output of crushed stone in 1980 was approximately 978 million tons. Of the total production, 74 percent was limestone, 11 percent was granite, and eight percent was traprock. About 11 percent of crushed stone is used to make cement and 13 percent is used as aggregate to make concrete. Thus, nearly one-fourth of all crushed stone is used to make concrete. Although stone resources are essentially unlimited in total quantity, zoning, quarrying, and other production restrictions have recently led to regional shortages. In particular, environmental problems have led to zoning decisions adverse to stone producers.

The crushed stone industry is probably second only to sand and gravel with respect to land-use conflicts and environmental problems. The problems are mainly due to the necessity for locating crushed stone aggregate supply sources near consumers, which are for the most part in areas of rapidly expanding urban growth. The production sites must be located near the consumers because of the low-cost, high-weight of stone, otherwise transportation costs can very quickly price stone out of competition or at least greatly increase construction costs.

The use of increasingly efficient production equipment and methods has resulted in a downward trend in constant dollar prices for crushed stone. This downward trend is expected, however, to reverse itself in the early 1980s as a result of increasing costs of pollution control, land rehabilitation, and transportation.

Industry Structure

The size of individual firms ranges from small independent producers with single plants to large diversified corporations with more than 50 plants. In 1980, there were about 1890 firms operating 4200 quarries, a substantial decrease from the 1976 totals of 2000 firms and 5400 quarries. The top 10 producers operate nearly 1000 quarries and account for about one-fourth of total production.

Plant capacities range from less than 25,000 tons per year to about 15 million tons per year. Only about four percent of the commercial plants are of the million ton capacity or larger, but these account for about 37 percent of the total output.

Noncommercial operators, consisting of Federal, State, county, and local agencies, produce crushed stone for use by or for the agencies. Noncommercial production has increased significantly since 1949 as a result of the expanded highway construction programs.

Crushed stone is produced in every State except Delaware and North Dakota. Leading States are Pennsylvania, Illinois, Texas, Missouri, and Ohio, which account for about 30 percent of the total output. In general, stone output of individual States correlates with population and industrial activity.

Industry Behavior

During the period 1958 to 1973, annual production increased steadily from 533 million tons to 1059 million tons. Following 1973, production decreased due to the recession, falling to 900 million tons per year in 1975 and 1976. During the period 1977 to 1979, the stone industry resumed its normal growth pattern, with production reaching 1.1 billion tons in 1979. Industry growth was again interrupted in 1980, as production dropped to an estimated 978 million tons.

Even though production was erratic in the seventies, the value of shipments increased steadily, rising from \$1.37 billion in 1970 to \$3.1 billion in 1980. Producer prices doubled during this period, climbing from \$1.58 per ton in 1970 to \$3.17 per ton in 1980, and the PPI rose from 108 to 217. In comparison, the PPI for all construction materials was 265 in 1980.

Mining and processing costs are decreasing, and stone prices are decreasing in terms of constant dollars. Based on constant 1977 dollars, the average annual price decreased steadily from \$3.11 per ton in 1956 to \$2.28 per ton in 1980. Other costs, such as land acquisition, land rehabilitation, and alleviation of environmental problems are increasing. Overall production costs, in constant dollars, should level off in the early 1980's and slowly rise thereafter.

Technology

More than 90 percent of crushed stone is presently mined from open quarries. In many areas, however, factors favoring large-scale production by underground mining methods are becoming more frequent and more prominent. Underground mines can be operated the entire year without interruptions, do not require extensive removal of overburden, do not produce much waste material that must be disposed of on the surface, and dispense with nearly all the problems of environmental disturbance, including surface rehabilitation costs. Another advantage of underground mines is the creation of valuable storage facilities.

Loading and hauling equipment has grown larger as higher production capacities have become necessary. Track-mounted equipment is predominant. Crushing and screening

plants have also become larger and more efficient, and extensive use is made of belt conveyors to transfer material from the pits to the loading areas.

Problems Facing the Industry

During the past decade, the stone industry became increasingly concerned with regulations and restrictions of operations designed to reduce and control air, water and sound pollution. Resource problems for all types of stone exist in localities of urbanization and industrial development, and will increase unless careful plans are made to utilize favorable areas for quarrying. Even when crushed stone is produced near the point of consumption, transportation charges are often greater than the cost for the crushed stone at the processing plant. Since about 75 percent of all crushed stone is shipped by truck, and considering the increasing costs of fuel and the fact that many producers are being forced further from their market areas, transportation costs will become an increasingly important part of the total cost of crushed stone. It is particularly important, therefore, that large construction projects such as OTEC, which will require thousands of tons of crushed stone for concrete aggregate, be located near adequate sources of stone.

Sand and Gravel Industry

About 33 percent of sand and gravel production is used as concrete aggregate in the construction of buildings and engineered construction projects such as highways, dams, and bridges. Another 15 percent is used as asphaltic concrete aggregate for highway construction, while nine percent is used for concrete products such as cement blocks, bricks, and pipes.

Sand and gravel is one of the most important construction materials, and its availability and cost have a disproportionately strong influence on the general economy. The number of people employed in the sand and gravel industry is relatively small compared with employment in other parts of the construction industry. However, products made with sand and gravel have a major impact on total employment in the construction industry. Employees of construction contractors, cement manufacturers, and the concrete industry are affected by the availability of sand and gravel.

Industry Structure

Sand and gravel is the only mineral commodity produced in all 50 states. There are about 7600 sand and gravel deposits and 6000 processing plants in the U.S. The commercial operations are owned by 4,000 companies while 700 noncommercial operations are owned primarily by city, county, or State highway departments. Individual sand and gravel operations range in size from those producing over 2 million tons annually to those producing less than 5,000 tons. The largest 1,000 sand and gravel deposits are over the 200,000 ton level and account for about 60 percent of total production. The largest 57 deposits are over the million ton level and account for 18 percent of total production. The largest 10 companies produce about 10 percent of the total sand and gravel.

Many producers are in the sand and gravel business exclusively, but others are diversified to various degrees in other mineral raw materials, intermediate construction products such as ready-mix concrete and concrete block, final manufactured products, or the construction of buildings, roads, and other structures. For example, both Lone Star Industries and Martin Marietta are among the top ten producers of sand and gravel as well as crushed stone, cement, and concrete.

Because sand and gravel is a high weight, low value commodity, it is necessary to produce it near the point of use. The larger sand and gravel operations are concentrated in the large, rapidly expanding urban areas, and, on a temporary basis, in areas where highways, dams, and other large-scale public and private works are under construction. The processing plants are fairly evenly divided between permanent plants and temporary plants. Most plants are located at the site of the deposit, and, conversely, most deposits are associated with a processing plant.

Industry Behavior

During the seventies, production of sand and gravel fluctuated along with other construction-related industries. In 1970, 915 million tons were produced, more than in any previous year. Production decreased slightly the following two years, and then increased to 955 million tons in 1973. During the 1974-75 recession, production fell sharply, dropping to 762 million tons in 1975, the lowest level since 1962. Following the

recession, production increased annually through 1978, when a new high of 966 million tons of sand and gravel were produced. Production decreased slightly in 1979, and dropped to an estimated 800 million tons in 1980.

Even though production has fluctuated, price increases have led to increases in the annual value of shipments. The value of shipments has doubled in the past decade, increasing from one billion dollars in 1970 to two billion dollars in 1980; a high of \$2.25 billion was achieved in 1979. Even a substantial price increase in 1980 however, could not make up for the sharp drop in demand, as the 1980 value of shipments decreased slightly from the 1979 level.

Despite the rising costs of labor, the higher land values, and the added costs of pollution control, selling prices of sand and gravel have risen rather slowly. Automation and increased operating efficiency have helped to limit price increases. The competitive nature of the sand and gravel industry, which is one of the most competitive of all industries, has also kept prices low.

The actual price per ton increased from \$1.01 in 1960 to \$1.18 in 1970. By 1980, the price had risen to \$2.81 per ton. In constant 1977 dollars, however, the price decreased steadily during the sixties, falling from \$2.09 in 1960 to \$1.83 in 1970. Since 1970, the constant dollar price has increased slowly, reaching \$2.02 in 1980. Prices can be expected to rise more sharply in the future, though, as sand and gravel is extracted from less favorable sources and as compliance with increasingly stringent environmental and land use regulations becomes more expensive.

As deposits and processing plants are forced to operate further from the metropolitan areas they serve, transportation costs will increase sharply. Consider, for example, the impact of transportation costs on the cost of concrete. In 1977, assuming a ten mile delivery of sand and gravel, the value per cubic yard of concrete was \$32.00. About \$2.50 of this cost was for transporting the sand and gravel. If a 20 mile delivery were required, the added cost to the consumer of concrete would be \$2.50 per yard, increasing the total cost from \$32.00 to \$34.50. If a 60 mile haul were needed, the total cost to the consumer would jump to about \$47.00. One yard of concrete requires approximately 1.6 tons of sand and gravel, valued at about \$3.50 in 1977 (before delivery). Clearly, transportation of sand and gravel is a very sensitive factor and may easily cost more than the material being transported.

Technology

Sand and gravel materials can be of any composition, natural or artificial, as long as they meet certain quality and size specifications. These materials may be crushed stone of all types, iron or steel slag, fly ash, bottom ash, boiler slag, and reclaimed material such as broken glass, crushed concrete, and so forth.

Sand and gravel generally occur in the same deposit, but the relative proportions vary greatly. Consequently, the problem of producing aggregate to rigid specifications can be difficult and involves combinations of many types of equipment, such as crushers, screens, washers, classifiers, and grinding mills. Most sand and gravel operations have a continuing challenge to maintain efficient mining techniques and processing plants. Loading, handling, and hauling of materials also must be efficient. All this concern is necessary because of the highly competitive nature of the market.

Major technological developments that have been instrumental in maintaining adequate production at stable or slightly declining constant dollar cost include use of larger operating units, more efficient portable and semi-portable plants, unitized plants for versatility of plant capacity, new prospecting methods utilizing aerial and geophysical surveying methods, and greatly increased rehabilitation and resale of mined areas where economically advantageous. Use of mined-out pits as sanitary landfill areas has been successful at numerous localities. Automatic controls, along with monitoring by a closed-circuit television system coordinated with radio communications systems, have been installed in many of the larger and newer operations, and these together with the use of improved equipment, have permitted recovery of salable fractions from deposits previously considered too low in quality for profitable exploitation.

Problems Facing the Industry

Although much progress is being made through premining planning, the sand and gravel industry continues to have problems with environmental controls, land-use conflicts, and reclamation practices. Major environmental considerations that must be dealt with in mining and processing sand and gravel are emission of particulate matter into the air, processing water discharge, and noise abatement. Also, employee and public health and safety are a major concern.

To be competitive in large metropolitan areas, new large plants should be fully automated and computerized, and fed from the extraction areas to the plant by belt conveyor rather than trucks. Capital costs for new plants or the conversion of older plants will be high but should pay for themselves over time through their efficiency. The capital investment risk can be high in a competitive and unsure market and the company must be reasonably assured of recovering its costs, with a profit margin, before it invests. This uncertainty is a major problem in determining if supply can meet the demand.

Sand and gravel resources of the United States and the world are extremely large. However, many deposits are not close to market areas and, therefore, are uneconomic to extract. Moreover, much of the resources may not meet the exacting specifications required for concrete and asphaltic concrete aggregates. Reserves, which are measurable amounts of sand and gravel that can be produced with current technology, under existing economic and political conditions, are controlled largely by land use and/or environmental constraints. Local shortages of either sand or gravel are common.

TITANIUM INDUSTRY

Titanium is critical to the proposed OTEC plants because it is a leading candidate metal for the heat exchangers. Its advantages over other proposed metals, such as stainless steel and aluminum, are its resistance to corrosion and biofouling, and its light weight. It is estimated that a single OTEC plant could require 10,000 tons of titanium metal, or approximately 36 percent of all titanium mill products produced in 1980.

Uses of Titanium

The U.S. Bureau of Mines supported early research on the metallurgy of titanium and its alloys, and first published useful research results in 1946. Commercial production of titanium metal began in 1948 with DuPont's production of titanium sponge. Contributions to the development of the infant industry came from the chemical industry, which developed and refined the production process through the ingot state, and from the steel industry, which provided fabrication expertise.

The United States consumed about 535,000 short tons of titanium contained in ilmenite, rutile, and titanium slag in 1977. Pigment manufacture accounted for about 95 percent of consumption; the remainder was used in making titanium sponge, welding-rod coatings, and in ceramic and glass formulations.

About 65 percent of the titanium metal consumed in the United States in 1977 was for aerospace applications, including aircraft and guided missile assemblies, spacecraft, and turbine engines for aircraft. The remainder was used in the chemical and electrochemical processing industry, in powerplants, in marine and ordnance applications, and in steel and other alloys.

Industry sales have historically been highly dependent on the aircraft industry. Between 1948 and 1975, production of titanium closely followed the demand for defense and commercial aircraft. To illustrate: sponge production climbed from 7,400 short tons in 1955 to 17,250 short tons in 1957, but fell to 4,585 short tons in 1958 and 3,898 in 1959.

This abrupt change occurred as the Federal government shifted its defense dependence from airplanes to missiles. Industrial applications began to provide a steadily-growing market in 1965, and accounted for about 20 percent of titanium mill product consumption by 1980, in the form of power generation, condensers, and chemical process equipment.

Number of Firms, Concentration

The titanium metal industry has always been small and specialized. There are currently only three firms producing titanium sponge metal in the United States. Prior to 1957, six firms produced sponge. The firms that survived the 1957 defense shift from airplanes to missiles were the most fully integrated of the original six. Of the three firms currently producing sponge, only one (Titanium Metals Corp. of America, TIMET Division) is fully integrated from the rutile concentrate to semifinished titanium products. TIMET is the largest of the three sponge producers, accounting for more than half of the annual domestic production. The RMI Company of Ohio accounts for about 30 percent of production and the Oregon Metallurgical Corporation accounts for the remaining 10 percent.

Titanium ingot is produced by eight firms, including the three producers of sponge. Titanium mill products are produced by about 20 firms. There is easy movement in and out of this production step because titanium mill products can be fabricated in stainless steel or speciality steel plants.

Production, Capacity, and Prices

Domestic production of sponge metal in 1980 is estimated at 22,500 tons. Production has increased each year since 1976, when only 11,537 tons were produced. Between 1966 and 1976, production fluctuated greatly, reaching a low of 9,260 tons in 1972 and a high of 19,933 in 1974. Annual production since 1966 has averaged 14,584 tons.

The production of titanium ingot (made from sponge plus titanium scrap) and titanium mill products has followed the same general pattern as the production of sponge. That

is, production fluctuated from 1966 to 1976, with 1974 as the peak year, and increased each year after 1976. Since 1966, ingot production has averaged 27,396 tons, with a low of 18,387 tons in 1971 and a high of 42,964 tons in 1980. Production of titanium mill products has averaged 15,853 tons since 1966, with a low of 11,241 tons in 1971 and a high of 27,637 tons in 1980.

The 1979 sponge metal capacity was about 23,000 tons. The three companies currently producing sponge have planned capacity expansions of 3,700 tons in the early 1980s. In addition, Dow Chemical Corporation and Howmet Turbine Components Corporation announced in 1979 the formation of a jointly owned firm, D-H Titanium Company, to scale up and commercialize an electrolytic process for sponge production. If successful, the company proposes to have a plant of 5,000 tons per year capacity operating by 1985.

These capacity increases are the first to be announced since 1967. As a result of the single-market dependency and the high cost of the metal, the titanium industry has had marked overcapacity during some periods. In recent years, capacity utilization increased as the demand for titanium metal increased. In 1980, capacity utilization was approximately 98 percent.

When the SST was cancelled in 1971, the four largest titanium ingot producers, accounting for 90 percent of ingot production, reported losses in excess of \$20 million on a sales volume of \$75 million. Between June and December, 1971, the country's three sponge manufacturers employing 775 persons closed their plants, in response to a combination of the SST cancellation and very slow program development for both military and commercial aircraft. Demand would be served by inventory accumulations and by imported sponge from the USSR and Japan.

In response to the 1971 plant closings and the Department of Defense's concern for a continued domestic titanium supply, the Office of Emergency Planning authorized the General Services Administration to acquire 7,000 tons of titanium sponge over a two-year period. Most of this was actually acquired and subsequently released back to the producers (TIMET & RMI) under a "buy-back" contract provision. With this stimulus, domestic production resumed in 1972.

The actual price of titanium sponge metal declined from \$2.05 per pound in 1958 to \$1.32 per pound in 1964, where it stayed until May 1973. Thereafter, the price increased gradually, reaching \$3.98 per pound in 1979. Prices nearly doubled in 1980, reaching \$7.02 per pound. The Producer Price Index declined from the 1967 base-year level of 100 to 95.5 in 1972. After 1972, the PPI increased annually, reaching 215.1 in 1977, and 521.3 in March 1981. The rapidly rising costs in recent years are due to economic and technological problems posed by implementation of environmental and pollution control laws, and to increased demand.

Production Process

The mineral sources of titanium products are rutile (TiO_2) and ilmenite (FeTiO_3). Rutile, the present source for sponge metal, is far less common than ilmenite. Deposits on Australia's east coast provide the major mill rutile supply. Rutile is the preferred raw material for titanium metal because of its nearly 100 percent TiO_2 concentration.

Ilmenite, the world's most abundant titanium mineral source, can be treated to produce a TiO_2 concentration sufficiently high that the product serves as a rutile substitute. Because of concern for depleting Australian rutile reserves and for U.S. dependence on foreign rutile sources, interest periodically arises in possible major commitments to domestic production of rutile substitutes from abundant U.S. ilmenite reserves. There has been commercial U.S. production of substitute, or synthetic, rutile, but no sponge is currently made from rutile substitutes.

This report focuses on titanium in metal form, but such use represents less than two percent of total domestic titanium end use. For example, in 1976 demand was divided between 504,000 short tons of titanium content for nonmetal uses (most notably pigment and paper coatings), and 8,000 short tons of titanium content for metal uses. For the most part, these metal and nonmetal uses follow independent production routes from ore to end product.

In the production of titanium metal, concentrated titanium dioxide (TiO_2) is first chlorinated to produce titanium tetrachloride (TiCl_4). Purified TiCl_4 is reduced with magnesium (the classic and most commonly used Kroll process) or magnesium (the Hunter process) under an inert atmosphere using a batch process to produce titanium sponge metal, the initial product in the flow of metal production.

Titanium production is capital and energy intensive. Major raw material requirements for producing one pound of sponge metal are approximately 2.2 pounds of rutile, 3.5 pounds of chlorine, 1.25 pounds of magnesium (or 2.1 pounds of sodium), about 0.3 cubic feet of inert gas, and about 0.3 pounds of petroleum coke. If the magnesium chloride formed in the reduction reaction is recycled, then about 0.2 pounds of magnesium and one pound of chlorine are required. Recycling of sodium provides comparable savings. Energy requirements are about 200,000 Btu per pound of sponge.

Converting sponge to ingot requires an additional 21,000 to 26,000 Btu per pound of ingot. Sponge is compacted, usually with some scrap additions, and made into ingot by two or more successive vacuum-arc-melting operations. Equipment required through the ingot stage is unique to titanium. Titanium's strong affinity for oxygen requires careful and expensive handling throughout the production process.

Ingots are fabricated into billet, rod and bar, plate, sheet, strip, and tube in either integrated titanium mills or specialty steel mills. The material requires some special handling but nothing outside the capability of an experienced fabricator.

The above description covers the major present production flow. It is probable that any substantial U.S. capacity increases in sponge metal production will produce sponge electrolytically, using TiCl_4 as a feed material. The Dow-Howmet venture proposes electrowinning in an effort to reduce production costs. TIMET also has electrolytic development underway. Significant cost reductions from electrolytic reductions will depend on ongoing technological improvements.

Imports and Exports

Imports of titanium sponge metal have averaged 3,556 tons per year for the last 10 years, with a low of 1,476 tons in 1978 and a high of 6,963 in 1974. Imports in 1980 were 4,500 tons. During the 1970's, imports accounted for 18.7 percent of domestic consumption. In 1980, imports accounted for 16.7 percent of domestic consumption.

Japan is the major free-world U.S. supplier; additional sponge is purchased from the USSR (non-aircraft uses) and from China. The USSR withdrew much of its sponge

export stream in recent years, reportedly in order to build titanium-hulled submarines. This created pressure in world markets on sponge supply, especially for European consumption. The U.S. does not presently utilize titanium for submarines; should it undertake such a program, titanium demand would increase dramatically.

Exports of titanium sponge metal are almost nonexistent, totaling a mere 97 tons in 1978 and 180 tons in 1979. The U.S. does, however, export substantial amounts of titanium scrap metal. In the 1970's, exports of scrap metal have averaged 5,645 tons per year.

Stockpile

The Federal strategic minerals stockpile goal for titanium sponge metal was raised in 1980 from 131,503 tons to 195,000 tons. Stockpile purchases, however, have not yet been authorized. In 1980, there were approximately 32,000 tons of sponge in the stockpile.

With regard to the OTEC program, titanium manufacturers can be expected to be reluctant to expand capacity to produce for a market subject to governmental cutback. One possible scenario under discussion is for the Federal government to agree to purchase for the stockpile any titanium produced or planned specifically for OTEC, but not used due to cancellation or postponement of OTEC projects.

FABRICATED STRUCTURAL METALS INDUSTRY

The fabricated structural metals industry group (SIC 344) is composed of firms that cut, bend, weld, drill, and otherwise convert mill shapes, primarily steel, into a variety of products, including: structural metal for buildings, bridges and ships; metal doors and trim; heat exchangers, condensers, boilers, and tanks; pipes, roofing, siding, and other sheet metal products; architectural and ornamental metalwork; prefabricated metal buildings; and miscellaneous metal work, including concrete reinforcing bars. The total value of shipments for the industry for 1978 was \$25.93 billion. The individual industries within the structural metals industry group to be examined in this profile, with 1978 value of shipments in parentheses, are:

- Fabricated structural metal (\$5.34 billion)
- Fabricated plate work (\$7.27 billion)
- Miscellaneous metal work (\$1.46 billion)

The total value of shipments for these three segments, for 1978, was \$14.07 billion, representing 54 percent of the value of shipments for the entire industry group.

Fabricated structural metal (SIC 3441) includes columns, joists, and tresses, which are used to build frameworks for buildings and bridges. This industry also provides products to the shipbuilding industry, and would be a source of materials used in constructing an OTEC hull. Fabricated plate work (SIC 3443) includes heat exchangers, boilers, condensers, and metal tanks. This industry could be expected to fabricate the titanium heat exchangers, as well as the condensers, for OTEC. Miscellaneous metal work (SIC 3449) includes concrete reinforcing bars, which will be used if the OTEC hull is constructed of concrete.

Fabricated Structural Metal (SIC 3441)

The fabricated structural metal industry comprises establishments primarily engaged in the manufacture of fabricated iron or steel, or other metal, for structural purposes, such as bridges, buildings, and sections for ships, boats, and barges. This industry is

examined here because it may contribute to the construction of OTEC plants, especially those with steel hulls. Most establishments in this industry, not just those providing fabricated steel for ships, boats, and barges, could contribute to the construction of an OTEC facility.

Industry Structure

As of 1977, there were 2,319 firms classified as structural metal fabricators. These firms owned 2,462 establishments, and less than half (1,074) had 20 or more employees. Since 1967, the number of companies has increased 24 percent, and the number of establishments has increased 26 percent. The number of establishments with 20 or more employees, however, increased less than 4 percent since 1967, and actually decreased slightly since 1972. The small size characteristic of firms is associated with the fact that there is no national market for their output. Instead, there are many overlapping local markets, and firms usually sell within a 200 mile radius of their plants.

Employment in this industry was 101,500 in 1958, and 101,100 in 1978. There were, however, fluctuations during this period. From 1959 to 1963, employment was under 100,000 each year; with a low of 92,400 in 1959. From 1964 to 1975, employment was over 100,000 each year, with a high of 112,100 in 1967 and 1969. For 1976 and 1977, employment again dropped under 100,000, averaging 98,000 for the two year period.

The ratio of production workers to total employees has held fairly constant at 74 percent for the past 20 years. The fairly sizable number of nonproduction workers in this industry may be related to the fact that much of the output is made to order and involves, therefore, a large work force for design and detail engineering work, preliminary to actual fabrication work.

Firms in this industry are highly specialized, with approximately 96 percent of the companies engaging exclusively in the manufacture of fabricated structural steel. In 1963, the 4-firm concentration was 15 percent; the 8-firm concentration was 11 percent, and the 50-firm concentration was 26 percent. These ratios decreased to 13 percent, 18 percent, and 38 percent, respectively, in 1970. The concentration ratios have continued to decline as new firms have entered the industry.

Fabricated structural metal products are produced nationwide. The leading states in 1977, in terms of value of shipments, were Texas (\$514 million), Pennsylvania (\$500 million), and California (\$351 million). The areas with the least production were the Mountain states (\$154 million) and the New England states (\$229 million).

Industry Behavior

The value of shipments for the fabricated structural metal industry increased from \$1.60 billion in 1958 to \$5.34 billion in 1978. Estimated value of shipments for 1979 and 1980 are \$5.96 billion and \$6.80 billion, respectively. Much of this increase has been due to inflation and, in recent years, output has actually declined. Output was 3.98 million tons in 1959 and increased continuously until 1973, when it peaked at 7.04 million tons. Output has been depressed since 1973, averaging 5.93 million tons for the years 1974 to 1978.

Demand for fabricated structural metal products is directly affected by construction activity, which in turn is tied to cyclical fluctuations in the overall economy. About 80 percent of the industry's goods are purchased by construction businesses. The increase in industry output from 1958 to 1973 was directly related to the general economic expansion which characterized most of that period. The decrease in output from 1974 to 1978 was directly related to the 1974-75 recession when construction activity decreased considerably. Although output began increasing again in 1977, it has not yet reached the record level of 1973.

The capacity utilization in the structural metal industry has been low throughout the 1970's. The average from 1973 to 1978 was 68 percent, with a low of 60 percent in 1975 and a high of 72 percent in 1978. This excess capacity is the result of decreased demand which began with the 1974-75 recession.

Output per employee hour generally has followed the same pattern as industry output, increasing from 1958 to 1973, and then dropping sharply. Although industry output began picking up in 1977, employee output remained steady from 1975 to 1978. Employee productivity growth has been retarded by increased requirements for quality control, the made to order nature of goods produced in the industry, and by the lag in adjusting employment to changing output levels. Because of the high skill level of the

work force, some employers attempt to retain employees during business downturns. When demand drops they tend to make lower bids for work, or bid on smaller jobs than they normally handle. This enables them to continue operating and retain their employees, and to cover some overhead costs in paying for capital equipment. However, this results in employee productivity declines during cyclical downturns.

Except for the period from 1968 to 1972, the United States has been a net exporter of fabricated structural metal. Imports have increased steadily since the mid-sixties, rising from \$10.5 million in 1964 to an estimated \$127.0 million in 1980. Exports, on the other hand, remained fairly constant from 1964 through 1972. Thus, the U.S. went from a net exporter of \$22.1 million in 1964 to a net importer of \$20.0 in 1972. Exports increased sharply in 1973, to \$87.0 million, and have continued to increase, rising to an estimated \$189.0 million in 1980. Net exports for 1980 are estimated at \$62.0 million.

There is some industry concern over the rising trend of imports, even though the U.S. has been a net exporter in recent years. While imports are still relatively small in relation to total industry shipments, amounting to only about 2 percent, since the industry is made up of many small firms with local markets, any imports into these markets can be damaging to individual companies operating in an area. Due to the unfavorable value-to-weight ratio and to intense competition from foreign fabricators, export markets are limited.

Productivity growth in the fabricated structural metal industry probably will not resume until output picks up. Industrial construction, the major market for the industry, did not increase until mid-1978. Much of the construction activity since 1973 has involved rehabilitation of existing structures. This is relatively inexpensive but does not benefit the structural metals industry. Neither does the move by corporations toward rural and suburban areas. Because land in these areas is cheaper, many of the office buildings are low structures which use little or no structural metal.

Regardless of the anticipated recovery in nonresidential construction, there are good signs for the future of the fabricated structural metal industry. Oil companies are increasing their orders for metal to construct offshore drilling platforms. These orders call for delivery in the early 1980's. Estimates have been made that more than 100,000

bridges in this country are in need of replacement. Although replacement is not being funded now, it could be a good long-range market for the industry.

Productivity growth will probably remain lower than the all-manufacturing average. The industry is tied to individualized, custom work. This prevents long runs of similar products, and the economies which accompany them. Work must continue on a flow basis, benefiting and accommodating the contractor rather than the manufacturer. Further, stringent quality control and testing will continue to be necessary.

Fabricated Plate Work (SIC 3443)

The fabricated plate work industry is comprised of firms engaged in the manufacture of heat exchangers, condensers, boilers, metal tanks, and nuclear generating equipment. This industry is examined here because it may be responsible for fabricating the condensers and titanium heat exchangers for OTEC facilities. Total value of shipments for this industry in 1977 was \$7,432 million, of which \$900 million was accounted for by heat exchangers and condensers.

Industry Structure

In 1977, 1,683 companies, operating 1,864 establishments, were classified as plate work fabricators. About half of these establishments had 20 or more employees. There were 102 establishments primarily producing heat exchangers and steam condensers, not including those used in nuclear applications.

From 1963 to 1971, the number of companies in the plate work industry increased slightly, from 1,301 to 1,349. The number of establishments also grew slowly, increasing from 1,383 in 1963 to 1,486 in 1971. The number of establishments with 20 or more employees, however, rose substantially, increasing from 601 to 795 during this period. From 1971 to 1977, there was a sharp rise in the number of firms, establishments, and establishments with more than 20 employees. In 1977, there were 1,683 companies operating 1,864 establishments, 944 of which had 20 or more employees. From 1958 to 1977, the number of establishments producing heat exchangers more than doubled, increasing from 43 to 102.

The fabricated plate work industry is more highly concentrated than is the fabricated structural metal industry. The 4-firm concentration ratio is about 29 percent. The eight largest firms account for about 35 percent of shipments, the 20 largest account for 46 percent, and the 50 largest account for 58 percent. Those companies producing primarily heat exchangers and steam condensers are somewhat more concentrated. The four largest companies have a 31 percent share of the market, the eight largest a 46 percent share, the 20 largest a 72 percent share, and the 50 largest a 90 percent share.

Although fabricated plate work establishments are located in all areas of the country, five states account for nearly 44 percent of the total value of shipments. These states, with 1977 value of shipments in parentheses, are: Ohio (\$732.3 million), Pennsylvania (\$681.1 million), Texas (\$661.8 million), North Carolina (\$612.1 million), and California (\$551.1 million). Total value of shipments for 1977 was \$7,432.4 million.

Heat exchanger and steam condenser establishments, although located in most areas of the country, are more geographically concentrated than the fabricated plate work industry as a whole. The following four states, with 1977 value of shipments in parentheses, account for about 60 percent of total shipments: Oklahoma (\$185.2 million), New York (\$124.5 million), Pennsylvania (\$117.3 million), and Texas (\$117.2 million). Total value of shipments for 1977 was \$900.5 million.

The fabricated plate work industry is generally not integrated. Mill products are purchased from steel mill product manufacturers, fabricated to a finished product, and sold. The major markets for heat exchangers include oil refineries, chemical plants, and power plants.

It takes specialized skills and experience to enter the large heat exchanger industry. Experienced engineers are needed to design heat exchangers and shop expertise is needed to cut, drill, and fit the heat exchanger parts. One problem facing potential entrants is that users are hesitant to purchase fabricated products requiring detailed engineering and design work from companies that have not established a good reputation.

Industry Behavior

The value of shipments for the fabricated plate work industry tripled between 1967 and 1977, increasing from \$2.59 billion to \$7.43 billion. About half of this increase was due

to inflation and half due to increased production. During this same period, the value of shipments for heat exchangers and condensers also tripled, rising from \$345.5 million in 1967 to \$1.1 billion in 1976 before dropping to \$900.5 million in 1977.

There is currently unutilized capacity in the fabricated plate work industry. The 1978 Federal Reserve Board's estimate of capacity utilization for the industry was 82.1 percent. The FRB estimates that, over the last ten years, capacity utilization has averaged about 80 percent, with a low of 69 percent in 1975 and a high of 86.2 percent in 1968. Industry spokesmen for the heat exchanger industry estimate capacity utilization for that segment at 65 percent to 75 percent.

In 1977, employment in the fabricated plate work industry was 123,500. About half the establishments had less than 20 employees, with the average being 66 employees per establishment. Employment has increased at an average annual rate of 1.8 percent over the past 20 years. Producers of heat exchangers and condensers employed 13,200 in 1977. Average employment per establishment was 129, indicating that heat exchanger establishments are generally larger than in the fabricated plate work industry as a whole.

In recent years, a relatively large part of the domestic demand for heat exchangers has been met by imports. It is estimated that imports account for 25 percent of the U.S. market, with most imports coming from Japan and Italy. Domestic producers have been unable to effectively compete with the lower prices and more attractive financial terms offered by foreign producers. The combination of foreign competition and the depressed domestic market for large heat exchangers in the past five years has been responsible for approximately 25 small companies leaving the heat exchanger business.

Industry spokesmen estimate that about 20 percent of the domestic heat exchanger companies have the capabilities to produce the large units required for OTEC. Some of these companies would have to expand, adding space, equipment, and employees. While the industry foresees no particular problems in such an expansion, there is some doubt that the tube and forge industry could keep up with demand. Furthermore, although there are ample supplies of stainless steel at present, titanium is in short supply.

Miscellaneous Metal Work (SIC 3449)

The miscellaneous metal work industry (SIC 3449) includes suppliers of fabricated concrete reinforcing bars (SIC 34494). In 1977, total value of shipments of miscellaneous metal work was \$1,332.9 million, \$900.1 million of which was accounted for by concrete reinforcing bars. Suppliers classified under SIC 3449 were responsible for \$667.4 million in shipments, or 74 percent of the total shipments of concrete reinforcing bars. Suppliers classified in the fabricated structural metal industry (SIC 3441) were responsible for shipments valued at \$68.5 million and other industries shipped \$140.5 million worth of fabricated concrete reinforcing bars. Smaller amounts were produced by companies producing other fabricated metal products.

From 1972 to 1977, shipments of miscellaneous metal work averaged \$1,376 million, with a low of \$994.6 million in 1972 and a high of \$1,734 million in 1974. During this same period, shipments of concrete reinforcing bars averaged \$868 million, with a low of \$583.3 million in 1972 and a high of \$1,156.6 million in 1974. During this six year period, concrete reinforcing bars accounted for 63 percent of the total value of shipments of miscellaneous metal work.

In 1972, the miscellaneous metal work industry was composed of 336 companies operating 418 establishments, 220 of which had 20 or more employees. By 1977, the number of companies had decreased slightly to 308, while the number of establishments decreased to 412. The number of establishments with 20 or more employees showed a proportionately greater decrease, falling to 185.

The geographic concentration of fabricators of concrete reinforcing bars follows the same pattern as fabricators of structural metal. Some production takes place in all sections of the country, but six states account for 46 percent of all production. These states, with 1977 value of shipments in parentheses, are: Texas (\$121.5 million), Pennsylvania (\$66.1 million), California (\$60.2 million), Illinois (\$59.5 million), South Carolina (\$54.4 million), and Ohio (\$52.2 million). The areas with the lowest production are the New England States (\$3.1 million) and the Mountain States (\$9.1 million).

There were 16,300 employees in the miscellaneous metal work industry in 1977, a substantial decrease from the 19,500 employed in 1972. In 1977, there were 10,200 production workers, while in 1972 there were about 13,100 production workers. The percentage of production workers decreased from 67 percent in 1972 to 62 percent in 1977.

FIBER GLASS-REINFORCED PLASTIC (FRP) INDUSTRY

Specific qualities are required for the OTEC cold water pipe, which may be up to 3,000 feet in length and 100 feet in diameter, and will have to withstand the deteriorating effects of the constant wave movements and corrosive effects of the ocean. Several proposed configurations make use of fiber glass-reinforced plastic, which has the following special qualities:

- 1) Corrosion resistant,
- 2) Alkaline chemical and acid resistant,
- 3) Fire and heat resistant,
- 4) Lightweight (easy to assemble),
- 5) Displays high strength-to-weight ratios,
- 6) Possesses greater durability than metals,
- 7) Excellent electrical insulating capability,
- 8) Possesses low energy or Btu content,
- 9) Displays lower maintenance costs than metals (needs no painting or scraping; retains color indefinitely),
- 10) Easily molded in soft or liquid state,
- 11) Possesses great stability (holds shape and form under great mechanical stress), and
- 12) FRP will not soften when made with thermosetting resins as the chemical process is irreversible even under high temperatures.

The production of fiber glass-reinforced cold water pipes is affected by the availability of certain materials. The main components are: 1) glass sand together with sodium compounds and limestone to produce the glass fibers; 2) the fiber glass filaments used to strengthen the plastic pipes; and 3) petroleum and natural gas and the thermosetting resins, epoxies and polyesters, which coat the glass fibers to enable molding the shape of the plastic pipes. These materials, which are classified in the following categories by Standard Industrial Classification Codes (SICs) and product codes, will be discussed separately as stages of production for the fiber glass-reinforced plastic pipes. They are:

- Industrial sand — SIC 1446; Glass sand — product code 14461
- Pressed and blown glass, n.e.c. — SIC 3229; Glass fiber, textile type — product code 32293
- Plastics materials and resins — SIC 2821; Thermosetting resins and plastics materials — product code 28214
- Miscellaneous plastics products — SIC 3079; Construction plastics products — product code 30796.

Glass Sand (SIC 14461)

Introduction

Statistical data for silica sand or glass sand, a major component in the manufacture of fiber glass, are not readily available over time. However, the glass sand industry in 1980 represented about 43 percent of the industrial sand and gravel industry (SIC 1446) which, in turn, represented about three percent of the total sand and gravel industry (SIC 144). The remaining 97 percent accounted for the construction portion of the sand and gravel industry (SIC 1442). Therefore, where data for glass sand were not available, estimates were based on information for the industrial sand and gravel industry.

Industry Size and Concentration

In 1980, about 15 million short tons of glass sand were produced by an estimated 45 establishments. This represented about 25 percent of the 113 companies and 179 establishments reported by the Bureau of Mines for the 1979 industrial sand and gravel industry. An inspection of 1979 production figures by tonnage size of operation for industrial sand and gravel reveals that the 54 larger operations (or about 34 percent of the industry) each produced 200,000 or more tons of industrial sand per year and comprised 81 percent of the total tons mined that year. Assuming the same proportion for glass sand operations, one-third of the industry produced over 11.7 million short tons in 1979. Some of the establishments produce both industrial and construction sand and gravel.

Capacity

The sand and gravel mines produced at about 80 percent of capacity in 1974, while for 1980, the capacity utilization was about 63 percent. The Bureau of Mines estimated the 1980 capacity at 1.3 billion short tons. The capacity utilization rate may be increased by the use of portable or semi-portable plants, as well as with automation and computerization of equipment, and improvement in methodology of extracting and transporting the sand.

Output and Value of Shipments

Output increased from 12.3 million short tons in 1958 to 34.7 million short tons in 1980 for industrial sand and gravel. A corresponding increase in value of shipments was reported from \$44.7 million in 1958 to \$249.7 million in 1980 was reported. The estimated average output per employee in 1980 was 6,000 short tons of glass sand. The corresponding 1980 output for glass sand was estimated at 14.9 million short tons and \$126.2 million.

Demand and Supply

The demand for glass sand has been steadily increasing from 1968, from ten million short tons to about 15 million short tons in 1980, representing a 50 percent increase over time. Despite a severe drop in demand for the total sand and gravel industry in 1975, the demand for glass sand actually increased one million short tons that year to equal 11 short tons as compared with 10 for 1974. These producers mine a sufficient amount to meet demand without having a large excess.

Prices

Despite rising costs in the construction industry, the price of sand and gravel increased very slowly from 1958 to 1976. The price per ton in constant 1976 dollars, for this time period, showed a 3 percent increase. In 1977, the actual price per ton for all sand and gravel was \$2.07; the price for industrial sand was \$5.70 per ton; and the price for ground fiber glass amounted to \$8.47 per ton. In 1979, however, the price for construction sand and gravel was \$2.26 per ton; the price for industrial sand (specifically for unground fiber glass) was \$7.93 per ton; while the price for ground fiber glass was \$14.72 per ton. Industrial sand used as a filler also reflected higher prices per ton with \$31.42 per ton reported in 1979.

Resources

There is an abundant supply in the U.S. of natural resources of silica sand and gravel, which is usually found in quartz. However, the sand used to make fiber glass must have certain qualities: a high degree of silica, a very low content of iron oxide and/or chromium compounds (as these affect the quality and appearance of the glass) and a high degree of fine particles to be used in the glass furnaces.

The availability of glass sand may be threatened by increasingly stringent government environmental controls which tend to result in higher operation costs. The costs of complying with the requirements regarding noise control, air and water pollution, and reclamation may force present producers to close their operations, while prospective producers may be discouraged from entering the industry.

Because of the bulk and weight of the glass sand, consumers or glass manufacturers are usually located near the sand mines. However, the miners may order special limestone, soda ash, or other components from mines in other states. Major producers and consumers of industrial glass and sand are located in Michigan, Illinois, New Jersey, California, Texas and Oklahoma.

Capital Expenditures

Capital expenditures for the glass sand industry were given for the early census years, but estimates were made for 1972 and 1977 based on the relationship to industrial sand and gravel, resulting in \$6.5 million and \$13.8 million, respectively. New operations would be expected to experience high capital costs in order to compete with existing producers, especially if they used the latest innovations in equipment, such as automation, computerization and transportation including conveyor mechanisms. (At present, much of the sand and gravel is moved by truck, but for long distances rail and barge may be used.) Also, new operations might take two to four years to reach full production levels.

Employment And Wages

Employment data obtained from the Census of Mineral Industries for census years for the industrial sand and gravel industry indicate an increasing trend from 1958 with

2,884 employees to 4,700 employees for 1977, about a 63 percent increase. The average annual wage per employee increased from about \$4,500 per year in 1958 to almost \$13,500 per year in 1977. For the glass sand industry, employment was reported as 1,628 and 1,700 for 1958 and 1967, respectively. Average annual wages for these years were \$4,600 and almost \$6,650, respectively.

Imports And Exports

Imports for the total sand and gravel industry remained steady at one million short tons annually from 1968-1977, while exports amounted to two or three million short tons per year through 1976, but equalled four million short tons in 1977. Domestic glass sand producers supply practically 100 percent of the domestic market.

Outlook

Although glass sand production shows an increasing trend and is in abundant supply, producers are faced with several problems which may curtail production and, therefore, severely impact the OTEC fiber glass-reinforced plastic cold water pipe program. Problems relating to government environmental control regarding excessive noise, wastewater discharge, washing down truck loads of sand and gravel to prevent additional air pollution from dust particles, as well as concerns over reclamation of mine sites (especially open pit mines) are causing mine owners to experience much higher operation costs. Decisions such as building fences around an unsightly mine area, or creating a park over a previous mine site, could discourage potential mine owners as well as cause active producers to close their mines when their operations become uneconomical. In addition, mine owners may have increased costs because of more frequent repair or replacement of equipment due to excessive wear from constant use created by the huge increase in demand for glass sand for the OTEC project.

Despite these problems, according to representatives of the industrial sand and gravel industry, the increased demand for silica sand will not be a hardship for producers. For each cold water pipe of 100 feet inside diameter, 3000 feet long, and 4 inches thick, they estimate approximately 100,000 tons of silica sand is needed. Since the industrial sand and gravel industry produced 32 million short tons of silica sand by 140 establishments in 1980 (for the foundries as well as for the glass industries), an additional demand of approximately 5 million tons for 50 cold water pipes over a 10 year period would present no difficulty to the industry.

Glass Fiber, Textile Type (Fiber Glass) (SIC 32293)

Textile type continuous glass fibers are used to reinforce the thermosetting resins which coat the glass fibers and form the cold water pipe in this configuration. Census data are available for some categories from 1958 through 1977 for census years on a product classification basis. Where data were not available, estimates or adjustments were made on an establishment basis by using statistics for Pressed and Blown Glass (SIC 3229) which included about 25 percent of textile type glass fiber (value of shipments) data in 1977. In addition, annual physical units and corresponding dollar values on a product basis were obtained from Current Industrial Reports for 1964 through 1978, and were adjusted to an establishment basis.

Industry Size and Concentration

In 1977, only 8 companies with 15 of the 382 establishments reported by Census for Pressed and Blown Glass, comprised the fiber glass industry (SIC 32293) which produced 856.8 million pounds of fiber glass, amounting to \$528.7 million. This is a highly concentrated industry, with the establishments producing the major portion of the output located in the following states, in descending order of approximate value of shipments: North Carolina, South Carolina, Ohio, Tennessee, Pennsylvania, Rhode Island, California, Kentucky and New York. Since the last census, a new and extremely large plant was established in Texas.

Capacity

Conversations with industry representatives revealed that large plants were not operating at full capacity, which was estimated at 200 million pounds of fiber glass per year for each plant. Most plants are operating between a 75 and 81 percent capacity.

Output and Value of Shipments

The manufacture of textile type fiber glass more than doubled from 1958 to 1979. In 1958, output amounted to 113 million pounds (valued at \$59.7 million) and in 1967 to 291

million pounds (valued at \$129.7 million). However, in 1979, 986 million pounds of textile type fiber glass were produced (valued at about \$640 million), which indicates that output more than tripled from 1967 to 1979.

Demand and Supply

Despite weaknesses displayed by fiber glass, demand is continually increasing for fiber glass products. Different techniques are being applied to make it more desirable, including adding various combinations of chemical compounds to the molten state to impart more favorable qualities. Although most of the properties of fiber glass-reinforced plastic are true of fiber glass, the fiber glass by itself cannot withstand the deteriorating effects of strong acids and alkalines. In addition, the glass filaments lose their unusual strength-to-weight quality when exposed to temperatures over 600^o Fahrenheit. (An example of this superior strength would be that a 1.5 inch diameter fiber glass rope will hold an object weighing 110 tons.) Output has increased dramatically from 1972 with a reported 560 million pounds of fiber glass, valued at over \$250 million to an estimated 985 million pounds at about \$640 million in 1979. This represented a 76 percent increase in production for 1972-1979.

Prices

From 1963 through 1975, the price per pound of textile type fiber glass remained fairly stable, fluctuating slightly over time from 47.5 cents per pound in 1963 to 49.3 cents per pound in 1974. After 1974, prices rose to 66.8 cents per pound for 1978, indicating a 35 percent increase from 1974 to 1978.

Manufacturing Process

Basically, continuous glass fibers are produced in either of two processes, the direct melt process or the marble melt process. In the first method, the batch mixture is heated at extremely high temperatures in a special furnace. This furnace may measure 28-30 feet wide, 150 feet long, and 4 feet high and may produce about 200 tons of glass per day. The molten glass thus formed is drawn through the many small holes punched out of a platinum plate positioned at the bottom of the furnace. As the molten glass crystallizes, fine hair-like glass filaments are formed and drawn through each of the holes and wound together on spools (forming packages) at the rate of 12,000 feet per minute, with each spool holding about 80 miles of continuous fiber filaments.

In the second process, the marble melt method, the molten glass is formed into 1-inch glass marbles by marble forming rolls. These marbles can be checked more easily for defects and bubbles at this stage and can be stored for later use, at which time they are remelted to form molten glass. Each marble, when melted, can be drawn into 97 miles of continuous fiber glass filament yarn. The same procedure as in the first method is continued from this point.

The continuous filament or continuous strand roving may be sprayed with a sizing, or lubricant, to coat each filament so that the fibers will not scrape against each other and break. Several strands of these filaments may be wound together, either straight or twisted, on the forming packages to result in different desired tensile strengths. These spools may be stored for future use or shipped to various manufacturers to be used in the manufacture of reinforced tires, auto bodies, boats, structural parts of aircraft, flame-proof fabrics, fiber glass panels used in construction for partitions or patio roofing, as well as for tanks and pipes.

Resources

Molten fiber glass is produced by mixing the carefully measured batch ingredients consisting of silica sand or glass sand (usually obtained from quartz-type rock), limestone, soda ash, salt cakes, and cullet (glass scrap). These ingredients are heated in a glass furnace at very high temperatures of 2,750° to 2,850° Fahrenheit. Most of these raw materials are in abundant supply in their natural state in the U.S.

To achieve specific desired properties in the glass fiber, different chemical or mineral compounds are added in different proportions to the basic raw materials. Some of these special properties are: resistance to the effects of heat, water, acids and chemicals, in addition to having a high strength-to-weight ratio, which is greater for fiber glass than for most metals including steel.

Capital Expenditures

The textile fiber glass industry is a capital-intensive industry with most of the various stages of production being controlled by expensive computers; e.g., one such computer for the filament winding process could cost from \$80,000 to \$130,000. Over the years,

capital investments have shown a definite increase, with \$7.6 million reported for 1963 and almost ten times that amount (\$75.1 million) reported for 1977.

Employment and Wages

The number of employees in the fiber glass industry increased about 88 percent from 1963 to 1977, from 5,118 to 9,600, respectively. The 1977 figure of 9,600 employees comprises about 21 percent of the total employment reported for the Pressed and Blown Glass industry (SIC 3229) which increased only 22 percent for the years 1963 to 1977 (from 37,999 to 46,200 employees).

The average annual wage per employee for Pressed and Blown Glass more than doubled from 1963 to 1977 (from \$5,455 in 1963 to \$12,398 in 1977). The fiber glass industry showed a very similar increase, from \$5,246 to \$12,188 for this same period.

Imports and Exports

Imports for fiber glass fluctuated from year-to-year, ranging from approximately 9 million pounds in 1975 to 22.5 million pounds in 1977, the peak year. In 1979 imports dropped over 50 percent to 10.4 million pounds. Exports in 1974 amounted to over 35 million pounds of fibrous glass, followed by a drastic decrease in 1975, of almost 17.5 million pounds. Although the annual poundage exported from 1976 through 1978 remained fairly stable at around 29 million pounds, the 1979 figure rose sharply to over 47 million pounds, representing about a 62 percent increase.

Outlook

Despite a drop in demand in early 1980 (from the construction industry) followed by a drop in output by some of the smaller fiber glass establishments, the larger fiber glass manufacturers (who experienced an increasing trend in production) appear very optimistic about the future of fiber glass. Especially since they are developing a higher capability of substituting fiber glass for other elements, thereby enlarging the market. Another important fact is that most of the required materials for producing fiber glass are relatively inexpensive and available. Meanwhile, production capacities are being

expanded in the larger firms in this highly concentrated industry through new technologies utilizing highly automated machinery and improved techniques to produce more output in less time.

As with the glass sand industry, the fiber glass industry will require higher costs for repairing machinery and equipment when processing much larger amounts of materials for OTEC than what ordinary wear and tear would require. One example would be that melting glass at high temperatures is very corrosive to glass furnace linings; thus, more frequent periodic repairs should probably be expected. However, industry representatives are reassured by the expansion of production capacities and indicate that a projected increase in demand for fiber glass (to be used in the fiber glass-reinforced plastic cold water pipes for OTEC power plants) would be warmly received and would be met easily and successfully.

Thermosetting Resins and Plastics Materials (SIC 28214)

Analyses for the Plastic Materials and Resins industry (SIC 2821), which encompasses the Thermosetting Resins and Plastics Materials industry (SIC 28214), can be made only by using data from 1972 through 1980, when available. Because of an SIC change made in 1972 by the Bureau of the Census, data are not comparable prior to 1972. About 2/3 of the 979 establishments for the overall plastics industry (SIC 2821) were reclassified as part of the Miscellaneous Plastics Products industry (SIC 3079) which is discussed in the next major section.

The thermosetting resins, which are used in a liquid state to coat the fiberglass filaments or other reinforcement materials, are comprised of the following types of resins: epoxies, polyesters, phenolics, silicones, urethanes, melamines and diallyl phthalate. The plastic pipe manufacturers must select the proper resin or combination of resins, as well as the specific process, to provide the special properties required for the end-use products. The special properties displayed by these resins that enhance the properties of the fiberglass are resistance to: chemicals and acids, weather conditions, electricity, and shrinkage. In addition, thermoset resins possess a unique feature, which is the stable or irreversible nature of the cured or hardened plastic. This plastic cannot

be softened or reformed after the desired temperature is reached. This property, which is not characteristic of thermoplastic resins, is a very important property for OTEC use.

Industry Size and Concentration

In 1977, the Thermosetting Resins and Plastics Materials industry (SIC 28214) was comprised of 119 establishments with output valued at \$1,487.1 million. This amount represented 13.7 percent of the \$10,818.0 million reported for the encompassing Plastics Materials and Resins industry (SIC 2821).

The Bureau of the Census data show that 397 establishments were operated in 1977 by 221 companies for SIC 2821, and that at least one-third of these establishments employed 100 or more employees. Although no company concentration data are available for 1977, some information does exist for 1972 which shows that ten percent of the 191 companies with 323 establishments accounted for about 65 percent of the value of shipments.

The 119 thermosetting resins and plastic materials establishments in 1977 were located throughout the U.S., with approximately one-third of them situated along or near the East Coast.

Capacity

The 1978 annual average capacity utilization rate for chemical materials was 87.1 percent, which showed a decided increase since the low rate of 72.9 percent in 1975. The operating capacity rate fluctuated from 1972 through 1978, peaking in 1973 at 94.2 percent.

With the continuing increase in demand, resin producers are expanding their capacity by either building new plants, or by modernizing or enlarging existing plants. It takes three to four years, however, to build new plants. Not all of this expansion will occur in the United States, as some major oil companies are building subsidiary petrochemical and plastics plants in foreign countries, e.g., Saudi Arabia, where they are signing agreements to have access to petroleum and natural gas which are both plentiful and cheaper than in the U.S.

Output and Value of Shipments

No output data in physical units are available from the Bureau of the Census for Plastics Materials and Resins (SIC 2821) nor for Thermosetting Resins and Plastics Materials (SIC 28214). However, the Bureau of Industrial Economics (BIE) has derived output on a product basis for the plastics materials and resins industry, ranging from 25.9 billion pounds in 1972 to 38.5 billion pounds in 1980, indicating an increase of 48.6 percent.

The value of industry shipments data in 1972 constant dollars (supplied by BIE) show a 22.9 percent increase for SIC 2821 from 1972 at \$4,478.2 million to 1978 at \$5,503.4 million. While, in current dollars, the value of shipments for the thermosetting resin industry almost doubled from \$788.2 million in 1972 to \$1,487.1 million in 1977, which represented 14 percent of the value of shipments in 1977 for the encompassing plastics materials industry.

Demand and Supply

Although demand for plastics materials and resins fell in 1975 and early 1980, the overall trend from 1972 through 1980 is definitely on the incline, as indicated by the value of shipments data. High interest rates and high taxes have contributed to a drop in sales early in 1980 for this industry by discouraging potential buyers from purchasing such end-use products as boats, cars, and large household appliances. By the end of 1980, total demand indicated some recovery as new markets are becoming available for plastics, which are not only lighter in weight than most other materials, but also cheaper, easier to work with, and more efficient in energy consumption.

For the last few years, resins suppliers (especially the smaller companies) have expressed some concern about availability of their major raw materials: petroleum and natural gas. Supplies are somewhat tight, but these producers are depending on technological improvements in equipment and processing, as well as the creation of new markets, to help them overcome raw material shortage problems.

Prices

The producer price index shows slight fluctuations (about 2 percent) for thermosetting resins for the years 1975 through 1978, with December 1975 as a base. However, as

petroleum prices rose, resin prices followed the same pattern, showing an 18.2 percent increase in 1979 and a 39 percent increase in 1980.

From 1975 to 1978, resin prices remained fairly stable, but thereafter they started to rise. Epoxies appear to command a higher price per pound of resin than the other types of thermosetting resins, amounting to \$0.81, \$0.93, and \$1.07 per pound for 1979, 1980, and 1981, respectively. Prices for the other types of thermosetting resins range from \$0.37 to \$0.60 in 1979, \$0.47 to \$0.67 in 1980, and \$0.51 to \$0.74 in 1981.

Capital Expenditures

Investment data for SIC 28214 are available from the Bureau of the Census for only two years, 1972 and 1977; these expenditures amount to \$27.5 million and \$53.7 million, respectively. Based on the annual investment experience shown for SIC 2821, the trend for the thermosetting resins industry should continue to rise, unless feedstocks are withheld due to petroleum or natural gas shortages.

Employment and Wages

The total employment for 1972 for SIC 28214 was 9,500 employees receiving \$103.1 million in wages. For 1977, employment was 9,800 with a corresponding total wage figure of \$153.7 million. Based on the performance of the encompassing 4-digit SIC industry, SIC 2821, whose employment showed an increasing trend through 1979 after the drop in 1975, an assumption can be made that employment for the thermosetting resin industry (which for 1972 and 1977 constituted about 17 percent of SIC 2821) will also continue to increase.

Imports and Exports

From the Bureau of the Census, import and export data are readily available on an SIC basis for Plastics Materials and Resins (SIC 2821) from 1972 through 1979, but data for Thermosetting Resins and Plastics Materials (SIC 28214) are only available for imports for 1978 and 1979. The thermosetting resins industry imported 47.1 million pounds of materials (valued at \$35.4 million) in 1978 and 48.6 million pounds (valued at \$39.3 million) in 1979. These figures represented about 14 percent of the plastics materials industry which has displayed an increasing trend from 1972 through 1979 (except for a

significant drop of 56 percent from 345 million pounds in 1974) ranging from 151 million pounds to 354 million pounds, respectively.

Although export data are not available on an SIC basis for SIC 28214, comparable export data are available for the plastics materials and resins industry from 1972-1979. Exports ranged from 1,880 million pounds (valued at \$455.1 million) in 1972 to 4,673 million pounds (valued at \$2,183.3 million) in 1979. However, a dramatic drop of 70 percent occurred in 1975. Thereafter, exports resumed their incline. It should be noted that exports far exceeded imports for this industry.

Outlook

Despite concern over the threatened shortages of petroleum and natural gas, the general outlook for plastics (according to representatives of the larger companies) is good due to increasing demand, improved technology and increasing capacity in the near future. Some of the industries who comprise part of the increased demand for resins and who are affected by resin shortages are: major appliances, automobiles, electronics, furniture, paints, and toys. Through continued research, with experimentation and advanced techniques in the use of resins, plastics are replacing many products, in part or whole, that are made of glass, metal, paper or wood.

Since resins have become so important to our economy and are used in many industries, the possibility of shortages occurring in the supplies of petroleum and natural gas should not be overlooked. According to one company official, the industry probably had sufficient resins (which are produced from chemical compounds or hydrocarbons obtained from petroleum and natural gas) to last for two years, but one huge order for resins for OTEC cold water pipes would exhaust these resin supplies. Although heating and energy uses for petroleum and natural gas probably have greater priority than resin production, an important point in favor of resins is that less energy is required in the production of resins than for most other materials. In addition, when plastics are substituted for other heavier materials in transportation vehicles, fuel consumption is decreased; thus, greater energy conservation is achieved.

Construction Plastics Products (SIC 30796)

Reinforced plastics products are included in the Miscellaneous Plastics Products industry (SIC 3079), which is often referred to as being comprised of "custom-processing" plants. These establishments often produce special-order items according to precise specifications; however, separate data for these establishments are often not available. For the Miscellaneous Plastics Products industry (SIC 3079), data from 1972 through 1980 are not fully comparable to the information available prior to 1972 due to an SIC change made by the Bureau of the Census. This change represented an increase of 8 percent to this industry in 1972, which resulted in the addition of 612 establishments with shipments amounting to \$1,115.5 million and with 25,900 employees who were reclassified and transferred from the Plastics Materials and Resins industry (SIC 2821), discussed in the previous section.

Since data are not always available for the Construction Plastics Products industry (SIC 30796), which is a component of SIC 3079, estimates for the missing information, when needed, are based on data for SIC 3079. Included as a component of SIC 30796 is the plastic pipes and fittings industry group, which in 1977 represented about 46 percent of the values of product shipments for construction plastics.

Industry Size and Concentration

Only 574 establishments with almost \$2,800 million in shipments were reported for the Construction Plastics Products industry (SIC 30796) in 1977. This represented 11.7 percent of the \$24 billion in value of shipments reported for the 10,212 establishments for Miscellaneous Plastics Products (SIC 3079).

Industry concentration data are not available in 1977 for SIC 30796; however, in 1972 the concentration ratio was high. On a product basis, the 50 largest companies for SIC 30796 accounted for 65 percent of the product shipments value of \$1.1 billion. The 4 largest companies for this industry represented 23 percent. For Miscellaneous Plastics Products in 1977, 1,123 establishments employing 100 or more employees represented 11 percent of the establishments for this industry and accounted for almost 41 percent of the total output.

Geographically, the construction plastics products establishments are fairly evenly distributed over the U.S., with slightly more than half of them located in the central division of the country.

Capacity

The rubber and plastics products industry shows an erratic capacity utilization rate from 1967 to 1978, with the highest peak of 98.6 percent occurring in 1968 and a second peak of 98.1 percent in 1972. Following the lowest point of 72.8 percent in the 1975 recession, the industry operated at an increasing utilization rate of 88.9 percent for 1978.

Output and Value of Shipments

Although no physical units of output are available for SIC 30796, Construction Plastics Products, value of shipments data are available from the Bureau of the Census. On an establishment basis, shipments for 1972 amounted to \$1,094.9, while for 1977, the dollar value amounted to \$2,761.7. These figures represent 10.2 percent and 11.7 percent, respectively, of the 4-digit SIC industry, Miscellaneous Plastics Products. On a product basis, however, historical data for the construction plastics products industry indicate an upward trend in shipments for each year, with the exception of 1975. This incline from 1972 through 1978 is further indicated by the value of shipments shown in constant 1972 dollars for SIC 3079 (supplied by the Bureau of Industrial Economics), showing a 48.9 percent increase from 1972 with \$10.7 billion, to 1978, with \$15.9 billion.

Demand and Supply

Except for a drop in demand because of the 1975 recession, and again in 1980 because of the slump in demand for construction and marine products, there is an increasing demand for plastic products as evidenced by the increasing values of shipments for 1972 through 1980. Because of their corrosion-resistant and acid resistant properties, plastic pipes have a longer "life" period and are in greater demand. Until now, producers have been able to meet the demand, but they are somewhat concerned about increased costs and possible shortages of petroleum and natural gas, whose curtailment could seriously affect future supply.

Prices

The producer price index for SIC 30796 increased from 100.0 in December 1975, used as the base, to 127.3 in 1980. Different types of plastics are used in the building and construction industry for pipes, fittings and conduits. Among the higher priced plastics are epoxies and thermoplastic (PBT) reinforced plastics for which prices of 76¢/lb. and 98¢/lb., respectively, were reported in 1977; while \$1.07 and \$1.28/lb. were reported for these plastics in 1980. Most of the lower priced plastics used in making pipes ranged from 27¢ to 39¢/lb. in 1977; while for 1980, these plastics were priced at 30¢ to 63¢/lb.

Manufacturing Process

Microprocessing computers are being used in many phases of production of plastics products. With the aid of such computers, the manufacturers of fiber glass-reinforced plastic pipes unwind the forming packages or spools of continuous fiber glass filaments (discussed earlier in Section B on fiber glass) and move the filaments through a vat of liquid thermosetting resins to bathe and coat the fiber glass on its way to the mold. The coated filament is then wound in a very complex pattern (often controlled by computer) onto a mandrel, which is a spindle or rod. This mandrel is a mold around which the resin coated filaments are wrapped in precise varying patterns and directions to provide maximum strength. After the determined number of layers of filament are wound, and after the mold is cured, usually at high temperatures, or dried and hardened, the mandrel is removed, leaving a hollow core cylinder. For ease of extraction, some mandrels are lubricated before the winding process and some mandrels are made in a collapsible form. Since the size of a pipe depends on the length and diameter dimensions of the mandrel, mandrels are often custom made to satisfy a special order.

Capital Expenditures

Despite the drop in investments in 1975 for the overall plastics products industry, amounts expended for capital investments steadily increased from 1972-1977. Assuming that the construction plastics products industry followed the same pattern, capital expenditures increased from \$76.2 million in 1972 to \$106.3 million in 1977. Investments are expected to increase through the 1980s as more effort in research and

experimentation is being expended to find more ways to replace metals and other materials with plastics.

Employment and Wages

The Construction Plastics Products industry for 1972 employed 28,400 people (whose wages equalled \$224.6 million). This constituted slightly over 8 percent of the 346,900 employees reported for SIC 3079. Even though the 1975 recession caused a drop in employment, by 1977 the number of employees for SIC 30796 increased to 39,200 workers who earned \$433.7 million, and who were included in the 453,700 employees reported for SIC 3079. It is interesting to note that, as reported by the Bureau of Industrial Economics, the Miscellaneous Plastics Products industry (SIC 3079) ranked first in employment for 1977 in a study of the 15 largest 4-digit (SIC) industries, and seventh according to value of shipments.

Imports and Exports

No import data were reported for Construction Plastics Products (SIC 30796) by the Bureau of the Census for 1972 through 1979. As for exports, no physical units were reported for this period, because of the miscellaneous character of the products, but dollar values of exports for this industry were available from 1972 through 1977. In current dollars, exports in 1972 amounted to \$8.9 million and increased dramatically to \$63.1 million in 1975, followed thereafter by a significant drop in 1976. Exports recovered slightly to \$43.1 million in 1977. However, because of the expanding capacity occurring through the building of resins and plastics establishments in some foreign countries (encouraged by the increasing tight supply of petroleum and natural gas), as well as through expansion of some establishments in the U.S., exports are expected to decrease when the new plants reach their full production level.

Outlook

Although processors in the resins and plastics industries showed concern early in 1980 over threatened shortages and increased costs of resins, current indications project an increasing trend in sales for the next few years. From the suppliers of the basic raw materials to the manufacturers of the finished fiber glass-reinforced plastic products, every effort is made to keep materials moving steadily and to assure sufficient output to meet the increasing demand.

Several methods which are being used to combat supply shortages are: 1) stockpiling, 2) resin stretching, 3) increasing capacity, and 4) continued research and improvement in manufacturing processes and techniques. Stockpiling occurs when processors sign contracts with their suppliers to purchase large enough quantities at controlled prices to ensure having sufficient materials on hand so production won't be cut back. "Resin stretching" involves mixing fillers, such as hollow glass spheres, sand, ground glass, or crushed shells, into the liquid resins to increase volume by extending the amount of resin mixture, but actually decreasing the amount of pure resin used per item. This technique results in a savings when low cost fillers replace part of the resins and may also yield a stronger product. To increase capacity, large oil companies are in the process of constructing new resins and plastics plants (which may take 3 to 4 years to build), often in foreign countries where petroleum and natural gas will be more accessible. In the U.S., additional capacity is being achieved by many companies through modernization or renovation of existing plants. Continued research is being undertaken to improve existing techniques and manufacturing processes and to find possible material substitutes, such as synthetics or compounding resins, or in using cheaper or imperfect quality resins for part of the high-grade resins.

Creating new markets is a method being used to combat a shortage in demand. Through further research, new ways of substituting plastics for metals, wood, glass, etc. are being found in order to increase and promote a high demand, as well as to conserve energy, since plastics consume less energy in the manufacturing process than most other materials.

Because of the concerted effort by these industries to ensure continued production and demand, industry representatives have a brighter outlook for the resins and plastics industries (especially the pipe and conduit industries) which are recovering from the 1980 slump and which are expected to have an increasing growth rate through the next few years. Finally, due to better availability of material supplies, and to the many advantages in the required characteristics and properties of the OTEC cold water pipe configuration, the choice of using fiber glass-reinforced plastic pipes seems to merit a high rank.

CABLE INDUSTRY

Two types of high voltage electrical transmission cables are required for OTEC: riser cables, which will extend from the OTEC plant to the ocean floor; and long distance power cables, which will connect the riser cable to on-shore facilities. None of the normal means of transmitting high voltage power is immediately applicable to OTEC.

The existing power wire and cable industry (SIC 33578) is considered a subindustry of the nonferrous wiredrawing and insulating industry (SIC 3357). The total value of shipments for establishments classified in the nonferrous wiredrawing and insulating industry amounted to \$6,595 million in 1977, an increase of 50 percent from 1972. The change reflected a general trend in the shipments of most of the products of the industry. Value added by manufacture, at \$2,118 million in 1977, was 46 percent above value added in 1972. In 1977, the industry had 66,300 employees, a decrease of 4 percent from 1972. The leading States in employment were New York, Indiana, Rhode Island, and Massachusetts, accounting for approximately 35 percent of the industry's 1977 employment.

In 1977, the power wire and cable industry consisted of about 30 establishments employing 7,600 people. The 1977 value of shipments was \$673.4 million. The number of establishments and employees decreased from the 1972 levels of 34 establishments and 8,300 employees. Due to inflation, however, the value of shipments increased over the 1972 level of \$463.6 million.

Riser cable suitable for OTEC has not yet been developed. Simplex Wire and Cable Company is currently engaged in research and development of riser cables. Recently awarded a \$1.5 million contract by the Department of Energy, Simplex has received a total of \$4 million since 1977 for R&D of a high voltage OTEC undersea power transmission cable.

In late fiscal year 1978 and early fiscal year 1979, Simplex and the Pirelli Company completed feasibility studies on submarine electric power transmission cables for OTEC commercial plants. The feasibility study results indicate that practically all aspects of electric cable transmission for the commercial 100 to 400 MW_e plant sizes considered

are beyond current state-of-the-art and knowledge. The studies did, however, divide the knowledge areas into riser cables, which will be subject to motions, fatigue, and connections, and the bottom cable, which will be rather static, but which will introduce cable laying problems and long-term environmental concerns. Both riser and bottom cables will require more development of manufacturing concepts.

For the pilot plant application, the conclusion was reached that presently available submarine cables would work for the bottom cable, but that the riser cable may be a technically critical item because of its being subject to an unprecedented combination of electrical and mechanical loads which are outside the long-term experience base of the undersea power cable industry. To resolve this problem, a riser cable conceptual design study is being performed by Simplex to design a riser cable which is within the state-of-the-art, but which will include mechanical armor and a strength member. Five concepts will be explored initially, then one will be chosen as a baseline for design and fabrication of test sections which can be tested on land.

In fiscal year 1979, Simplex began a survey of suitable facilities for testing full scale cable sections, and a survey of suitable manufacturing facilities for potential commercial manufacture of the five concept designs. In addition, Simplex completed a preliminary static load analysis for a riser cable and has developed criteria of testing techniques for measuring fatigue, electro-mechanical response, insulation and sheathing. Giannotti and Associates has assisted in developing the analytical methodology for calculating fatigue factors and stresses resulting from platform motions, currents, and vortex shedding.

Existing cable plants would not have the capabilities required to produce the very long lengths of OTEC power cables. It has been estimated that a dedicated plant for production of such cables would cost about \$22 million (1976 dollars).

ASSESSMENT OF U.S. SHIPYARDS FOR OTEC CONSTRUCTION

Overview

The U.S. shipbuilding industry is being affected by the current economic recession, and there are no shipyards working at full capacity. In fact, the small number of firm contracts for U.S. flag ships have forced many U.S. shipyards to seek other construction projects to help keep employment at a minimal level. For example, the Bethlehem shipyard at Sparrows Point has begun building offshore oil platforms for use in the Gulf of Mexico to help relieve backlogs for these platforms at the Bethlehem-Beaumont facility. In this way Bethlehem can increase their capabilities in an industry that is flourishing while maintaining the shipyard at Sparrows Point.

The repair function at most U.S. yards does not seem to be affected adversely by the shipbuilding recession, and the conversion of older hulls for different purposes appears to be a very cost effective approach and is generally flourishing.

In making the five year projection of U.S. shipyard availability to build OTEC facilities, no problem arising from Naval priority projects or U.S. merchant marine backlogs could be ascertained. All shipyards reviewed would have graving docks, personnel, and support shops available for OTEC construction. In short, the availability of yards does not appear to be a limiting factor.

When assessing the capabilities of each shipyard for OTEC construction, the field of possible qualified yards begins to narrow. The two scenarios for deployment of 25 and 50 OTEC facilities have been used in the brief assessment of each candidate yard which follows.

Clearly, the qualified shipyards must not only have OTEC construction capabilities but must be favorably located, i.e., reasonably close to the intended OTEC operating sites. For example, OTEC plants built on the Atlantic and Gulf Coast cannot be expected to be deployed in the Pacific Ocean. A Panama Canal transit in either direction for an OTEC plant is clearly impractical. A matrix of shipyards used in OTEC construction and the operational location for these OTEC facilities has been derived for both the 25 plant and 50 plant scenario (Figures 3 and 4). From these matrices, projections emerge.

The following data is drawn from a study prepared for ORI in January 1980, entitled "Assessment of OTEC Construction in U.S. Shipyards." For the 25 commercial OTEC scenario, only shipyards mentioned in that study were considered. For the 50 OTEC plant scenario, other yards were sited due to the Atlantic Ocean and Gulf Coast clustering of sites. It was deemed improbable that the shipyards mentioned in the ORI study could reasonably handle the construction of 44 OTEC plants. There are 28 major U.S. shipyards mentioned in the ORI study that have building or graving dock facilities in excess of 475 feet in length. These yards and their geographical location are shown in Figure 1, located at the end of this section.

Of these yards, Fraser Shipyard, Bay S.B., American S.B.-Lorian and American S.B.-Toledo are located on the Great Lakes. Access to the Atlantic Ocean from these yards is limited by the St. Lawrence Seaway locks which have beam capacity of 75 feet. Therefore, these yards were eliminated from further consideration as suitable for OTEC construction.

Two shipyards, Seatrain S.B. and Sun Shipbuilding, are no longer in operation. Therefore, for the 25 OTEC commercialization scenario, they were not considered.

Also eliminated from further consideration were the following 12 yards: Bath Iron Works, Maryland S.B. and D.D., Norfolk S.B. and Dry Dock (D.D.), Alabama S.B. and D.D., Levington (Orange), Levington (Gulfport), Bethlehem-Beaumont, Galveston S.B., Marathon Le Tourneau, Todd-Los Angeles, FMC Corp., and Todd-Seattle. These yards were eliminated from further consideration because of a variety of factors, including lack of suitable access channel to deep water, lack of engineering and skilled labor force, and lack of complex construction experience and/or financial capabilities to undertake a project of this size.

From the "first cut" analysis, 10 shipyards emerge from the initial 28 candidates as yards suitable for OTEC construction under the 25 plant scenario. They are:

- General Dynamics-Quincy
- Bethlehem-Sparrows Point
- Newport News S.B.
- Tampa Ship Repair
- Ingalls-Litton

- Avondale
- National Steel and S.B.
- Bethlehem - San Francisco
- Triple A
- Lockheed S.B.

A detailed analysis of the capabilities of these shipyards is included at the end of this section. Each analysis includes type of facility, dock dimensions, crane lift capacity, nearest flotation site, a diagram of the shipyard, and a graph showing employment and construction projections.

Conclusions Derived From Shipyard Matrix

1. Any shipyard that would become involved in the construction of 400MW_e OTEC plants would accrue up-front capital cost for the purpose of either enlarging graving dock facilities or dredging or construction of new shop facilities. Therefore, a shipyard would only consider OTEC construction if there was a strong possibility that more than one OTEC plant would be manufactured at that yard. Construction of an OTEC facility with a 400 MW_e capacity would take approximately 3 years, and the lead time for final engineering would be approximately 2 years for the first plant at any yard. Therefore, 1984 would appear to be the earliest that any shipyard could begin construction. We therefore assessed that no U.S. shipyard could be responsible for the construction of more than 6 OTEC plants by year 2000. Newport News Shipbuilding was a possible exception in the 50 scenario case due to its large physical capacity.

2. General Dynamics - Quincy was not considered a likely candidate for OTEC construction because the access to the Atlantic Ocean is limited by a bridge with a width of 175 feet. In the case of the 25 OTEC scenario, other shipyards appear to be more practical for construction. However, in the 50 scenario case expansion of the old bridge may be warranted, thus allowing the Quincy yard to construct OTEC plants.

3. All yards on the Pacific coast seem equally qualified to construct OTEC plants. NASCO has an over-sill depth of 16 feet which may cause problems if dredging were not environmentally permitted. However, the choice between NASCO, Triple A, and Bethlehem Shipbuilding - San Francisco was arbitrary. Lockheed has been actively pursuing OTEC related opportunities and was therefore allotted the largest number of OTEC facilities to construct.
4. Hawaii does not have any shipbuilding capability for constructing OTEC vessels and we could not foresee new facilities being constructed for only 5 or 6 plants.

FIGURE 1

SHIPBUILDING INDUSTRY IN THE UNITED STATES

FIGURE 2

SHIPYARD SCENARIO LEGEND

QUINCY	GENERAL DYNAMICS, QUINCY MASS.
S.S.	SUN SHIPBUILDING, CHESTER, PA.
BS-SP	BETHLEHEM SHIPBUILDING, SPARROWS POINT, MD.
NNS	NEWPORT NEWS, VA.
TAMPA	TAMPA SHIP REPAIR & DRY DOCK
OPS	OFFSHORE POWER SYSTEMS, JACKSONVILLE, FLA.
INGALLS	INGALLS LITTON, MISS.
AVONDALE	AVONDALE SHIPBUILDING, NEW ORLEANS, LA.
BS-B	BETHLEHEM BEAUMONT, TX.
NASCO	NATIONAL STEEL AND SHIPBUILDING SAN DIEGO, CALIF.
TRIPLE A	TRIPLE A SAN FRANCISCO
BS-SF	BETHLEHEM SHIPBUILDING, SAN FRANCISCO
LOCKHEED	LOCKHEED SEATTLE, WASH.

FIGURE 3

MATRIX OF
SHIPYARDS UTILIZED IN CONSTRUCTION OF OTEC FACILITIES
25 OTEC PLANT FACILITIES BY YEAR 2000

	OTEC'S ATLANTIC		Quincy	BS-SP	NNS	GULF COAST				PACIFIC OTEC SITES	NASCO	Triple A	BS-SF	Lock
	TOTAL	OTEC SITES				OTEC SITES	Tampa	Ingalls	Avondale					
<u>ISLAND</u>														
ELECTRIC	4	2		2						2				2
ALUMINA	2	1			1					1				1
AMMONIA	2									2	1		1	
<u>COASTAL</u>														
ELECTRIC	11					11	3	4	4					
<u>MID-OCEAN</u>														
AMMONIA	6	6		3	3									

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FIGURE 4

MATRIX OF
SHIPYARDS UTILIZED IN CONSTRUCTION OF OTEC FACILITIES
50 OTEC PLANT FACILITIES BY YEAR 2000

SITES APPLICATION	TOTAL OTEC SITES	ATLANTIC OTEC SITES	QUINCY	BS-SP	S.S.	NNS	GULF COAST SITES	TAMPA	OPS	INGALLS	AVONDALE	BS-B	PACIFIC OTEC SITES	NASCO	TRIPLE A	BS-SP	LOCK
ISLAND																	
ELECTRIC	7	4			3	1							3				3
ALUMINA	4	3				3							1				1
AMMONIA	5	3	1	2									2	1		1	
COASTAL																	
ELECTRIC	22						22	3	5	5	5	4					
MID-OCEAN																	
AMMONIA	12	12	3	3	3	3											

FIGURE 5a

FACILITY CAPABILITIES FOR SHIPYARDS

Name: General Dynamics Corporation
 Quincy Shipbuilding Division
 97 East Howard Street
 Quincy, Mass. 02169

1. Type of facility - graving docks
2. Dock dimensions - 5 qualifying docks

<u>Dock Size</u>	<u>Maximum Ship Size LOA-Beam</u>	<u>Depth Over Sill</u>
1 - 950' x 150'	936' x 143'	28'
2 - 867' x 132'	860' x 123'	28'
2 - 874' x 150'	860' x 144'	22'

3. Crane Lift Capacity
 - 1 - 1200 ton gantry - services (drydocks)
basins #6 and #7
 - 1 - 150 ton gantry - slips #11 and #12
4. Nearest flotation site - 80.5 km (50 mi.)
Cape Cod Bay - 20 fathoms of water
5. 175' wide bridge limits access to yard
6. Diagram of General Dynamics, Quincy Ship-
building Division,

FIGURE 5b

GENERAL DYNAMICS
QUINCY SHIPBUILDING DIVISION

FIGURE 5c

GENERAL DYNAMICS, QUINCY
NUMBER OF YARDS - 1

UNEMPLOYED LABORERS - 200000

SOURCE: SHIPYARD DATA FROM FORM NA812 WHEN PROVIDED
OFFICE OF SHIP CONSTRUCTION, MARITIME ADMINISTRATION

FIGURE 6a

FACILITY CAPABILITIES FOR SHIPYARDS

Name: Bethlehem Steel Corp.
Sparrows Point Yard
Sparrows Point, Md. 21219

1. Type of facility - graving dock
2. Dock dimensions - 1 qualifying

<u>Dock Size</u>	<u>Maximum Ship Size LOA-Beam</u>	<u>Depth Over Sill</u>
1200' x 201'	1200' x 192'	29'

3. Crane Lift Capacity
2 - 100 ton rail cranes
75 x 50 ton tower cranes
4. Nearest flotation site - 290 km (180 mi)
through Chesapeake Bay to 20 fathom curve
72.4 km (45 mi) due east of Cape Henry.
5. Diagram of Bethlehem Steel Corp., Sparrows
Point,

FIGURE 6b

BETHLEHEM STEEL CORPORATION

SPARROWS POINT YARD

FIGURE 6c

SHIPBUILDING INDUSTRY WORKLOAD PROJECTION

DETHLEHEN STEEL CORP., S.P.

NUMBER OF YARDS - 1

BSS

100
HUNDREDS OF PRODUCTION WORKERS

SOURCE: SHIPYARD DATA FROM FORM NA32 WHEN PROVIDED
OFFICE OF SHIP CONSTRUCTION, MARITIME ADMINISTRATION

FIGURE 7a

FACILITY CAPABILITIES FOR SHIPYARDS

Name: Newport News Shipbuilding and Dry Dock Co.
4101 Washington Avenue
Newport News, Va. 23607

1. Type of facility - graving docks
2. Dock dimensions - 3 qualifying docks

<u>Dock Size</u>	<u>Maximum Ship Size LOA-Beam</u>	<u>Depth Over Sill</u>
960' x 128'	960' x 124'	35'
1100' x 140'	1100' x 136'	40'
1600' x 250'	1600' x 246'	32'

3. Crane List Capacity

1 - 900 ton gantry - services 1600 ft. dock
1 - 310 ton gantry - services the 960 ft. and
1100 ft. docks

140 ton mobile cranes
65 ton locomotive and floating cranes

4. Nearest flotation site - 20 fathom curve 121 km
(75 mi) from the shipyard or 72.4 km (45 miles)
due east of Cape Henry.
5. Diagram of Newport News,

NEWPORT NEWS

**PIERS 7, 8, 9, AND DRYDOCKS
SERVED BY 25 TON
LOCOMOTIVE CRANES
W/MAX. BOOM 110'**

[illegible]

FIGURE 7c
 NEUPORT NEWS SHIPBLDG.
 NUMBER OF YARDS - 1

SOURCE: SHIPYARD DATA FROM FORM NA332 WHEN PROVIDED
 OFFICE OF SHIP CONSTRUCTION, MARITIME ADMINISTRATION

FIGURE 8a

FACILITY CAPABILITIES FOR SHIPYARDS

Name: Tampa Ship Repair & Drydock Co., Inc.
P.O. Box 1277
Hooker's Point
Tampa, Florida 33601

1. Type of facility - graving dock
2. Dock dimensions - 1 qualifying dock

<u>Dock Size</u>	<u>Maximum Ship Size LOA-Beam</u>	<u>Depth Over Sill</u>
900' x 150'	896' x 146'	26'

3. Crane Lift Capacity
175 ton gantries
4. Nearest flotation site - 56.3 km (35 mi) to
20 fathom curve in the Gulf of Mexico.
5. Diagram of Tampa Ship Repair and Drydock Co.,

FIGURE 8b

TAMPA SHIP REPAIR AND DRY DOCK CO.
TAMPA, FLORIDA

FIGURE 8c.

TAMPA SHIP REPAIR

NUMBER OF YARDS - 1

TAM

MANUFACTURING PRODUCTION WORKERS

OCTOBER 1, 1979

SOURCE: SHIPYARD DATA FROM FORM NA812 WHEN PROVIDED
OFFICE OF SHIP CONSTRUCTION, MARITIME ADMINISTRATION

FIGURE 9a

FACILITY CAPABILITIES FOR SHIPYARDS

Name: Ingalls Shipbuilding Division Litton Industries
P.O. Box 149
Pascagoula, Miss. 39567

1. Type of facility - Level building positions
2. Dock dimensions - launch from 5 qualifying positions

<u>Dock Size</u>	<u>Launch Maximum Ship Size LOA-Beam</u>	<u>Depth Over Sill</u>
640' x 177'	800' x 173' (1)	41'

3. Crane Lift Capacity
6 - 200 ton
- 25 to 75 tons
4. Nearest flotation site - 64.4 km (40 mi) to 20 fathom curve south of Pascagoula Harbor entrance.
5. Diagram of Ingalls Shipbuilding,

(1) Used for launching ships.

FIGURE 9b

INGALLS SHIPBUILDING DIVISION OF LITTON SYSTEMS, INC.

16-Mirley Cranes
Serve East & South Wharves,
Integration Area and Bays

WEST RANK
PACIFIC RIVER

FIGURE 9c

SOURCE: SHIPYARD DATA FROM FORM NA832 WHEN PROVIDED
OFFICE OF SHIP CONSTRUCTION, MARITIME ADMINISTRATION

FIGURE 10a

FACILITY CAPABILITIES FOR SHIPYARDS

Name: Avondale Shipyards, Inc.
P.O. Box 50280
New Orleans, La. 70130

1. Type of facility - floating dock for launching and ship ways
2. Dock dimensions - 2 qualifying units

<u>Shipway Size</u>	<u>Maximum Ship Size LOA-Beam</u>	<u>Depth Over Sill</u>
FD 900' x 260'	1000' x 216'	37'. (used for launching)
SW 1050' x 174'	1020' x 174'	(Launching on FD)
SW 1165' x 130'	1200' x 126'	(Side launching)

3. Crane Lift Capacity
600 ton barge crane
200 ton fixed
4. Nearest flotation site - 214 km (133 mi) through Mississippi River to 20 fathom curve in Gulf of Mexico
5. Diagram of Avondale Shipyard,

FIGURE 10b

AVONDALE SHIPYARD

FIGURE 10c

SOURCE: SHIPYARD DATA FROM FORM MAR12 WHEN PROVIDED
OFFICE OF SHIP CONSTRUCTION, MARITIME ADMINISTRATION

FIGURE 11a

FACILITY CAPABILITIES FOR SHIPYARDS

Name: National Steel and Shipbuilding Co.
28th Street and Harbor Drive
San Diego, Calif. 92138

1. Type of facility - building dock
2. Dock dimensions - 1 qualifying dock

<u>Dock Size</u>	<u>Maximum Ship Size LOA-Beam</u>	<u>Depth Over Sill</u>
1000' x 176'	980' x 170'	16'

3. Crane Lift Capacity
 - 175 ton gantry
 - 60 ton
4. Nearest flotation site - 72.4 km (45 mi) to Isthmus Cove, Santa Catalina Island, Calif.
5. Diagram of National Steel & Shipbuilding,

FIGURE 11b
NATIONAL STEEL AND
SHIPBUILDING CO.

FIGURE 11c

NATIONAL STEEL - SHIPBLDO

NUMBER OF YARDS - 1

SOURCE: SHIPYARD DATA FROM FORM NA832 WHEN PROVIDED
OFFICE OF SHIP CONSTRUCTION, MARITIME ADMINISTRATION

FIGURE 12a

FACILITY CAPABILITIES FOR SHIPYARDS

Name: Triple "A" Machine Shop, Inc.
P.O. Box 24460, Hunters Point
San Francisco, Calif. 94124

1. Type of facility - graving dock
2. Dock dimensions - 1 qualifying dock

<u>Dock Size</u>	<u>Maximum Ship Size LOA-Beam</u>	<u>Depth Over Sill</u>
1092' x 143'	1088' x 136'	47'

3. Crane Lift Capacity
 - 1 - 300 ton fixed crane
 - 49 ton
 - 35 ton
4. Nearest flotation site - 611.5 km (380 mi) to Isthmus Cove, Santa Catalina Island, Calif.
5. Diagram of Triple "A" Machine Shop,

FIGURE 12b

TRIPLE "A" MACHINE SHOP, INC.

HUNTERS POINT

FIGURE 13a

FACILITY CAPABILITIES FOR SHIPYARDS

Name: Bethlehem Steel Corp.
San Francisco Yard
P.O. Box 7963
San Francisco, Calif. 94120

1. Type of facility - floating dry dock
2. Dock dimensions - 1 qualifying dock

<u>Dock Size</u>	<u>Maximum Ship Size LOA-Beam</u>	<u>Depth Over Sill</u>
900' x 148'	950' x 144'	37.6'

3. Crane Lift Capacity
- 60 ton
4. Nearest flotation site - 611 km (380 mi) to
Isthmus Cove, Santa Catalina Island, Calif.
5. Diagram of Bethlehem Steel Yard, San Francisco

FIGURE 13b

BETHLEHEM STEEL CORP. SAN FRANCISCO YARD

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FIGURE 14a

FACILITY CAPABILITIES FOR SHIPYARDS

Name: Lockheed S.B. and Construction Co.
2929 16th Avenue, S.W.
Seattle, Washington 98134

1. Type of facility - 3 floating docks
3 shipways
2. Dock dimensions - Shipways non-qualifying
unless enlarged.

Shipway Size	Maximum Ship Size	Depth
<u>Shipway Size</u>	<u>LOA-Beam</u>	<u>Over Sill</u>
1 - 700' x 100'	690' x 90'	30
2 - 650' x 90'	600' x 95'	30

3. Crane Lift Capacity
Whirleys up to 50 tons.
4. Nearest Flotation site - About 35 fathoms just
outside yard and about 100 fathoms about
12 miles from yard.
5. Diagram of Lockheed, Yards 1 and 2

FIGURE 14b

LOCKHEED
2929 16TH AVENUE, S.W.
PLANT 1

FIGURE 14c

LOCKHEED
2330 S.W. FLORIDA ST.
PLANT 2

CONSTRUCTION PRODUCTION WORKERS

FIGURE 14d
 LOCKHEED SHIPBLDG.
 NUMBER OF YARDS = 1

JULY 1, 1979

SOURCE: SHIPYARD DATA FROM FORM MAR32 WHEN PROVIDED
 OFFICE OF SHIP CONSTRUCTION, MARITIME ADMINISTRATION

OFFSHORE SUPPORT INDUSTRY

Background

Approximately 50 years ago the oil industry began drilling operations in the shallow water of the Gulf of Mexico. As the offshore oil and gas industry developed platform construction techniques and increased their knowledge of platform station keeping, they moved further offshore in their search for petroleum, entering more remote areas of the world, such as the North Sea. Today, this industry is drilling in ocean depths exceeding 1000 feet, from platforms that are as tall as the Empire State Building.

Very shortly after the oil companies moved some of their operations offshore, another industry developed to assist them in deployment of platforms and in resupply for platform functions. Today, this offshore support industry is a flourishing business operating primarily out of Louisiana and Texas, in close proximity to the Gulf of Mexico oil and gas field which they serve. According to a spokesperson for the New Orleans Offshore Marine Service Association, there are approximately 3,000 support vessels, including supply and support ships, tugs, crane and derrick barges, and launches, with over 30,000 persons employed either onboard ship or in an onshore capacity.

General Discussion

The offshore support industry, in establishing crew requirements for any vessel, uses the baseline Coast Guard requirements for that vessel and then applies a two man per billet ratio. In other words, for every Coast Guard required position sited on board a vessel, two people, each working a 12 hour shift are required. This two man per billet ratio constitutes a single crew. The distance from the offshore support vessel deployment and the length of on-site support time required is used to determine whether a vessel will need a single crew or an additional rotational crew. This rotational crew will be on land and rotated with the ship's operational crew if the time on-site is greater than one month. These crews would alternate at two week intervals. If a second rotational crew is necessary for the particular offshore support function, then the Coast Guard baseline requirements must be multiplied by four to arrive at the exact manpower requirement.

Vessels in the offshore support fleet are classified in the following manner; the first gross classification designates the vessel as self-propelled or non self-propelled, and as

a tug or a barge. Once this is established, the vessel is further classified according to gross tonnage for tugs and tonnage of cargo carried or tonnage of cargo lift capability for derrick barges. Implied in the gross tonnage classification of tugs is the size of vessel that the tug can assist.

The following charts, derived from the September 1979, Department of Commerce, Maritime Administration study entitled "Workforce Supply and Demand Study for the Offshore Oil and Gas Exploration Support Craft Industry, 1979-1988," estimates the number of offshore oil and gas support vessels which are self-propelled for each of the following gross tonnage classifications:

<u>Tonnage Classification</u>	<u>Number of Vessels</u>
Under 100 gt	1,853
100-199 gt	783
200-999 gt	210
1,000 gt and over	5
TOTAL	<u>2,851</u>

Baseline Coast Guard manning requirements are shown in Table A (tables are at end of profile). As can be seen from this table, not only the numerical requirements of personnel increases with each progressively larger tug class, but also the grade of license increases indicating that more skill is required for the manning of larger tugs. It must be remembered that the offshore support industry uses a two man per billet system which would double these figures and, for a lengthy tour, a double crew would be necessary, quadrupling the figures (as reflected in Table B). A double crew requirement in most OTEC deployment activities is projected due to the length of time required in offshore deployment of the OTEC plant.

The 1979 MarAd study showed that industry growth averaged 3.39% per year. Table C reflects the baseline growth in Coast Guard required billets and Table D shows the industry personnel growth using the two man per billet offshore industry requirement. The report warned that, in key categories of skilled personnel, serious shortages were already being experienced and would continue to increase over the next decade if Coast Guard regulations were not relaxed and if industry training and retention incentives

were not implemented. For example, 1979 personnel shortages in the Master and Mate job classification were estimated at 51%, and other skilled trades such as engine officers and oilers were estimated at 54%.

This shortage of key personnel was cited by the report as being caused by the Coast Guard examinations. It was felt that they covered too broad an area of expertise, requiring in-depth knowledge of vessels not slated to be under the command of the applicant. Further, the at-sea length of service time was cited as being too long to make career advancement in this industry appear attractive. Therefore, bright qualified people were leaving the field in order to advance faster. The report also stated that career paths were not clearly defined to provide a person entering the field with sound job direction. (Table E reflects shortage projections).

As a result of the MarAd report and the efforts by the offshore support industry, in 1980 Congress passed P.L. 96-378, entitled "Small Vessel Inspection and Manning Act." This law was designed to ease the present and projected shortage of small vessel personnel in the following ways:

- The amount of sea service time was decreased to allow for a faster promotion schedule,
- The Coast Guard was directed to outline definite career paths with exam requirements and sea service time clearly stated, and
- The Coast Guard licensing exams were to be restructured.

A spokesperson for the New Orleans Marine Service Association stated that P.L. 96-378 has already had an affect on the industry. There is optimism that shortages of personnel will be eliminated over the next few years even with substantial support industry growth. However, the offshore support functions necessary for OTEC deployment and servicing will differ from those the oil and gas industry demands and will change the demogrpahics of this industry in some ways. At the end of this section, after a review of the specific OTEC requirement affects on the offshore support industry, projected demographic changes will be outlined. This document is intended to provide a tool for industry growth planning.

Before addressing the more specific uses of the offshore industry as it would apply to OTEC, two additional pieces of background information are required:

- The offshore industry sells its services on a day/rate basis. Included in this rate is the distance that the vessel will travel and the length of time on-site. If the round trip travel and on-site time is greater than one month, then rotational crew and vessel resupport costs must be factored into the final rental fee.
- OTEC deployment, especially the CWP deployment, requires low wind and wave conditions. Therefore, a weather factor of 20-25% downtime must be applied when determining length of rental time.

OTEC Deployment

Available data is not sufficient to provide an accurate forecast of the number of offshore personnel necessary for OTEC vessel deployment and CWP attachment operations. However, it is safe to make some general statements and assumptions.

First, because of the size of a 400 MW OTEC facility, the largest offshore support vessels, the 1,000 ton tug and derrick barge with a lifting capacity of 600 tons, would be employed during the towing of the OTEC facility from the shipyard to its operating site and during the CWP placement operation. Currently, there are five such 1,000 ton tugs in the U.S. offshore fleet, all operating out of the Gulf of Mexico. Whether new tugs of this size would be necessary cannot be determined at this time. Also, qualified personnel with unlimited licenses may not be available in sufficient numbers in view of current industry shortages.

Second, smaller support craft would also be utilized in the deployment operation. Submergence vehicles and divers would be necessary for the CWP attachment and final OTEC fitting operation. Helicopters would be required to perform resupply and transport functions during the entire operation.

Third, although the offshore support industry, servicing the East Coast, Caribbean and Gulf Coast market, is well established, it may have problems servicing OTEC plants under the 50 plant scenario. The OTEC Commercialization Scenario for 25 OTEC

plants postulates that 20 of the 25 operating OTECs would be located in Atlantic and Gulf Coast waters, while in the 50 OTEC scenario, 44 OTECs would be in operation in this area. The deployment of 20 OTEC plants in this area would tax the existing large support craft availability and increase the demand for qualified personnel. However, with careful scheduling and no rise in other offshore operations, it could be workable. In the case of the 50 OTEC scenario with 44 OTECs being deployed, the offshore support industry would not be able to handle this workload based on the projected growth rate. The increased demand for highly qualified personnel would cause the existing shortage to increase irrespective of measures taken under P.L. 96-378.

When an offshore industry spokesperson was questioned concerning this shortage issue and the possibility of deployment of a large number of OTEC vessels, he agreed that present growth projections would not be sufficient. Nevertheless, he believes that the leadtime associated with the construction of 44 OTEC facilities would be sufficient to allow the industry to plan for the additional demands.

The offshore support industry servicing the West Coast is centered in the Santa Barbara area and maintains only small to medium sized support vessels. It would, therefore, have no impact on the OTEC industry in this area. On the other hand, the large Pacific Ocean basin offshore support industry, located in Singapore, would have a potential impact. The Singapore facilities represent U.S. owned companies as well as foreign entities and thus could partially utilize U.S. workers for their manpower requirements. U.S. workers would perform most of the licensed high skilled jobs, but qualified foreign labor would be used whenever possible for all jobs. This is due to the high relocation costs for U.S. workers, to the higher wage scale enjoyed by these workers, and to the nationalistic sentiments to utilize indigenous workers. While the profits from these overseas operations filter back to the U.S. through the U.S. corporations, an increase in these foreign operations would not directly affect the U.S. workforce projections. In the 25 and 50 OTEC Commercialization Scenarios, only five and six OTEC plants, respectively, would be deployed in the Pacific off Hawaii. This level of deployment activity is not seen as being of sufficient size to warrant establishment of a U.S. based deployment center in the Pacific Basin, except in Hawaii.

Fourth, in the case of the OTEC plants producing electricity cabled to shore, a definite problem arises. To date, the U.S. Naval Sea Lift Command is the only group allowed by

law to lay electrical cable offshore in U.S. waters. This requirement would have to be relaxed if the construction of a significant number of OTEC plants producing electricity cabled to shore were a foreseeable reality.

OTEC Crew Rotation and Resupply

The OTEC crew rotation and resupply function would be an ongoing process starting from the beginning of OTEC deployment operation and continuing throughout the operational life of the OTEC vessel. Smaller support crafts and helicopters would perform these functions. It is projected that these functions would be performed from land bases close to the operating OTEC plant. A light support craft center is already well established for the Gulf Coast, and new centers of light support would develop in Puerto Rico and Hawaii. It is probable that the related personnel would relocate their families to these new centers of job opportunity, thus stimulating the land based economies of the associated areas.

TABLE A

COAST GUARD MANNING REQUIREMENTS

	<u>Under 100 GT.</u>	<u>1000 GT. to 199 GT.</u>	<u>200 GT. to 999 GT.</u>	<u>1000 GT. and over</u>
<u>Deck Officers</u>				
Operators	2	-	-	-
Limited Licenses	-	3	3	-
Unlimited Lic.	-	-	-	4
<u>Engine Officers</u>				
Limited License	-	-	1	-
Unlimited Lic.	-	-	-	4
<u>Deck - Unlimited</u>				
Able Seaman	-	2	2	6
Ord. Seaman	-	1	1	3
Deckhands	2	-	-	-
<u>Engine - Unlicensed</u>				
Oilers	-	1	1	3
Firemen/Watertenders	-	-	-	3
Totals*	4	7	8	23

*As can be seen from this chart, not only are the numerical requirements different in the Coast Guard required manning, but also the grade of license required for the larger tugs is different.

TABLE B
INDUSTRY MANNING REQUIREMENTS

	Under 100 GT.			100 GT. to 199 GT.			200 GT. to 999 GT.			1000 GT. and over		
	C ¹	S ²	D ³	C ¹	S ²	D ³	C ¹	S ²	D ³	C ¹	S ²	D ³
<u>Deck Officers</u>												
Operators	2	4	8	-	-	-	-	-	-	-	-	-
Limited Licenses	-	-	-	3	6	12	3	6	12	-	-	-
Unlimited Lic.	-	-	-	-	-	-	-	-	-	4	8	16
<u>Engine Officers</u>												
Limited Licenses	-	-	-	-	-	-	1	2	4	-	-	-
Unlimited Lic.	-	-	-	-	-	-	-	-	-	4	8	16
<u>Deck - Unlimited</u>												
Able Seaman	-	-	-	2	4	8	2	4	8	6	12	24
Ordinary S.	-	-	-	1	2	4	1	2	4	3	6	12
Deckhands	2	4	8	-	-	-	-	-	-	-	-	-
<u>Engine - Unlicensed</u>												
Oilers	-	-	-	1	2	4	1	2	4	3	6	12
Firemen/Watertenders	-	-	-	-	-	-	-	-	-	3	6	12

¹ Coast Guard Requirements.

² 2 man per billet - Single Crew

³ Double Crew.

Table C

Estimated Total Billet Requirements For the M&O Fleet

(Assuming a constant 3.39 percent proportionate fleet growth rate and a single crew requirement)

Forecast Year	Operators	DECK DEPARTMENT					ENGINE DEPARTMENT				
		Limited ^{1/} Licenses	Unlimited Licenses	Deck Hands	Ordinary Seamen	Able Seamen	Limited Licenses	Unlimited Licenses	Oilers	Firemen Watertenders	Total
1979	3,706	2,979	20	3,706	1,008	2,016	210	20	1,008	15	14,688
1980	3,832	3,080	20	3,832	1,042	2,084	217	20	1,042	15	15,184
1981	3,962	3,184	20	3,962	1,078	2,155	224	20	1,078	15	15,698
1982	4,096	3,292	20	4,096	1,114	2,228	232	20	1,114	15	16,227
1983	4,235	3,404	20	4,235	1,152	2,304	240	20	1,152	15	16,777
1984	4,378	3,519	20	4,378	1,191	2,382	248	20	1,191	15	17,342
1985	4,527	3,639	20	4,527	1,231	2,462	257	20	1,231	15	17,919
1986	4,680	3,762	20	4,680	1,273	2,546	265	20	1,273	15	18,534
1987	4,839	3,890	20	4,839	1,316	2,632	274	20	1,316	15	19,161
1988	5,003	4,021	20	5,003	1,361	2,721	283	20	1,361	15	19,808

^{1/} Limited either as to tonnage or as to route.

Table D

Estimated Total Manpower Requirements For the M&O Fleet

(Assuming a constant 3.39 percent proportionate fleet growth rate, a 2.0 men-per-billet ratio and a single crew requirement)

DECK DEPARTMENTENGINE DEPARTMENT

<u>Forecast Year</u>	<u>Operators</u>	<u>Limited Licenses</u>	<u>Unlimited Licenses</u>	<u>Deck Hands</u>	<u>Ordinary Seamen</u>	<u>Able Seamen</u>	<u>Limited Licenses</u>	<u>Unlimited Licenses</u>	<u>Oilers</u>	<u>Firemen Watertenders</u>	<u>Total</u>
1979	7412	5958	40	7412	2016	4032	420	40	2016	30	29,376
1980	7664	6160	40	7664	2084	4168	434	40	2084	30	30,368
1981	7924	6368	40	7924	2156	4310	448	40	2156	30	31,396
1982	8192	6584	40	8192	2228	4456	464	40	2228	30	32,454
1983	8470	6808	40	8470	2304	4608	480	40	2304	30	33,554
1984	8756	7038	40	8756	2382	4764	496	40	2382	30	34,684
1985	9054	7278	40	9054	2462	4924	514	40	2462	30	35,838
1986	9360	7524	40	9360	2546	5092	530	40	2546	30	37,068
1987	9678	7780	40	9678	2632	5264	548	40	2632	30	38,322
1988	10006	8042	40	10006	2722	5442	566	40	2722	30	39,616

Table E

SUPPLY AND DEMAND
Table 1

ESTIMATED SUPPLY AND DEMAND INTERACTION-DECK DEPARTMENT

ASSUMES INDUSTRY'S GROWTH, ATTRITION AND UPGRADE RATES AND U.S. COAST GUARD'S RULES, REGULATIONS AND PROCEDURES WILL REMAIN UNCHANGED

	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
<u>Limited Licensed Mates and Masters</u>										
DEMAND ^{1/}	5,958	6,160	6,368	6,584	6,808	7,038	7,278	7,524	7,780	8,042
SUPPLY										
Previous Year Workforce ^{2/}	2,919	3,236	3,549	3,858	4,165	4,471	4,776	5,080	5,385	5,692
New Entrants Per Year ^{3/}	553	572	591	611	632	653	675	698	722	747
Yearly Attrition ^{4/}	236	259	282	304	326	348	371	393	415	438
Total Supply ^{5/}	3,236	3,549	3,858	4,165	4,471	4,776	5,080	5,385	5,692	6,001
Shortage in Men ^{6/}	-2,722	-2,611	-2,510	-2,419	-2,337	-2,262	-2,198	-2,139	-2,088	-2,041
Shortage as a Percentage of Demand ^{7/}	-45.69%	-42.39%	-39.42%	-36.74%	-34.33%	-32.14%	-30.20%	-28.43%	-26.84%	-25.38%
	*	*	*	*	*	*	*	*	*	*
<u>Operators</u>										
DEMAND ^{1/}	7,412	7,664	7,924	8,192	8,470	8,756	9,054	9,360	9,678	10,006
SUPPLY										
Previous Year Workforce ^{2/}	5,337	5,293	5,265	5,291	5,248	5,257	5,279	5,313	5,357	5,411
New Entrants per Year ^{3/}	713	738	763	788	815	843	871	901	931	963
Workforce to Upgrade to Master and Mate ^{8/}	371	382	394	408	422	436	450	466	482	498
Yearly Attrition ^{4/}	386	384	383	383	384	385	387	391	395	400
Total Supply ^{5/}	5,293	5,265	5,251	5,248	5,257	5,279	5,313	5,357	5,411	5,476
Shortage in Men ^{6/}	-2,119	-2,399	-2,673	-2,944	-3,213	-3,477	-3,741	-4,003	-4,267	-4,530
Shortage as a Percentage of Demand ^{7/}	-28.59%	-31.30%	-33.73%	-35.94%	-37.93%	-39.71%	-41.32%	-42.77%	-44.09%	-45.27%
	*	*	*	*	*	*	*	*	*	*
<u>ABLE SEAMEN</u>										
DEMAND ^{1/}	4,032	4,168	4,310	4,456	4,608	4,764	4,924	5,092	5,264	5,442
SUPPLY ^{1/}										
Previous Year Workforce ^{2/}	1,895	2,091	2,282	2,470	2,657	2,843	3,029	3,213	3,397	3,582
New Entrants per Year ^{3/}	545	563	582	602	623	644	666	688	711	736
Workforce to Upgrade To Mate ^{8/}	182	190	197	203	210	217	225	232	240	249
Yearly Attrition ^{4/}	167	182	197	212	227	241	257	272	286	301
Total Supply ^{5/}	2,091	2,282	2,470	2,657	2,843	3,029	3,213	3,397	3,582	3,766
Shortage in Men ^{6/}	-1,941	-1,886	-1,840	-1,799	-1,765	-1,735	-1,711	-1,695	-1,687	-1,674
Shortage as a Percentage of Demand ^{7/}	-48.14%	-45.25%	-42.69%	-40.37%	-38.30%	-36.42%	-34.75%	-33.29%	-31.95%	-30.76%
	*	*	*	*	*	*	*	*	*	*
<u>DECK DEPARTMENT</u>										
Total Skilled Shortage in Men ^{9/}	-6,782	-6,896	-7,023	-7,162	-7,315	-7,474	-7,650	-7,837	-8,037	-8,245
Total Skilled Shortage as a Percentage of Demand ^{10/}	-38.97%	-38.33%	-37.75%	-37.24%	-36.78%	-36.36%	-35.99%	-35.66%	-35.37%	-35.10%

* See Footnotes on Next Page

LIMITED LICENSED ENGINEERS

	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
DEMAND ^{1/}	420	434	448	464	480	496	514	530	548	566
SUPPLY										
Previous Year Workforce ^{2/}	193	294	392	448	464	480	496	514	530	548
New Entrants per Year ^{3/}	122	126	88 ^{11/}	49	50	52	55	54	57	59
Yearly Attrition ^{4/}	21	28	32	33	34	36	37	38	39	41
Total Supply ^{2/}	294	392	448	464	480	496	514	530	548	566
Shortage in Men ^{6/}	-126	-42	0	0	0	0	0	0	0	0
Shortage as a Percentage of Demand ^{1/}	-30.00%	-9.68%	0	0	0	0	0	0	0	0

* * * * *

OILERS

	2,016	2,084	2,156	2,226	2,304	2,382	2,462	2,546	2,632	2,722
DEMAND										
SUPPLY										
Previous Year Workforce ^{2/}	927	817	718	666	657	653	651	650	555	660
New Entrants per Year ^{3/}	106	110	113	117	121	125	129	134	138	143
Workforce to Upgrade to Engineer ^{11/}	122	126	88	49	50	52	55	54	57	59
Yearly Attrition ^{4/}	94	83	77	77	75	75	75	75	76	77
Total Supply ^{2/}	817	718	666	657	653	651	650	655	560	667
Shortage in Men ^{6/}	-1,199	-1,366	-1,490	-1,571	-1,651	-1,731	-1,812	-1,891	-1,972	-2,055
Shortage as a Percentage of Demand ^{1/}	-59.47%	-65.55%	-69.11%	-70.51%	-71.66%	-72.67%	-73.60%	-74.27%	-74.92%	-75.50%

ENGINE DEPARTMENT

	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
Total Skilled Shortage in Men ^{2/}	-1,325	-1,408	-1,490	-1,571	-1,651	-1,731	-1,812	-1,891	-1,972	-2,055
Total Skilled Shortage as a Percentage of Demand ^{10/}	-54.39%	-55.92%	-57.22%	-58.36%	-59.30%	-60.15%	-60.89%	-61.48%	-62.01%	-62.50%

^{1/} From Table 4

^{2/} Estimated Workforce as of December 31 of the previous year.

^{3/} Based on an annual compounded growth rate of 3.39% of the base (1978) new entrants from upgradings and formalized training institutions.

^{4/} For limited licensed deck and engine personnel, attrition is equal to the sum of the Previous Year Workforce and New Entrants per Year times the attrition value found on Table 6. For operators, able seamen and oilers, attrition is equal to the sum of Previous Year Workforce and New Entrants per Year minus people who upgrade to the next higher level times the attrition values found on Table 6.

^{2/} Total Supply is equal to Previous Year Workforce plus New Entrants per Year minus Workforce to upgrade minus Yearly Attrition.

^{6/} Total Supply minus Demand.

^{7/} Shortage in Men divided by Demand.

^{8/} The Workforce needed to upgrade to master and/or mate is assumed to come from operators and able seamen workforces. For the purpose of this analysis, 66.7 percent of these upgraders will come from the operator workforce, the remainder from the able seamen workforce.

^{9/} The summation of shortages in men for this department

^{10/} Total Skilled Shortage in Men by department divided by the summation of Demand by department.

^{11/} When an equilibrium occurs, the number of new entrants will not exceed demand for new entrants.

SUPPLY AND DEMAND
Table 2

ESTIMATED SUPPLY AND DEMAND INTERACTION-DECK DEPARTMENT
REQUIREMENTS TO MAINTAIN EQUILIBRIUM AT A 3.39% ANNUAL GROWTH RATE IF EQUILIBRIUM IS ACHIEVED IN 1980 WORKFORCE

	1979 ^{1/}	1980	1981	1982	1983	1984	1985	1986	1987	1988
<u>Limited Mates and Masters</u>										
DEMAND ^{1/}	5,958	6,160	6,368	6,584	6,808	7,038	7,278	7,524	7,780	8,042
SUPPLY										
Remaining Previous Year Workforce ^{2/}	2,919	3,016	5,741	5,935	6,136	6,345	6,559	6,783	7,012	7,251
New Requirements From Previous Year Attrition ^{3/}	N.A.	N.A.	419	433	448	463	479	495	512	529
New Requirements for Growth ^{4/}	N.A.	N.A.	208	216	224	230	240	246	256	262
SUBTOTAL-New Entrants Needed ^{5/}	N.A.	3,144	627	649	672	693	719	741	768	791
Total Supply ^{6/}	3,236	6,160	6,368	6,584	6,808	7,038	7,278	7,524	7,780	8,042
Shortage in Men ^{1/}	2,722	0	0	0	0	0	0	0	0	0
Shortage as a Percentage of Demand ^{8/}	45.69%	0%	0%	0%	0%	0%	0%	0%	0%	0%
* * *										
<u>Operators</u>										
DEMAND ^{1/}	7,412	7,664	7,924	8,192	8,470	8,756	9,054	9,360	9,678	10,006
SUPPLY										
Remaining Previous Year Workforce ^{2/}	5,337	4,933	7,143	7,385	7,635	7,894	8,161	8,438	8,724	9,020
Upgrading Requirements for Mates and Masters ^{2/}	N.A.	1,572	314	325	336	347	360	371	384	396
New Requirements from Previous Year Attrition ^{3/}	N.A.	N.A.	521	539	557	576	595	616	636	658
New Requirements for Growth ^{4/}	N.A.	N.A.	260	268	278	286	298	306	318	328
SUBTOTAL-New Entrants Needed ^{5/}	N.A.	4,303	1,095	1,132	1,171	1,209	1,253	1,293	1,338	1,382
Total Supply ^{6/}	5,293	7,664	7,924	8,192	8,470	8,756	9,054	9,360	9,678	10,006
Shortage in Men ^{1/}	2,119	0	0	0	0	0	0	0	0	0
Shortage as a Percentage of Demand ^{8/}	28.59%	0%	0%	0%	0%	0%	0%	0%	0%	0%
<u>Able Seamen</u>										
DEMAND ^{1/}	4,032	4,168	4,310	4,456	4,608	4,764	4,924	5,092	5,264	5,442
SUPPLY										
Remaining Previous Year Workforce	1,895	1,936	3,860	3,991	4,126	4,267	4,411	4,560	4,715	4,874
Upgrading Requirements for Mates and Masters ^{2/}	N.A.	1,572	313	324	336	346	359	370	384	395
New Requirements from Previous Year Attrition ^{3/}	N.A.	N.A.	308	319	330	341	353	364	377	390
New Requirements for Growth ^{4/}	N.A.	N.A.	142	146	152	156	160	168	172	178
SUBTOTAL-New Entrants Needed ^{5/}	N.A.	3,804	763	789	818	843	872	902	933	963
Total Supply ^{6/}	2,091	4,168	4,310	4,456	4,608	4,764	4,924	5,092	5,264	5,442
Shortage in Men ^{1/}	1,941	0	0	0	0	0	0	0	0	0
Shortage as a Percentage of Demand ^{3/}	48.14%	0%	0%	0%	0%	0%	0%	0%	0%	0%

* Footnotes on next page.

SUPPLY AND DEMAND
TABLE 2 (Continued)
ESTIMATED SUPPLY AND DEMAND INTERACTION-ENGINE DEPARTMENT
WORKFORCE REQUIREMENTS TO MAINTAIN EQUILIBRIUM AT A 3.39% ANNUAL GROWTH RATE IF
EQUILIBRIUM IS ACHIEVED IN 1980

Limited Licensed Engineers	1979 ^{11/}	1980	1981	1982	1983	1984	1985	1986	1987	1988
DEMAND ^{1/}	420	434	448	464	480	496	514	530	548	566
SUPPLY										
Remaining Previous Year Workforce ^{2/}	193	274	405	418	433	448	463	480	494	511
New Requirements from Previous Year Attrition ^{3/}	N.A.	N.A.	29	30	31	32	33	34	36	37
New Requirements for Growth ^{4/}	N.A.	N.A.	14	16	16	16	18	16	18	18
SUBTOTAL- New Entrants Needed ^{5/}	N.A.	160	43	46	47	48	51	50	54	55
Total Supply ^{6/}	294	434	448	464	480	496	514	530	548	566
Shortage in Men ^{7/}	-126	0	0	0	0	0	0	0	0	0
Shortage as a percentage of Demand ^{8/}	30.00%	0%	0%	0%	0%	0%	0%	0%	0%	0%

* * * * *

Oilers	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
DEMAND ^{1/}	2,016	2,084	2,156	2,228	2,304	2,382	2,462	2,546	2,632	2,722
SUPPLY										
Remaining Previous Year Workforce ^{2/}	927	733	1,869	1,934	1,999	2,066	2,137	2,208	2,284	2,361
Upgrading Requirements for Engineers ^{10/}	N.A.	160	43	46	47	48	51	50	54	55
New Requirements from Previous Year Attrition ^{3/}	N.A.	N.A.	215	222	229	238	245	254	262	271
New Requirements for Growth ^{4/}	N.A.	N.A.	72	72	76	78	80	84	86	90
SUBTOTAL- New Entrants needed ^{5/}	N.A.	1,511	330	340	352	364	376	388	402	416
Total Supply ^{6/}	817	2,084	2,156	2,228	2,304	2,382	2,462	2,546	2,632	2,722
Shortage in Men ^{7/}	1,199	0	0	0	0	0	0	0	0	0
Shortage as a Percentage of Demand ^{8/}	-59.47%	0%	0%	0%	0%	0%	0%	0%	0%	0%

^{1/} From Table 4.

^{2/} Previous Year Workforce times attrition values from Table 6.
Subtract this amount from the previous year workforce.

^{3/} Workers loss from attrition is equal to attrition values from Table 6 times previous year workforce.

^{4/} Growth requirements are equal to 3.39% times previous year demand.

^{5/} New entrants required is equal to upgrade requirements plus new requirements for growth and attrition. Numbers may be slightly higher if attrition of new Entrants occur that year.

^{6/} Supply is equal to Remaining Previous Year Workforce plus New Requirements from Previous Year Attrition and new Growth.

N.A.- Not Applicable

^{7/} Total Supply minus Demand

^{8/} Shortage in Men divided by Demand.

^{9/} Assumes 50% of new Mates and Masters Entrants for that year will come from upgraders from this classification.

^{10/} Assumes 100% of new engineer entrants for that year will come from upgraders from this classification.

^{11/} See Supply and Demand Table 1 for 1979. Methodology for 1979 is not exactly comparable with footnotes 1-10.

ALUMINUM INDUSTRY

Uses of Aluminum

The output of an aluminum reduction plant may be cast into various solid forms (ingot) or transported molten to fabricating plants. In 1978, the major markets for ingot shipments were: transportation, 51 percent; consumer durables, 13 percent; and machinery and equipment, 12 percent. In 1979, industries consuming aluminum ingot and mill products included: containers and packaging, 23.7 percent; building and construction, 22.4 percent; transportation, 22.2 percent; electrical, 11.4 percent; consumer durables 7.4 percent; machinery and equipment, 6.9 percent; and other markets, 6 percent.

Aluminum markets which have shown particular growth in recent years include cans and containers, and aerospace and automotive applications. Aluminum's penetration of the beverage can market increased from 23 percent in 1972 to 57.5 percent in 1979. Energy-saving applications of aluminum in the motor vehicle sector are also increasing. Aluminum usage averaged 118 lbs/car in 1979, up from an average of 83 lbs. in 1975 models. This figure is expected to range between 200-285 lbs. by 1985. Aluminum use in aircraft, particularly large transports, has also increased in recent years.

Number of Firms, Concentration

In 1980, primary aluminum was produced by 12 domestic companies operating 33 plants. Prior to 1940, the Aluminum Company of America (Alcoa), with three plants, was the only company producing primary aluminum in the United States. During the 1940s, Reynolds Metal Company and Kaiser Aluminum and Chemical Corporation began production at six plants while Alcoa added two more plants. Capacity increased markedly in the fifties, sixties, and early seventies as the "Big Three" (Alcoa, Reynolds, and Kaiser) added 8 plants and as new firms entered the industry. With the exception of an Alumax Inc. plant that began production in 1980, and a small experimental plant that started-up in 1976, no new primary aluminum plants have been opened since the early 1970's.

In 1979, the Big Three operated 20 of the 33 primary aluminum plants, and accounted for 64 percent of domestic production. U.S. primary aluminum capacity has historically been concentrated in these three companies. As new firms entered the industry, however, the extent of this concentration declined from 100 percent in 1950 to 88 percent in 1960. By 1970 the 3-firm concentration was 71 percent.

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Geographic Location

Because electricity cannot be transported efficiently over long distances and because bauxite deposits usually occur far from aluminum consuming centers, the location of primary aluminum plants involves consideration of:

- The availability of low-cost power;
- The availability and delivered cost of alumina; and
- The distance to market for ingot.

None of these factors is necessarily overriding; rather, the lowest cost of delivered metal must be determined. The majority of existing primary aluminum plants have located near sources of low-cost power or near ingot markets. Alumina plants in recent years have located near bauxite mines.

Washington, Oregon, and Montana account for 32 percent of the total production; Alabama, Louisiana and Texas, 20 percent; Indiana, Kentucky, Maryland, New York, West Virginia and Ohio, 32 percent; and Arkansas, Missouri, North Carolina and Tennessee, 16 percent.

Integration and Diversification

Of the twelve firms domestically producing primary aluminum, only Alcoa and Reynolds are vertically integrated from domestic mining through primary metal production. Most of the other firms, except for Revere Copper and Brass Incorporated, the National Aluminum Company, and the Southwire Company, are also integrated from bauxite mining through metal production through their foreign affiliates or subsidiaries, or through partial ownership.

While Alcoa and Reynolds primarily produce aluminum, other producers are more diversified. Kaiser produces agricultural and industrial chemicals and refractories materials, mines and sells iron ore, engages in international commodity trading and real estate activities, and has interests in nickel and shipping. Consolidated Aluminum Corporation produces industrial chemicals and screw machine products; Anaconda Aluminum Company mines, smelts and refines copper and produces industrial valves;

and Revere manufactures copper, copper alloys, steel products and other nonferrous metal products. Other firms are similarly diversified.

Capacity and Capacity Utilization

The U.S. aluminum industry in the 1950s and 1960s expanded capacity eightfold as it attempted to acquire markets with low-cost metal. The industry had, however, overextended in the 1960s and was nearly destroyed in the early 1970s when shipments were at a record high because Federal controls, instituted in 1971, froze the price of ingot at a low 25¢/lb. Burned by overcapacity and aggressive pricing in the past, U.S. aluminum producers have held back expansion, produced at near-capacity, and increased prices as far as the market and Federal price guidelines will allow.

During the 1958-79 period, domestic primary aluminum capacity grew from 2.19 million tons to 5.28 million tons, with an annual growth rate of 4.4 percent. The annual capacity growth rate has ranged from a high of 14.8 percent between 1965-66 and a low of less than 0.1 percent between 1976-77.

Since the early 1970s, no new commercial-scale plants have been built in the United States with the exception of an Alumax plant in South Carolina, and none are planned in the near future with the possible exception of another Alumax plant in Oregon. Between 1972 and 1979, domestic primary aluminum capacity grew at only 1.5 percent per year.

Capacity utilization in the primary aluminum industry has been historically high. The average annual capacity utilization for the 1958-1979 period was 89 percent. In 1979, capacity utilization was 95 percent.

Production and Prices

Production of primary aluminum has increased annually since the 1940's, except for 1975 when production suffered a sharp decline. Production nearly tripled between 1950 and 1960, increasing from 0.7 million tons to 2.0 million tons. From 1960 to 1970, production doubled, as 4.0 million tons of primary aluminum were produced in 1970. By 1974, production had reached 4.9 million tons. Production decreased to 3.8 million tons in the recession year of 1975. There has been an increase in production each year since 1975, with a record 5.0 million tons being produced in 1979.

The value of shipments of primary aluminum has increased each year since 1963, with the exception of 1970 and 1971, when price controls were in effect, and 1975, when production dropped sharply. In 1963, the value of shipments was \$1.1 billion. By 1973, the value of shipments had increased to \$2.3 billion, and by 1977, it had increased to \$4.6 billion. The value of shipments for 1979 was \$6.1 billion.

The historical price stability of aluminum has been an important factor in the high rate of growth of the industry relative to other metal-producing industries and to the general economy. Between 1958 and 1973, the average price of ingot ranged between a low of 22.6 cents/lb. in 1963 and a high of 29.0 cents/lb. in 1971. The producer price index for the primary aluminum industry from 1967-1973 ranged from a low of 96.8 in 1972 to a high of 112.9 in 1970.

Since 1973, however, aluminum prices have been increasing sharply, going from 25.3 cents/lb. in 1973 to an average price of 59.4 cents/lb. in 1979. The producer price index for the industry has risen from 101.3 in 1973 to 278.4 in 1979. These price increases from 1973-1979 were brought about by numerous factors, including the increased cost of fuels and electric energy, the increase in bauxite levies, and increases in other raw materials costs. Also, during the early 1970's, major producers' prices were controlled by the government. Since then, prices have been subject to guidelines set by the Council on Wage and Price Stability. Since the mid-1960s, actual market prices of primary aluminum have varied above or below the quoted price.

Cost of Production

The energy, labor, and raw materials required to produce one short ton of primary aluminum metal were estimated by the Bureau of Mines to fall within the following limits:

Alumina	1.9-1.95 short tons
Makeup cryolite	10-70 pounds
Makeup aluminum fluoride	25-60 pounds
Calcium fluoride	4-8 pounds
Energy	
Alumina reduction (electricity)	45-60
Electrode carbon:	
Petroleum coke, calcined (700 to 950 pounds)	9-12 million Btu
Pitch (280 to 330 pounds)	3-4 million Btu
Anthracite coal (40 to 80 pounds)	.5-.1 million Btu
Anode and cathode baking (oil, gas, electricity)	.1-5.5 million Btu
Holding furnace, ingot casting, and melting operations (gas, oil, electricity)	5.2-7.8 million Btu
Total labor and supervision	8-20 man-hours

The cost of primary aluminum production varies depending on the type, size, and location of the aluminum plant, and on power, labor, raw materials, and environmental costs. Operating costs for primary aluminum facilities, excluding profit and capital charges, were estimated to fall between \$500 to \$800 per ton of aluminum in 1977, up from \$300 to \$600 per ton in 1974. The capital cost of a primary aluminum plant, estimated to range from \$1200 to \$1800 per annual ton of capacity in 1974, was expected to range from \$1500 to \$2000 per ton of capacity in 1977. In 1976, the average capacity of the domestic primary aluminum plants was 165,000 short tons. Currently, 200,000-ton plants are considered economic.

Technological Change

The high rate of growth in the aluminum industry has been maintained by a large, continuing research effort to develop new products and improve production efficiency. Much of the current research is aimed at developing processes to utilize domestically available nonbauxitic raw materials to produce alumina and at increasing the energy efficiency of aluminum production processes.

Development of a commercially viable process for producing alumina from nonbauxitic raw materials is seen as possible by 1985. Meanwhile, improvements in bauxite refining

are expected to result from increases in energy efficiency and from modifying materials handling equipment.

Technological improvements in alumina reduction may include: adding compounds to the electrolyte to lower power consumption; changing the materials and/or configuration of electrodes, cathode leads, and cells; improving the thermal efficiency of the cell; and computer control of the electrolysis. In addition, a commercial-scale pilot facility using a new process for reduction of aluminum chloride to produce metal began operating in 1976. The process operates at lower temperatures, eliminates fluorine pollution, and uses up to 30 percent less electricity than the conventional process.

As part of a voluntary industrial energy conservation program established by the Federal government, the aluminum industry reduced energy consumption per pound of metal produced by 10 percent between 1972 and 1980. Prior to World War II, 12 kWh were required to produce one pound of primary aluminum. Currently, the average requirement is about 8 kWh, while the newest, most efficient plants use about 6 kWh. The pilot facility using the new aluminum chloride process is reported to use 4.5 kWh per pound.

No technological barriers prevent entering the primary aluminum industry. Information is readily traded, so that companies can buy the best available technology.

Employment

In 1977, the primary aluminum industry employed 28,600 employees in 32 plants. Average employment per facility was 894. The industry payroll was \$555 million and the payroll per employee \$19,426. Average hourly earnings of production workers was \$9.36.

Between 1958 and 1977, employment increased by an average of 2.8 percent per year, ranging from a high of 12.8 percent between 1966-67 and a low of -9.4 percent between 1970-71. Employment in the aluminum industry is expected to grow about as fast as the average for all industries through the mid-1980s. Aluminum companies generally hire and train inexperienced workers for production jobs, which account for 75 to 80 percent of industry employment.

Average employment per facility for the last 20 years ranged from 750 to 1,000, with no evident upward or downward trend. A more useful figure might be employment per thousand tons of capacity, which generally declined from 7.93 in 1958 to 5.51 in 1977.

Payroll per employee and average hourly earnings of production workers in the primary aluminum industry are somewhat higher than the average for manufacturing industries. Both have increased at an average annual rate of six percent over the last 20 years. In recent years, annual increases have ranged from 10 to 14 percent.

Most production workers in the aluminum industry belong to labor unions. In addition, labor organizations represent some office and technical personnel. The unions having the greatest number of members in the industry are United Steel Workers of America; Aluminum Workers International Union, and International Union, United Automobile, Aerospace and Agricultural Implement Workers of America.

Imports and Exports

Historically, the U.S. has been a net importer of aluminum ingot. In 1979, the U.S. imported 570,634 short tons of crude metals and alloys valued at \$646 million, and exported 200,650 short tons of crude ingots and slabs valued at \$264 million. Major countries from which aluminum ingot is imported are Canada, Ghana and Norway. Ingot is exported to Mexico, Japan and Canada.

Although 90 percent of the domestic supply of aluminum raw materials is imported, most of the domestic demand for primary aluminum metal is met by U.S. producers. During the 1968-1979 period, the U.S. produced an annual average of 94 percent of the primary aluminum metal it consumed. Although the U.S. is expected to continue producing a major part of the metal it consumes because of the relatively high handling and transport costs of the metal, an increasing proportion of domestic demand will probably be met by imports from countries with low-cost electricity. The Bureau of Mines estimates that U.S. production of primary aluminum metal in 1985 and 2000 will comprise 85 and 80 percent, respectively, of probable U.S. demand.

Domestic Supply-Demand Forecasts

Domestic demand for primary aluminum metal from 1968 to 1979 increased at an annual rate of five percent, from 3,792 to 5,281 thousand short tons. Since domestic mine production was relatively stable during this period, the U.S. became increasingly reliant on imported aluminum materials. The proportion of total metal demand met by old scrap increased during this period.

Recent Bureau of Mines projections estimate probable domestic primary metal demand in the year 2000 to be 13 million short tons. This represent an average annual growth rate of 4 percent. Distribution of this probable total metal demand (includes primary and secondary) by end-use is: Transportation, 3.8 (25.3%); Construction, 3.0 (20%); Cans and Containers, 3.0 (20%); Electrical, 1.9 (12.7%); Appliances and Equipment, 1.3 (8.7%); Machinery, 1.2 (8%); and other, .8 million short tons (5.3%).

Unpublished Bureau of Mines' projections of probable domestic primary metal supply are 7 million tons in the year 1990 and 9.5 million tons in the year 2000. Using linear regression of U.S. primary aluminum production from 1958-1979, estimates for 1990 and 2000 are 6.9 and 7.7 million tons, respectively.

Recent estimates of bauxite reserves estimate a recoverable aluminum equivalent of 10 million short tons in the U.S. and 5.6 billion short tons for the world. Although world supplies of bauxite are adequate to meet probable year 2000 world demand, improved technology will be required to enable the U.S. to maintain a constant ratio level of production of primary aluminum from domestic ores.

Future of the Market

Although the aluminum industry has had record profits over the last few years, the industry may lose some markets to importers or to competitive materials, such as plastics, fiber glass, and high-strength steel. Because of rising prices and tightened supply, some aluminum applications in automobiles have been cut and aluminum's penetration of the beverage can market may slow. Since 1973, the average price of steel has not increased as much as the average price of aluminum.

Where expected demand may exceed domestic supply, imports are likely to increase. This increase may be met largely by Alcan, a Canadian company, which will be expanding capacity in the early 1980s. But in future years, aluminum imports will likely be coming from U.S. ventures abroad.

The aluminum industry in the U.S. is becoming a mature industry with growth slowing in many of its major markets, such as residential construction and automobiles, and no new big markets are foreseen. In contrast, more rapid growth in markets is seen for Europe, Japan, and developing industrial nations.

Because of more rapid growth in markets abroad, the rapid depletion of cheap power in the U.S., uncertain U.S. energy policy, delays caused by environmentalists, and the fact that most bauxite comes from outside the U.S., major domestic aluminum producers are expanding their metal producing capabilities abroad. Countries where U.S. investment may be made include Australia and Brazil, which are rich in bauxite and cheap energy. Both countries are considered relatively safe for production overseas. Australia has large quantities of coal, for cheap power, and high unemployment. Brazil has a lot of hydroelectric potential. Some \$4 billion of U.S. aluminum capital has already been committed in Australia and New Zealand, and smelting capacity in these countries is expected to nearly triple with the addition of one million tons by 1985. Alcoa's outlays in Brazil by 1984 will total \$900 million.

Aluminum Production and OTEC

After bauxite is refined to obtain alumina, primary aluminum metal is produced through electrolytic reduction of alumina. This production requires large amounts of continuous, low-cost electricity. Depending on the plant location and the type of power used, energy may account for 10-40 percent of the cost of aluminum ingot production. A 200,000-ton/year plant might require as much as 50 million kWh/yr for alumina reduction. Because of the large use of electricity for primary aluminum production, national and regional energy policy decisions will play an increasingly important role in locating future facilities.

There has been a rapid depletion of cheap power in the U.S.. In the Pacific Northwest, where 10 plants provide over 30 percent of the nation's primary aluminum capacity, the Bonneville Power Administration has not been able to assure uninterruptible power (because of the high demand for electricity and the unpredictability of precipitation). Replacement power, when available, has cost up to 10 times BPA's price. Further, even BPA's power cost has been increasing rapidly. To purchase BPA power, aluminum producers were paying 3.19 mills/kWh in 1979. At the end of 1980, the cost had risen to 6.13 mills. Replacement power in the PNW has been estimated to cost from 25 to 60 mills/kWh. These factors have led to periodic shutdowns on potlines in the PNW.

The passage of the Pacific Northwest Electric Power Planning and Conservation Act, P.L. 96-501, in December 1980, grants BPA the authority to assemble additional blocks of power to give industry guaranteed, long-term power. It will be high-cost power, however, guaranteed only for present facilities, with the exception of a planned Alumax plant in Oregon.

Future primary aluminum plants are expected to locate in areas of low-cost thermal or undeveloped hydroelectric energy, where energy costs may be low enough to offset other costs such as transportation, raw materials. or marketing. Because of the depletion of low-cost domestic energy, and the fact that the U.S. must import 90 percent of its raw materials for aluminum production, domestic aluminum producers are shifting much of their capital investment overseas.

Several organizations, including APL and TRW, have considered conceptual designs for OTEC plant ships which would reduce alumina to aluminum metal on board. This process is attractive for OTEC application because it is energy intensive and because the alumina is already imported over long distances and the OTEC alumina reduction plants could be located near alumina shipping routes. Aluminum also appears to be an attractive initial product for the OTEC island energy complex concept, i.e., use of OTEC plants off Puerto Rico, Hawaii, or tropical islands to supply electricity by cable to onshore industrial complexes.

AMMONIA INDUSTRY

The energy produced by an OTEC plant may be used for the production of ammonia, which presently requires large amounts of natural gas as a feedstock. Ammonia could be manufactured aboard an OTEC plant from nitrogen, which can be extracted from the air, and hydrogen, which is made by electrolysis of seawater. Ammonia is formed in an equilibrium process with little evolution of heat so that it efficiently transforms electrical energy into storable chemical energy. It is easily liquefied, stored, and transported.

Number of Firms, Concentration

In 1940, there were only seven anhydrous ammonia producers in the United States, with a total annual production capacity of half a million tons. The number of firms increased steadily until 1969, when there were 71 firms. By 1976, though, there were only 57 firms operating 93 plants. By 1980, the number of operating plants had decreased to 64. The decrease in the number of firms was a result of mergers and of firms leaving the industry. Many of the firms leaving the industry did not possess derivative capacity. That is, they did not have the capacity to produce other nitrogenous fertilizers from ammonia.

In 1940, the 4-firm concentration was 96 percent. From 1951 to 1969, 4-firm concentration decreased from about 63 percent to 20 percent, and 8-firm concentration decreased from 85 percent to 35 percent. Recently, concentration has increased and in 1975, 4-firm concentration was about 25 percent, and 8-firm concentration was about 40 percent.

During the 1960s, there were important changes in the geographical concentration of ammonia production. There was a shift from a scattered, market-oriented pattern of production to one based heavily in the south (Mississippi, Arkansas, Louisiana, Oklahoma, and Texas). Between 1960 and 1975, the proportion of ammonia capacity in these States rose from 32 percent to 52 percent. There were three reasons for this change:

- Availability and cost of transporting natural gas;
- Improvements in storage technology and increases in storage capacity in the areas of use; and

- The ability to use interior and coastal waterways for barge movements of ammonia.

Production

Production of anhydrous ammonia nearly tripled between 1960 and 1972, increasing from 4.8 million tons to 13.1 million tons. Production continued to increase steadily after 1970, reaching 18.9 million tons by 1980.

Production of other ammonia compounds also increased during this period, though not as rapidly as production of anhydrous ammonia. Between 1960 and 1967, production of ammonium nitrate increased from 3.1 million tons to 7.2 million tons; production of ammonium sulfate increased from 0.9 million tons to 2.2 million tons; production of nitric acid increased from 3.3 million tons to 7.9 million tons.

Capacity

About half of the nitrogenous fertilizer plants now on stream began production between 1963 and 1969, a period of extensive capacity buildup in the industry. During this period, capacity increased from about 7 million tons per year to about 19 million tons, leading to an overcapacity problem.

By 1969, capacity utilization dropped to 70 percent after being above 90 percent in the early 1960s. From 1969 to 1972, capacity actually decreased, falling to less than 17 million tons. Responding to increased demand and rising fertilizer prices, capacity began increasing in 1973, reaching a peak of 22 million tons in 1978. After the closing of some older plants, capacity fell to about 21 million tons in 1980. Capacity utilization in recent years has been about 90 percent. Production in 1979 was 17.2 million tons, and 18.9 million tons in 1980.

Plant Capacity

Currently, most plants are operating in the 600-1000 tons per day range. Many of these plants began operating soon after the centrifugal compressor was successfully incorporated into plant design in 1963. Several newer plants are operating at 1200 tons per day (considered the optimum economic size) or greater.

Extent of Integration and Diversification by Firms

Anhydrous ammonia producers and their parent firms are involved in the production and distribution of a wide range of goods and services. About 76 percent of ammonia producers or their parent companies produce chemicals and allied products other than fertilizers. A large share of the ammonia production capacity is controlled by the petroleum industry (22%), the chemical industry (17%), and cooperatives (21%). As an indication of backward integration into raw materials production, about 25 percent of the firms producing ammonia are involved in crude petroleum and natural gas extraction, with eight percent engaged in natural gas production and distribution.

Vertical integration has increased in recent years. Ammonia firms owning one or more derivative plants own about 80 percent of U.S. ammonia capacity and almost 90 percent of total ammonia derivative capacity. Much of the increase in vertical integration is closely related to the trend toward agglomeration of production facilities. There are several advantages to such colocation:

- The efficient, competitive production of urea, ammonium nitrate, and other derivative products depends directly on an adequate supply of ammonia. Many of the process lines for derivatives have been built in conjunction with or as complements to ammonia plants.
- Onsite use of ammonia in derivatives eliminates the necessity of transporting the raw material to other locations for derivative manufacturing.
- Similar labor skills are required to operate all of the plants.
- Agglomeration of production facilities enables producers to spread the costs of offsite facilities and services.
- There can be significant economies in administration and maintenance of the entire complex.

The State of Technological Change in the Industry

There have been tremendous advances in fertilizer productive technology in the last three or four decades. Through the early part of the seventies, these advances were accompanied by a reduction in the unit cost of producing fertilizer, thereby making these products more economical for users. Along with many of the technological advances, a trend has also developed toward building larger manufacturing plants, as economies of scale are significant for many types of fertilizer plants. This cost behavior has direct implications for longrun planning by the industry and, consequently, for future fertilizer supplies.

Modern ammonia plants are centered around closely related and integrated steps for gas generation, purification, and synthesis. These steps were often separate in older designs. In newer plants, the energy available within the process has been considered more closely in relation to the energy needed to operate the entire plant. Further, process conditions have been selected to make more efficient and economic use of machinery and equipment.

Some of the more important changes in plant design which evolved from the incorporation of these concepts are as follows:

- Complete redesign of the steam-generator system.
- Recovery of waste heat concurrent with economic selection of equipment.
- A substantial increase in reforming pressure, leading to high thermal efficiency and lower compression costs.
- Reduction in synthesis pressure to allow the use of centrifugal compressors in the synthesis cycle.

- Virtual elimination of electric power consumption by using a highly efficient energy cycle.

As the total market and inseason demand for ammonia continued to grow, advances were made in storage design and the capacities of storage units increased. Refrigerated vessels were successfully introduced, permitting the containment of ammonia at atmospheric pressure. Larger transport units could be used, and barge and ship movement of refrigerated ammonia became practical. A change in industry orientation began to occur — toward larger production plants operating near full capacity year round, simultaneously supported by sufficient storage and distribution facilities.

Production Costs

Natural gas is the largest variable cost component in domestic anhydrous ammonia plants. Many ammonia producers are susceptible to gas curtailments, especially during the winter, when interstate gas supplies may be diverted to residential and other priority users. There is little variation in the amount of gas used per ton of production regardless of size or age of plant. This applies to gas used both as a feedstock and for heat and power.

With the exception of natural gas, average cost declines as plant size increases. Other significant variable costs are:

- Electricity: the larger, centrifugal-type plants are nearly self-sufficient.
- Labor: most plants require five operating laborers per shift, and their costs are spread over larger volumes of output in the larger (600-1000 ton per day) plants.

The most significant fixed costs are:

- Compressors and other production equipment: "battery limits" are more expensive for the larger plants, but the average cost is less.

- Maintenance and overhead: again, total costs are higher but average costs decrease as plant size increases.

An example of economies of scale is shown by figures published by the Department of Agriculture in 1977. Operating costs per ton of ammonia produced by three different sized plants were given as follows:

- 400 ton-per-day plant: \$ 86.90
- 600 ton-per-day plant: \$ 72.94
- 1000 ton per-day-plant: \$ 64.77

Investment and working capital costs per ton were:

- 400 ton-per-day plant \$ 54,000
- 600 ton-per-day plant \$ 47,666
- 1000 ton-per-day plant \$ 40,400

The costs of production given above assumed a cost of \$.50 per MCF. For each size plant, the average cost of natural gas per ton of ammonia was \$19.00. However, new contracts in 1979 were signed at \$2.50 per MCF, leading to a cost of natural gas per ton of ammonia of \$95.00. This is more than the total cost of production in 1976. Thus, the increasing costs of natural gas has had, and will continue to have, a dramatic effect on prices of anhydrous ammonia and other fertilizer products.

The average physical inputs per ton of anhydrous ammonia production, by size of plant, are given below. Economies of scale exist for electricity, especially for plants with a capacity over 1000 tons per day, and for labor.

Output	Inputs			
Tons per day	Natural Gas			
	Feedstock	Heat and Power	Electricity	Production workers
	<u>1,000 cubic feet</u>		<u>Kilowatt-hours</u>	<u>Man-hours</u>
Less than 200	24.8	15.7	572	.90
200-400	23.3	13.0	686	.59
401-600	22.0	11.7	403	.37
601-1,000	23.3	17.6	182	.19
More than 1,000	23.0	14.7	36	.21
Average				
Simple	23.3	14.3	396	.50
Weighted	23.0	14.6	216	.30

Barriers to Entry

Uncertainties, economies of scale, and the capital-intensive and technical orientation of ammonia manufacturing plants have made it more difficult and costly to enter the industry. Firms with production facilities that were operating early in the 1970s have a competitive advantage over newer firms because of the sharply increasing capital costs in recent years.

As capital and energy costs continue to increase, construction of new plants will be subject to increasingly stricter decision criteria within firms. It seems unlikely that firms which have never operated in the fertilizer industry will attempt to enter the industry in the next decade, barring the improbable recurrence of the rapid growth of fertilizer demand in the 1960s or of the capacity shortfall of the early 1970's. Successful penetration of the fertilizer market requires efficient production and orderly and efficient marketing of the products involved. The costs of marketing have increased considerably over time and these expenditures, as well as those for production, will make it more costly to enter the industry.

World Supply-Demand Forecasts*

As can be seen from the chart below, U.S. net imports of anhydrous ammonia have increased rapidly in the past two years. One reason for this is that the cost per ton of imports has remained relatively constant, while the cost per ton of domestic production has increased more than 30 percent since 1978. Net imports, as a percent of domestic consumption, have averaged about 6.6 percent the last two years.

<u>1000's Metric Tons</u>	<u>1977</u>	<u>1978</u>	<u>1979</u>	<u>1980</u>
Imports	878	956	1581	2013
Exports	<u>264</u>	<u>475</u>	<u>502</u>	<u>704</u>
Net Imports	<u>614</u>	<u>481</u>	<u>1079</u>	<u>1309</u>
<u>Million Dollars</u>				
Imports	93.0	97.5	149.8	203.3
Exports	<u>29.5</u>	<u>42.1</u>	<u>52.1</u>	<u>97.2</u>
Net Imports	<u>63.5</u>	<u>55.4</u>	<u>97.7</u>	<u>106.1</u>

According to the Tennessee Valley Authority (TVA), world ammonia capacity increased 61 percent during the 1969-77 period, and is expected to increase 47 percent from 1977 to 1985. During this period the North American increase is expected to be negligible, and a supply deficit of nitrogen is forecast by 1985. The availability and rising price of natural gas is the major reason for the lack of growth of productive capacity in North America. World capacity of ammonia is expected to reach 124 million tons in 1985, compared to 102 million tons in 1979.

World supplies of nitrogen are expected to be adequate through 1985. World demand and supply for nitrogen fertilizers is expected to increase at an annual rate of 4.8 percent. The greatest growth in ammonia supply capability is expected in the Soviet Union and Eastern Europe. The largest increase in demand will come from developing countries, where populations are increasing most rapidly. In addition, centrally planned economies are intent upon upgrading their people's diet and are expected to increase their use of fertilizers. The greatest increases in nitrogen use are forecast for the Far East and Latin America.

* The projections in this section are based on forecasts made by the FAO/UNIDO/World Bank Fertilizer Working Group

Nitrogen supply capacity in developed countries is expected to be so slow that their current 40 percent supply share will drop to 33 percent by 1985. Developing countries will increase their supply share from 18 percent to 24 percent.

Prices

The industry appears to be subject to major fluctuations which directly affect fertilizer prices, supplies, and industry profits. In the 1960's, demand grew at a steady rate, but growth in demand was outweighed by large increases in productive capacity. As a result, prices fell. By 1971, the growth of productive capacity almost stopped because of unprofitability and several firms left the industry. Fertilizer prices increased nearly 150 percent between 1971 and 1975. At the same time, however, production costs increased greatly because of greater capital and energy costs. Prices decreased from 1975 through 1978. Although prices have increased since 1978, they have not reached the 1975 level.