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Printed in the United States of America. Available from National Technical Information Service, U. S. Department of Commerce, 5285 Port Royal Road, Springfield, Virginia 22161

ANL/EES-TM-18

TECHNOLOGY CHARACTERIZATION:
HIGH BTU GAS TRANSMISSION

APRIL 1977

PREPARED BY

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FOR

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UNDER
ANL CONTRACT 31-109-38-3728

SARGENT & LUNDY REPORT SL-3600

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I INTRODUCTION

On December 22, 1976, Argonne National Laboratory authorized Sargent & Lundy to prepare a technology characterization for high Btu gas transmission. The scope of work was confined to a literature review. The work was divided into four specific areas as follows: 1) A summary of pertinent information from the environmental report of the Great Lakes Gas Company for a 365-mile high pressure pipeline serving American Natural Gas Company's proposed lignite gasification plant in North Dakota; 2) Statistical information concerning the operation of the existing United States natural gas transmission pipeline network; 3) A summary of pertinent information from the environmental impact statement of the United States Department of Interior for the proposed 1,619-mile Northern Border Pipeline from Morgan, Montana to Delmont, Pennsylvania; and 4) A summary of pertinent information from the environmental impact statement of the Federal Power Commission for a proposed El Paso Natural Gas Company 418-mile pipeline within the State of Texas which was to be constructed in response to the displacement of natural gas by Liquefied Natural Gas (LNG) importation on the East coast.

Items 1 and 2 above each constitute a major section of the report. Items 3 and 4 were grouped under the common heading New Large Scale Pipelines. Each of the environmental reports or impact statements for the proposed pipelines was summarized with respect to a general description of the pipeline, terrain, and construction procedures. A brief general description of the qualitative environmental impacts associated with construction and the quantitative environmental residuals associated with operation of the pipeline is included in the report. Sections are also included for accident frequency and severity, manpower requirements, and cost for construction and operation.

In addition, basic statistical information concerning the operation of existing United States natural gas transmission pipelines is presented for energy use, environmental residuals, accident frequency and severity, manpower requirements, and cost. The information was obtained from various sources in the literature.

II GREAT LAKES GAS COMPANY PIPELINE

The information in this section is summarized from the Dakota Transportation Project, Volumes I and III, Application for a Certificate of Public Convenience and Necessity, Before the Federal Power Commission, Docket No. CP75-283, March, 1975.

A. Description

1. Pipeline - Great Lakes Gas Transmission Company's (Great Lakes') proposed Dakota Transportation Project would consist of approximately 365 miles of 30-inch diameter high pressure substitute natural gas (SNG) pipeline. The proposed pipeline would deliver 0.275 bcfd of SNG produced by the ANG Coal Gasification Company near Beulah, North Dakota, to an existing 36-inch diameter Great Lakes natural gas pipeline at a compressor station near Thief River Falls, Minnesota. The SNG, produced by the gasification of lignite coal, would be transported by the existing Great Lakes pipeline from Thief River Falls, Minnesota to the Michigan-Wisconsin Pipe Line Company (Michigan-Wisconsin) near Crystal Falls, Michigan to supply energy-deficient areas of Wisconsin and Michigan. Great Lakes, the ANG Coal Gasification Company, and Michigan-Wisconsin are all affiliates of the American Natural Gas Company.

   The SNG would be compressed to a pipeline pressure of approximately 970 psi and the pressure would drop to about 700 psi at the Thief River Falls Compressor Station. Compressor stations along the 365-mile pipeline would not be necessary. Aboveground facilities would consist of five microwave communications towers at approximately 60-mile intervals, a series of main line valves at 15 to 20-mile intervals, and a district headquarters near Devils Lake, North Dakota.

2. Terrain - The proposed pipeline would be located in twelve counties in North Dakota and one county in Minnesota beginning in Mercer County, North Dakota and extending in an easterly direction through the North Dakota counties of Oliver, McLean, Ward, McHenry, Sheridan, Pierce, Benson, Ramsey, Nelson, Grand Forks, and Walsh terminating in Marshall County, Minnesota. The proposed pipeline would be located within the existing Burlington Northern Railroad right-of-way, including a proposed railroad spur from the plant site, for the first 56 miles. After crossing the Missouri River near Washburn, North Dakota, the pipeline would follow and be located within the Soo Line Railroad right-of-way for approximately 309 miles to Great Lakes' Thief River Falls Compressor Station.

   For approximately the first 128 miles the pipeline would cross the Missouri Plateau, an area which had been affected by both strong and weak glacial activity in the geological past, in the southwestern part of North Dakota. The glacial effects were mainly the deposition of drift that followed the preexisting landform. In areas of large elevational changes, extensive water erosion has taken place, leaving areas of sandstone and shale bedrock exposed and remnant drift deposits.

   The lower-lying lands east of the Missouri River do not exhibit as great an elevational difference as on the west side and were more strongly affected by glacial deposition. Continuing east beyond the Missouri River is the Missouri Slope, an area with occasional depressions and potholes, which leads up to a highlands area known as the Missouri Coteau.

   The Missouri Coteau is a 30- to 50-mile wide band of "dead-ice" moraines on the eastern edge of the Missouri Plateau. The coteau is from 200 to 400 feet above the Drift Prairie of central North Dakota. This change in elevation occurs at the Missouri Escarpment, which delineates the eastern boundary of the Missouri Plateau.

   The Drift Prairie is a uniformly level-to-undulating area which extends eastward from the Missouri Plateau to the Red River Valley. It has a poorly developed drainage system and is marked by numerous depressions and potholes which collect run-off water. This area is covered by glacial drift deposits several hundred feet in depth.

The proposed route crosses approximately 138 miles of the Drift Prairie before crossing the Pembina Escarpment and entering the Red River Valley area of eastern North Dakota and western Minnesota.

The Red River Valley, a remnant of glacial Lake Agassiz, is a level lake plain of deep fertile soils with sand and ridges at its eastern and western edges. The proposed route crosses approximately 86 miles through the Red River Valley to its terminus at the Thief River Falls Compressor Station.

Land usage in the area to be crossed by the proposed pipeline is predominantly agricultural, with open range livestock in those areas less suited for crop production. A total of 79 acres of new right-of-way will be required for the proposed pipeline project out of a total required land area of 2,189 acres (based on a 50-foot wide right-of-way).

3. Construction Procedures - The proposed pipeline would be constructed in a single phase from April or May through November in 1980, but certain areas would be constructed during winter months to mitigate impacts on wetland areas.

Prior to actual construction, the pipeline right-of-way may be surveyed and staked to identify the intended location of the pipe and any underground utilities crossing the proposed route. Since the pipeline follows the existing railroad right-of-way almost exclusively, the pipeline alignment is defined except for minor deviations within the railroad right-of-way, near the gasification plant, potential urban center avoidances, and major river crossing sites.

Construction of the proposed pipeline would consist of the following general procedures: clearing and grading of right-of-way, stringing, trenching, line-up and welding, pipe coating and lowering-in, backfilling, clean-up and restoration, and hydrostatic testing.

Clearing and grading of right-of-way would consist of the removal of trees, large rocks, brush and logs. Where required, topsoil would be segregated by bulldozing approximately eight inches of soil for separate storage and replacement. Partial leveling and smoothing of abrupt changes in ground contour may be accomplished by bulldozing and grading. Since the proposed route follows railroad right-of-way almost exclusively, the amount of grading and heavy vegetation removal required would be minimal except where the proposed route deviates from the railroad right-of-way or where floodplain woodlands are encountered.

During the stringing operation, pipe is moved from storage areas to the prepared right-of-way by truck and unloaded by crane in a continuous line. The pipe required for stream and road crossings and in urban areas is stockpiled in a nearby area. Stringing is coordinated with the advance of the trenching crews.

Trenching involves excavating the pipe ditch or trench with a trenching machine or backhoe. The typical trench depth not on railroad right-of-way would be five to six feet and at least six and one-half feet on the railroad right-of-way in order to provide four feet of cover. When existing utilities are encountered, the crossing is carefully excavated using special techniques such as tunneling. Rock-laden areas would be excavated by the use of special equipment or drilling and blasting if required.

After the pipe has been bent in the field to compensate for minor variations in alignment, the pipe would be lined up and welded. The pipe is welded in a continuous line along the side of the trench and the welds are then inspected according to Department of Transportation rules and regulations for gas pipelines.

In the pipe coating operation the pipe is cleaned, primed, and coated with coal tar, asphalt or other material while asbestos felt and heavy kraft paper are simultaneously spirally wound around the pipe. An electronic detector is used to inspect the coated surface for any defects which are promptly repaired and reinspected. The pipe is then lowered into the trench by side-boom crawler tractors equipped with special belt slings for handling the coated pipe.

When the pipe has been inspected and approved in its final position in the trench, the trench is backfilled with material previously excavated and stored along the side of the right-of-way. Unsuitable materials such as large rocks are separated and disposed of during cleanup and restoration. After the trench has been filled and compacted, any topsoil segregated prior to trenching will be bulldozed over the area and normal contours and drainage will be restored.

Cleanup and restoration involve the removal and disposal of surplus equipment, material and miscellaneous debris, the revegetation of the railroad right-of-way, and restoration of temporary work space at streams and road crossings. All affected areas would be revegetated with appropriate grasses and small shrubs, but trees and large bushes would not be reestablished.

Stream banks, coulees and other water courses would be restored as near to their previous state as possible. In areas where erosion may be a problem, structures would be constructed to prevent erosion of the right-of-way.

Cleanup and restoration would be completed when all temporary facilities and installations have been removed and relocated existing utilities such as: fences, utility lines, fence posts, barriers, utility markers, right-of-way markers, etc., have been replaced. Pipeline markers would also be placed at specific locations to identify the pipeline.

Hydrostatic testing of the pipeline would be performed after the completion of all backfilling and cleanup operations. Each test section would be 15 to

20 miles in length, the distance between mainline valves. Testing may be performed in sequence by moving the test water from one test section to another. The source or sources of hydrostatic test water would be determined in advance of construction of the pipeline.

Special construction methods would be required in certain areas along the proposed route. Boring and tunneling would be employed at railroad and road crossings with the pipe being pulled or pushed through the excavation. A pipe casing or thick wall pipe may be necessary to support the load at some crossings. Since the proposed route is located inside the railroad right-of-way, federal regulations require increased pipe wall thickness.

Existing drainage systems would be temporarily interrupted during construction and would be restored after construction is completed. Agricultural drain tiles should not be encountered along the railroad right-of-way.

Access to the proposed route would be provided by the existing railroad right-of-way and county and other public use roads. New access roads may be required where deviations from the railroad right-of-way occur, such as at appropriate stream crossings. Any temporary construction roads would be restored to the landowner's satisfaction.

Stream crossings, with the exception of the Missouri River, would be crossed by excavating from the banks with backhoes or drag lines. Excavated material would be deposited on the streambed or adjacent banks. The pipe would be dragged or pulled along the right-of-way and into the streambed trench. Where high banks border the stream, the pipe would be fabricated parallel to the stream and then swung across the stream and lowered into place. The excavated material would then be used to backfill the trench and the stream banks would be restored and revegetated.

The Missouri River would be crossed using floating excavation equipment such as a clam shell or drag line mounted on a barge. The pipe would be concrete-coated and buried two to five feet below scour depth. It would be placed in the trench by pulling the string of pipe across the river with a winch, guiding it into position in the trench. The required construction time would be about 50 days.

Avoiding various commercial and agricultural structures within the railroad right-of-way would require special construction techniques but no demolition or relocation of structures would be required. In most cases, trenching and pushing or pulling the pipe into position would be effective. When an existing structure occupies the entire right-of-way, the pipeline would be routed under the railroad tracks to follow the right-of-way on the opposite side of the tracks.

The proposed crossing of the Snake Creek embankment, an earthen dam which separates Lake Sakakawea and Lake Audubon, will require special methods and a special crew. The embankment currently serves as a causeway for the Soo Line Railroad, U.S. Route 83, an electrical transmission line, and a telephone cable. Also buried within the two and one-fourth mile long embankment are a series of drain pipes at 400-foot intervals. A feasible crossing may be made between the railroad line and U.S. Route 83 with two lanes of the four-lane highway serving as access for construction.

Wetland and pothole areas traversed by the railroad right-of-way would be crossed by one of several special techniques depending upon the area to be crossed. One method would be trenching and pipe laying in winter months followed by restoration after the spring thaw. In other areas, simply weighting and sinking the pipe or trenching and pushing or pulling the pipe into the trench might be employed.

Construction of the proposed pipeline would be continuous over its 365-mile total length, utilizing four main line spreads, a special spread for construction through towns along the right-of-way, a special spread for the Missouri River Crossing, and a special spread for the dry land crossing of the Snake Creek Embankment. A summary of the material requirements of a typical main line pipeline construction spread and the percent available from local sources is shown in Exhibit 1.

B. Construction

1. Environmental Impacts (Qualitative) - Since the major portion of the proposed pipeline would be constructed within an existing railroad right-of-way, its impact on the land it traverses would be minor and short-term.

Construction impacts related to landslides would involve the loss of integrity of the railroad embankments. This may affect normal operation of the railroad and result in economic loss to the railroad and inconvenience to the users. Landslides are most likely to occur along areas of the Knife and Missouri Rivers.

The major impact of construction on soils would occur as a result of disturbance of the vegetative cover and soil profile during construction. Some alteration of soil productivity would result in an economic impact in agricultural areas and secondary, adverse impacts to wildlife habitat in other areas.

There are four main physical settings in which the proposed pipeline route could impinge upon woodland areas. These include woodlots and stands of bottomland hardwoods in low, wet areas; riparian stands of hardwoods along perennial drainages; shrub and savannah areas in coulees and in other areas of stronger relief; and in artificially established shelterbelts and field windbreaks. All four settings contribute to overall species diversity and soil stability. Shelterbelts and field windbreaks reduce soil losses in a landscape otherwise highly vulnerable to wind erosion. Impacts resulting from clearing of the right-of-way or work space in woodlands could include a loss in aesthetic quality, a small loss of woodland habitat, loss of stream shading and bank stabilization, and loss of wind protection.

Short-term impacts on wetland areas attributed to construction would result from disturbances to waterfowl nesting and brood rearing. Impacts on nesting waterfowl would be greatest in the latter part of May, in June, and most of July. A number of special use areas such as federal and state wildlife areas and wetland easement areas occur along the railroad right-of-way such as the Wolf Creek and De Trobriand Game Management Areas in McLean

County, North Dakota near Lake Sakakawea and may be susceptible to construction disturbances if all construction did not adhere to railroad right-of-way. Based on limited field observations and examination of topographic maps, a total of 21 miles of wetlands may be encountered along the proposed route.

Federally recognized rare and endangered species which might be affected by construction include: the black-footed ferret, the Northern greater prairie chicken, the whooping crane, the Mississippi sand-hill crane, and two predatory raptors, peregrine and prairie falcons.

There are also some status-undetermined species with possible impact considerations. These include the swift fox, American osprey, ferruginous hawk, prairie pigeon hawk, eastern pigeon hawk, northern long-billed curlew, Columbian sharp-tailed grouse and the mountain plover. The Caspian tern, while not recognized officially, is considered a rare breeder in saline lakes in North Dakota.

No significant adverse impacts are expected to occur to rare or endangered species or other status-undetermined species during construction.

Surface waters along the proposed route which serve as sources for municipal, industrial, and agricultural water supply may be temporarily affected by construction activities due to short-term increases in silt loads. Since these silt loads would be short-term and should be less than that occurring from natural causes, water supply impacts resulting from construction activities should be minimal.

Air pollution during construction activities would result from the generation of fugitive dust, the burning of debris, and the operation of construction vehicles. The effects of these activities on air quality would be localized and short-term in nature. Dust control procedures would be required in certain areas along the proposed route, particularly around communities.

Water quality impacts would result mainly from siltation due to construction at stream crossings and overland runoff. Other construction-related activities such as trench dewatering, hydrostatic testing, and floodplain clearing with subsequent erosion problems could also result in short-term water quality impacts. The effects of construction activity on water quality would be minimal and of short-term duration.

2. Accident Frequency and Severity - Accident frequency and severity related to construction activities were not discussed in the Dakota Transportation Project Report.

3. Manpower Requirements - The total manpower requirements for the four main line spreads would be 1,748 persons, averaging 437 persons per spread. Manpower requirements for the special spreads have not been determined. An additional 10 to 20 percent manpower requirement is estimated for survey, inspection, right-of-way acquisition, engineering, and other miscellaneous support functions. Approximately 65 percent of the work force would be nonlocal and transient.

4. Cost - The total installation cost of the proposed pipeline including land acquisition, materials, and construction cost, exclusive of the cost of the pipe, is estimated at $37 million. The total capital cost including all construction, equipment, pipe and other materials for the pipeline system, including the microwave towers and district office near Devils Lake, is estimated at $102.7 million in 1974 dollars. Approximately $1,284,800 for easements in North Dakota and Minnesota is included in the construction cost. Detailed economics, in 1974 dollars, are presented in Exhibits 2 and 3.

C. Operation

1. Environmental Residuals (Quantitative) - Since no compressor stations would be required, operation of the proposed pipeline would not be expected to affect air quality and noise levels along the proposed route. Operation and maintenance of the pipeline should not affect water quality along the proposed route due to appropriate erosion control measures.

2. Accident Frequency and Severity - The presence of the proposed pipeline within significant segments of railroad right-of-way in both urban and non-urban areas and potential impacts due to natural and third party accidents or catastrophes would be minimized by adherence to the Department of Transportation, Minimum Safety Regulations for Gas Pipeline Systems (49 CFR 192).

3. Manpower Requirements - Payroll costs of $125,000 per year, in 1974 dollars, are included in Exhibit 4. This figure represents the cost of ten additional employees' salaries and is the only indication of operating manpower requirements in the report. These payroll costs are listed as transmission expenses and do not include administrative and general expenses.

4. Cost - The total cost of service after possible credits for the proposed SNG pipeline is estimated to be $23,582,000, in 1974 dollars, for the first year of operation. Detailed cost of service economics, both before and after possible credits, are given in Exhibit 5 for the first, second and third years of operation. Additional supporting details are included in Exhibit 4.

III EXISTING PIPELINES

A. Description

1. Data Base - Basic statistical data concerning the natural gas industry is contained in three annual publications: 1) Gas Facts published by the American Gas Association, 2) Minerals Yearbook published by the United States Bureau of Mines, and 3) Statistics of Interstate Pipelines published by the Federal Power Commission.

   The American Gas Association is the gas utility industry trade association. Data contained in Gas Facts is developed through the voluntary cooperation of responding gas companies. Sources of information include American Gas Association questionnaires, reports filed with regulatory commissions, the Uniform Statistical Report (financial statement filed annually), financial publications, and other statistical reports. According to the American Gas

Association, reported data for 1975, the latest year currently available, represented 95 percent of total gas sales. The remaining five percent of the data was estimated from other sources. Presumably, although not specifically stated, the data base includes both interstate and intrastate pipeline systems.

The U.S. Bureau of Mines annually publishes the Minerals Yearbook. The latest edition currently available is 1973. The yearbook is published in three volumes concerning basic mineral statistics for the United States, individual states, and the world respectively. Although primarily concerned with the mining of minerals, Volume I contains a valuable chapter of statistics on natural gas. The Bureau of Mines also publishes a natural gas annual as part of the Mineral Industry Surveys series. Data is available for the year 1975. Much of the information is identical to that included in the Minerals Yearbook which takes considerably longer to publish.

The Federal Power Commission annually publishes basic statistical data entitled Statistics of Interstate Pipelines. The latest edition available is 1974. Data in this publication is compiled for Class A and B interstate natural gas pipeline companies and major interstate natural gas pipeline companies. Class A and B pipeline companies include those with gas operating revenues between $25,000 and $1,000,000 and represent more than 99 percent of natural gas sales by all interstate pipeline companies regulated by the Federal Power Commission. Major interstate companies represent those with annual combined sales for resale and interstate gas transported or stored for a fee in excess of 50 billion cubic feet. In 1974 thirty-four companies were classified as major interstate companies. The Federal Power Commission is concerned only with the regulation of interstate pipelines and this publication, therefore, does not contain data on the intrastate pipelines.

One other source of data which contains basic statistical information is the Federal Power Commission's National Gas Survey. The National Gas Survey was established on February 23, 1971. The organization of the survey consisted of the appointment of an Executive Advisory Committee to the

Federal Power Commission which retained overall responsibility for the survey. Technical advisory committees for supply, transmission, and distribution were established under the Executive Advisory Committee. Additional technical committees and coordinating committees were established as the survey progressed.

The results of the National Gas Survey were published in five volumes. Volume III dealt with the transmission segment of the natural gas industry and was published in 1973 and released in the summer of 1974. Three companion volumes concerning supply, distribution, and special reports were also published at that time. A summary volume (Volume I) was published by the Federal Power Commission in 1975.

The data contained in the National Gas Survey deals specifically with the interstate pipeline network although conclusions, in several instances, are extended to include the intrastate pipeline network. Unfortunately, in most cases 1970 was used as the base year. Therefore, the information is somewhat outdated particularly for economic statistics. Projections were made for subsequent years including 1975. However, personal communication with Federal Power Commission staff indicates that a widespread effort has not been undertaken to update the survey or validate the projections made (Reference 1). Despite this, the National Gas Survey remains a valuable reference tool particularly in attempting to avoid possible errors caused by applying raw statistical data to specific problems.

2. Existing Pipeline Network - Transport of high Btu gas occurs in gathering, where natural gas is transported from individual wells to a common compressor station, processing point or main pipeline, in transmission, where natural gas is transported from a source of supply to a distribution point or point of interconnection, and in distribution, where natural gas is transported to consumers. The focus of this section concerns the transmission system.

Transport of high Btu gas occurs by companies engaged in production (gathering), transmission, and distribution. Transmission companies are primarily engaged in the operation of a gas transmission system. Distribution companies are primarily engaged in the operation of a gas distribution system. Industry structure also includes integrated companies which operate both transmission and distribution systems and combination utilities which supply some other utility service in addition to natural gas. The focus of this section concerns transmission companies. Statistical data used has been separated to reflect this segment of the natural gas industry. Definitions of the natural gas industry system and structure developed by the American Gas Association are presented in Exhibit 6.

Exhibit 7 presents a complete gas flow diagram for the United States for the year 1975. This exhibit is presented as an aid in understanding the existing transmission pipeline network in the U.S. As indicated in the exhibit, an estimated 17.6 trillion cubic feet of gas was delivered to consumers in 1975. This volume of gas was transported through a pipeline network of 262,600 miles. This transmission network also includes compressors totaling an estimated 12.1 million horsepower (Reference 2, p. 49).

B. Operation

1. Energy Use - The U.S. Bureau of Mines reports that in 1975 fuel utilized in pipeline operation was 582,963 million cubic feet. This amount represents 3.3% of delivered natural gas to consumers in 1975 which was 17.6 trillion cubic feet. The U.S. Bureau of Mines does not differentiate the pipeline fuel utilized for field-gathering, transmission, and distribution systems.

   Hittman Associates reports that compressors are not normally used on distribution mains and in a similar calculation for the year 1970 apportioned the amount of fuel utilized between field-gathering and transmission systems based on the percentage of field-gathering and transmission pipeline mileage (Reference 3, p. V-7). Another equally valid method of deriving fuel requirements for transmission would be to apportion total fuel requirements based on the ratio of installed compressor horsepower on transmission systems to total-installed compressor horsepower. This has been done in Exhibit 8 which indicates that an estimated 414,200 million cubic feet of natural gas was used as pipeline fuel by the transmission segment of the gas industry in 1975.

2. Environmental Residuals - Environmental residuals resulting from high Btu gas transmission and distribution have been calculated by Hittman Associates. A summary of these residuals is given in Exhibit 9. The only environmental residual given by Hittman is the emission of nitrogen oxides. The figure quoted is 103 tons of nitrogen oxides (NO_x) emitted from compressor station operation per trillion Btu of gas processed. This quantity assumes that gas engines are utilized to drive the compressors. If gas turbines are utilized to drive the compressors, the corresponding quantity given by Hittman is 2.82 tons of NO_x per trillion Btu of gas processed.

A check of these values reported by Hittman indicates that the derivation was made by utilization of an emission factor of 7300 lb of NO_x per million cubic feet of gas fired for gas engines and 200 lb of NO_x per million cubic feet of gas fired for gas turbines. The corresponding figures are 7.3 and 0.2 lb of $NO_x/10^6$ Btu respectively with natural gas at 1000 Btu/scf. In 1970, 7.22×10^5 million cubic feet of gas was used as pipeline fuel. Hittman apportioned the amount of pipeline fuel used in transmission based on the percentage of field-gathering and transmission pipeline mileage as discussed in the previous section. The quantity of NO_x emitted was then calculated from the appropriate emission factor (Reference 3).

A study performed for the U.S. Department of Health, Education and Welfare (HEW) in 1970 derived estimated quantities of NO_x emitted by gas turbine and gas engine operation on natural gas pipelines in the United States during the year 1967. The data is presented in Exhibit 10. The data indicates that in 1967 approximately three-fourths of pipeline fuel requirements were for gas engines. Gas engines accounted for approximately 99 percent of nitrogen oxides emissions resulting from gas pipeline operation. Emission factors utilized for gas engines and gas turbines were identical to those used by Hittman. According to the report, pipeline fuel requirements between gas engines and gas turbines were apportioned based on Minerals Yearbook data for 1967. Unfortunately, a check of the most recent Minerals Yearbook for 1973 indicates that data presented in this edition would not enable an update of gas engine and gas turbine fuel requirements.

Since publication of the Hittman and HEW studies the U.S. Environmental Protection Agency (USEPA) has updated and revised the emission factors for gas engines and gas turbines. The revised values are given in Exhibit 11. A significant change was made for gas engines which now have a variable emission factor based upon engine load. For instance, as evidenced in Exhibit 11, the emission factor can vary from 12.6 lb $NO_x/10^6$ Btu of gas fired for an engine at 1000 hp to 3.0 lb of $NO_x/10^6$ Btu of gas fired for an engine at 100 hp. A significant change was also made for gas turbines by effectively doubling the emission factor to 0.4 lb $NO_x/10^6$ Btu (assuming natural gas at 1000 Btu/scf).

Environmental residuals resulting from operation of compressors for the entire gas utility industry in 1973 were estimated by the Southwest Research Institute (SWRI) in a study published in February, 1975. Emission factors used in the study were derived primarily from actual tests conducted at SWRI's Emission Laboratory in San Antonio, Texas. All work was sponsored by the American Gas Association.

The initial data base consisted of a survey of American Gas Association member companies. Operating data, model, and horsepower rating for gas engines and gas turbines were collected. Only gas engines and gas turbines over 1000 hp were considered. Individual emission factors for families of similar gas engines were utilized. This methodology was reviewed and approved by the Diesel Engine Manufacturers' Association (the association also covers gas engines). For the gas turbines, individual emission factors were utilized for each model. Test data was correlated with manufacturer data. The survey accounted for 86 percent of the gas industries installed compressor horsepower over 1000 horsepower and 75 percent of total installed compressor horsepower.

Survey data for the year 1973 are presented in Exhibit 12. Data is presented only for nitrogen oxides, carbon monoxide, and hydrocarbons. No attempt was made to estimate sulfur or particulate emissions. Gas engines accounted for approximately 70 percent of the installed horsepower, 71 percent of the total operating time, and 95 percent of the estimated nitrogen oxides emissions in 1973. Gas engines also accounted for over 90 percent of the carbon monoxide and hydrocarbon emissions.

Results from the survey were extrapolated by SWRI for the total gas utility industry and are presented in Exhibit 13. Emissions were extrapolated by the ratio of total gas utility industry installed compressor horsepower (14,858,000) as reported by the American Gas Association for the year 1973 to the installed horsepower for the survey (10,995,000). This method assumes that the proportion of gas engines and gas turbines below 1000 hp is not significantly different than that reported in the survey for gas engines and gas turbines over 1000 hp. It also assumes that emission factors for the population of gas engines and gas turbines below 1000 hp are not significantly altered.

The emission of nitrogen oxides reported by SWRI is significantly lower than the earlier figure calculated by the U.S. Department of Health, Education and Welfare. This point is addressed in the SWRI study which indicates that an emission factor for gas engines of 11 grams per brake horsepower-hour was utilized compared to a factor of approximately 26 grams per brake horsepower-hour in the previous study (Reference 4, p. 40). These values are equivalent to 3.0 lb $NO_x/10^6$ Btu and 7.3 lb $NO_x/10^6$ Btu respectively.

The Southwest Research Institute did not apportion the emission data between transmission and field gathering. An estimate was obtained of the transmission component of these emissions by taking the ratio of installed transmission horsepower to total installed horsepower for the gas utility industry times the estimated emissions for the gas utility industry in 1973 as reported by SWRI. These values are presented in Exhibit 14.

3. Accident Frequency and Severity - Occupational health statistics for many major industries and for certain specific industry groups are compiled annually by the National Safety Council. The program is voluntary and the National Safety Council relies on reports from participating industries and organizations for the statistical data base. Based on an evaluation of the reported injury rates, annual safety awards are made. The most recent occupational health statistics issued by the National Safety Council for selected industry groups are presented in Exhibit 15.

The data base does not permit the separation of deaths from permanent total disabilities. A death is defined as any fatality resulting from work. A permanent total disability is any disability other than death which permanently and totally incapacitates a worker from following any gainful occupation, or which results in the loss of, or the complete loss of use of, any of the following in one accident: a) both eyes; b) one eye and one hand, arm, leg or foot; or c) any two of the following not on the same limb; hand, arm, leg, or foot.

Statistics for the pipeline gas industry were included within the petroleum industry and represent pipeline gas operations of major petroleum companies. Other divisions within the petroleum industry group include drilling, engineering and general service, exploration, manufacturing, marine, marketing, natural gas processing, crude oil pipeline, pipeline products, production, and research and development. It is believed that the statistics quoted for the pipeline gas industry segment are the most representative for the existing pipeline transmission network since the occupational health statistics quoted for the gas industry in Exhibit 15 apparently include undifferentiated data for natural gas production, transmission, and distribution companies.

Reference data for the automobile and underground coal mining industries are included in Exhibit 15 for information purposes only. The automobile and underground coal mining industries had the lowest and highest disabling injury rate per million manhours among major industries classified by the National Safety Council in 1974 and therefore serve as a reference basis.

Actual comparisons between industries and comparisons on an historical basis within the same industry must be conducted with caution. The number of participants in the program varies within each industry category and fluctuations also occur in the number of participants within the same industry category from year to year.

In a more general sense, the voluntary nature of the program may result in bias toward greater participation from safety conscious companies. In other words, if statistics were gathered from the industry as a whole, greater disabling injury rates may be reported. In addition, the data base does not account for the basic hazardous nature of the particular industry. Although exhibiting relatively high disabling injury rates, a particular industry may actually be enforcing strict safety procedures but the high rates observed may in part be due to the potential danger of the particular occupation.

Similar statistics for natural gas transmission companies compiled by the American Gas Association are listed in Exhibit 16. The data reported includes only disabling injuries and mandays lost due to those injuries. Separate fatality statistics were not available. A comparison with Exhibit 15 indicates that a reasonably close correlation exists between data for the pipeline gas segment of the petroleum industry and natural gas transmission companies for the common year 1973.

Fatality rates of workers for major industries for the year 1975 are presented in Exhibit 17. Total fatalities and number of fatalities per 100,000 workers are included. Data for the gas industry is listed separately having been compiled within the major heading of Transportation and Public Utilities.

The Department of Transportation's Office of Pipeline Safety reports data with respect to gas pipeline failures. The data is differentiated with respect to occupational (job-related) and nonoccupational (civilian) fatalities and injuries for 1975. This data is presented in Exhibit 18. Approximately 60 percent of the gas transmission and gathering pipeline failures occurring in 1975 were caused by outside forces. In 1975, injuries resulting from nonoccupational exposure to gas pipeline failures were equivalent to those resulting from occupational exposure. One fatality was recorded for non-occupational exposure while five fatalities were associated with occupational exposure to pipeline failures in 1975.

4. Manpower Requirements - Gas utility industry employee and payroll statistics for investor-owned transmission companies for the period 1960-1975 are presented in Exhibit 19. Data was available for public-owned gas utilities but was not differentiated between distribution and transmission companies. Approximately 94.6 percent of the gas utility industry work force is employed by investor-owned utilities (Reference 2, p. 190).

   An analysis of the data indicates that in 1975 the average annual wage for an employee of an investor-owned gas utility was approximately $15,500. If the average wage paid to an employee involved with construction activities is the same as for an employee involved with pipeline operation, an estimate of the number of employees specifically involved with pipeline operation can be made from available data. These estimates for the period 1960-1975 are presented in Exhibit 20.

   Exhibit 20 also indicates the transmission pipeline mileages for each year. From this data, an estimate of the manpower requirements to operate the existing United States transmission pipeline network can be made. In 1975 an average of 0.12 men/mile were required to operate United States transmission facilities, or in other words 12 men per equivalent 100-mile section of pipeline. This figure apparently represents the total work force including office and administrative personnel and should not be interpreted as the manpower requirements for operation and maintenance crews. Although the manpower requirements decreased from 1960-1970 and then increased slightly in 1975, the limited historical data presented does not permit an evaluation of developing trends.

5. Cost - Operating expenses during 1975 for investor-owned natural gas transmission companies, as reported by the American Gas Association, are

presented in Exhibit 21. Total operating expenses including operation, maintenance, depreciation, and taxes were $10,560,000,000. These expenditures represented approximately 88.8% of operating revenues for 1975 of $11,898,000,000.

Cost of operation and maintenance are itemized in Exhibit 22. Subtotals are given for gas purchased, other production and purchasing expenses, storage, transmission, distribution, customer accounts, sales, and general and administrative expense components of the total operation and maintenance cost. As evidenced by the data, the cost of gas purchased by the transmission companies represented approximately 85 percent of the total cost of operation in 1975.

A further summary of the basic cost data is presented in Exhibit 23. The data is listed in the form of total operating, operation and maintenance expenses with the transmission component of each category listed separately.

IV NEW LARGE SCALE PIPELINES

A. Northern Border Pipeline

The information in this section is summarized from the North Border volume of the Alaska Natural Gas Transportation System final environmental impact statement (FEIS) issued by the U. S. Department of the Interior in March, 1976.

1. Description

a. Pipeline - The proposed Northern Border Pipeline is a 1,619-mile buried pipeline for the transportation of natural gas from Morgan, Montana to a final termination point near Delmont, Pennsylvania. The Northern Border Pipeline is the final segment of the proposed Arctic Gas Pipeline, a 5,580-mile pipeline for delivery of natural gas from fields discovered at Prudhoe Bay, Alaska to markets in the continental United States. The Arctic Gas Pipeline would transport 4.5 billion cubic feet per day (bcfd) of natural gas. One-half of this quantity would be derived from the Prudhoe Bay fields for delivery to the United States and the remaining gas would be derived from the MacKenzie Delta area of Canada for delivery to Canadian markets.

Ownership of the Northern Border Pipeline would consist of a partnership of affiliates of Northern Natural Gas Company, Michigan-Wisconsin Pipe Line Company, Natural Gas Pipeline Company of America, Panhandle Eastern Pipe Line Company, Columbia Gas Transmission Corporation, and Texas Eastern Transmission Corporation. These companies serve a 29-state area of the north central and northeastern United States. Natural gas will be delivered to the member companies at 10 distribution points along the length of the pipeline.

Daily average design capacity for the pipeline would be 1655.0 MMCFD under summer conditions (1885.3 MMCFD winter conditions) at the inlet. Under summer conditions the delivery volume of gas would be 1612 MMCFD (1826.8 MMCFD winter conditions). The pipeline would range from 24 to 42 inches in diameter with a wall thickness of 0.368 to 0.930 inches. Natural gas delivery points and delivery volumes for the Northern Border Pipeline are summarized in Exhibit 24.

Gas would enter the pipeline at 1,435 psig. Twelve compressor stations would be located along the pipeline to maintain this pressure. A listing of pertinent design information for the compressor station sites is given in Exhibit 25. Nine of the compressors are rated at 30,000 hp while three of the compressors are rated at 13,500 hp. The compressors would be driven by gas turbines. The turbines would utilize fuel from the pipeline itself. Additional auxiliary equipment for the pipeline would include 13 measuring stations (one measuring station at each of the ten delivery points and one measuring station at each of three emergency delivery points), a communication system consisting of 87 microwave towers, and 100 block valves. The Northern Border Pipeline would contain no gas treatment facilities since the gas being transported from Alaska would already have undergone purification.

b. Terrain - The Northern Border Pipeline would traverse all or portions of Montana, North Dakota, South Dakota, Minnesota, Iowa, Illinois, Indiana, Ohio, West Virginia, and Pennsylvania. Land requirements have been estimated at 20,736 acres for construction and 11,516 acres (permanent) for operation. A summary of the anticipated land requirements is included in Exhibit 26. The pipeline will require a 100-foot right-of-way during construction. A 54-foot right-of-way would be maintained during operation and 40 feet of this right-of-way would be maintained free of tall shrubs and brush.

The 1,619-mile pipeline would traverse through a variety of different land usage patterns. The predominant land usage, however, would be cultivated agricultural land. The type of land use throughout the length of the pipeline is identified in Exhibit 27.

Topographic features of the proposed route which passes "across the glaciated northern part of the midcontinent region from the western Great Plains to the plateau country of western Appalachia" are limited. Along much of the route the local relief ranges from one to five ft/mile. The general lack of topographic relief is due primarily to the fact that this region was glaciated. Minimum and maximum altitudes over the entire length of the pipeline are approximately 460 feet in Illinois and 3,050 feet in Montana.

Actually the pipeline enters the continental United States at 2,650 feet in altitude and terminates at 1,340 feet in altitude. The most prominent topographic features along the route are the valleys of the Missouri, Ohio, and upper Mississippi Rivers. These valleys are approximately 100 to 300 feet in depth and extend in cross sections for distances up to four miles. In all, twelve major rivers would be crossed by the pipeline. A number of other steep valleys exist along the proposed route although of much narrower width. Three other prominent topographic features which exist along the proposed route include the Killdeer Mountains of west-central North Dakota, and the Couteau's du Missouri and des Prairies in east-central South Dakota.

c. Construction Procedures - Construction of the pipeline will consist of the following operations: 1) stringing, 2) trenching, 3) bending, 4) line up, 5) welding, 6) pipe coating, 7) lowering in, and 8) backfilling. The stringing operation results in the unloading of pipe sections hauled to the construction area by truck from designated pipe storage areas. The pipe is deposited in a continuous line along the pipeline right-of-way in advance of trenching and pipelaying crews.

Trenching is accomplished by rotary wheel ditching machines or mechanical backhoes in soft strata and by tractor-drawn rippers and mechanical backhoes in rock strata. If the tractor-drawn rippers cannot be used, drilling and blasting are required. Mats are used to cover the area preventing unnecessary scatter of rock debris and provide a measure of personnel safety. The trench is generally excavated to a depth of 30 to 36 inches greater than the diameter of the pipe in soft strata and 18 to 24 inches in rock strata. The Northern Border Pipeline would be approximately five and one-half feet wide at trench depth. Topsoil would be removed separately, stockpiled, and reapplied at the surface depending on the requirements of the individual landowner.

Bending is accomplished by a track mounted hydraulic bending machine. All pipe is to be delivered in straight sections and the bending operation, where necessary, is performed in the field.

The line-up operation consists merely of the proper positioning of the newly delivered pipe sections to the forming pipeline. Welding serves to attach the new pipe section to the continuous pipeline which is laying beside the trench. Welded portions are placed on supports along the length of the trench. A visual check of welds is made by a qualified inspector and radiographic inspection is conducted according to federal standards for natural gas pipelines.

Pipe coating involves the external coating of the pipeline with corrosion resistant material such as coal tar, epoxy material, or plastic. Electronic detectors are used to locate defects in the coating. All defects are re-coated prior to the lowering in operation.

Side boom tractors are utilized to lower the welded pipe sections into the trench. In rock strata a layer of padding material, usually sand or gravel from the nearest commercial source, is used on the bottom of the trench. After the pipe is lowered into the trench it is inspected for possible damage to the pipe coating. If deemed necessary, a shield of asphalt or fiber will be installed to protect the pipe in the backfilling operation.

The final construction operation is backfilling which deposits extracted fill material (stored at the side of the trench) above the pipeline. Excavated material which is unsuitable for use during backfilling is disposed of in a landfill site approved by the landowner. Replacement backfill materials, where required, may be obtained from commercial borrow pits. Subsoil and stored topsoil will be replaced separately where the landowner requires it. The surface will be graded to conform to the natural contour of the surrounding land. A small crown of additional material will be present initially until natural subsidence occurs. Appropriate grasses will be seeded along the right-of-way to provide for vegetation restoration.

Where appropriate, special construction techniques will also be employed. The crossing of all state, national, and interstate highways, and all railroads will be accomplished by a boring and casement method. This method involves the excavation of a large pit on each side of the road or railroad and the insertion of a casing or tunnel liner. The pipeline in turn will be inserted within the casing. These activities are usually completed ahead of conventional pipe laying.

Special techniques will also be employed in crossing the 12 major rivers identified previously. Various dredging methods can be employed in these circumstances including the use of backhoes, draglines, clam dredges, dipper dredges or a combination of these. The use of each piece of equipment will depend largely on the condition of the stream and its underlying strata. For instance, a dragline will most probably be utilized for large rivers with unconsolidated bottom sediments or wide floodplains.

The pipeline would be installed by a bottom pull method, floating barge method, or a barge method. In the bottom pull method of pipe installation, a winch located on one side of the river pulls lengths of welded pipe from the opposite side of the river. Individual pipe sections are stored on a rack and then moved on a roller track for welding to the pipeline being pulled by the winch.

In the floating barge method lengths of pipe equal to the river width are welded together on a barge. The barge is then positioned along the pipeline trench and welded to completed pipeline sections on each side of the river bank. The completed pipeline is then lowered to the riverbed.

The barge method involves anchoring a barge containing sections of coated pipe on one side of a river. Welding is done on the barge and the pipe is continually fed out along rollers as the barge proceeds to the opposite river bank. A summary of the major materials and supplies to be utilized during construction of the pipeline is presented in Exhibit 28.

After construction of the pipeline is completed, hydrostatic testing will begin. This procedure involves the testing of the completed pipeline for leaks using water. Each mile of pipeline will require the use of 380,000 gallons of water and testing will occur in 20-mile segments. Test water will be drawn from approved sources and will normally be discharged to established surface waters. Water quality degradation resulting from the discharged water is expected to be minimal.

2. <u>Construction</u>

   a. <u>Environmental Impacts (Qualitative)</u> - A detailed analysis of the environmental impacts associated with construction activities of the Northern Border Pipeline project is beyond the scope of this report. However, a brief summary of some of the unique and important impacts as detailed in the FEIS of the U.S. Department of the Interior (USDI) follows.

According to the USDI, pipeline construction will lead to a decrease in microbial activity and contamination of the topsoil along the corridor route due to a mixing of the soil profile. The overall result will be reduced productivity of the land. This effect will be most pronounced in the agricultural growing areas of the Midwest. It should be noted, however, that, as previously mentioned individual landowners may request the segregation of topsoil and lower strata.

Another adverse environmental effect of construction identified by the USDI was the possibility of lowered productivity of agricultural land resulting from disruption of tile drain fields. This effect would also be most heavily experienced in Midwestern agricultural regions. Possible adverse environmental effects were also identified for the Eastern portion of the pipeline route by the USDI in the form of mud slides.

Specifically, the pipeline route crosses prime waterfowl habitat areas in North and South Dakota and Minnesota. Loss of habitat and harassment of wildlife during construction will occur. Another definite impact listed by the USDI was the alteration of wildlife habitat due to the maintenance of a brush and tree-free corridor for the pipeline route.

b. Accident Frequency and Severity - Little quantitative information on anticipated accident frequency and severity statistics is contained in the USDI FEIS for construction of the Northern Border Pipeline project. The applicants do state that all provisions of the Occupational Safety and Health Act (OSHA) will be complied with. The possible mud slides identified above which may occur during construction of the eastern portion of the pipeline route may result in loss of life.

c. Manpower Requirements - Scheduled operation of the Northern Border Pipeline is July 1, 1980. Pipeline construction would occur primarily in the summer months according to the following schedule: May 1978 through November 1978, May 1979 through November 1979, and May 1980 through June 1980. All compressor stations would be constructed from May 1979 through June 1980. Each station is expected to be completed within six months. Communication towers are scheduled for construction from May 1979 through April 1980 with each individual tower constructed within approximately six to eight weeks.

Estimated manpower requirements for construction of the Northern Border Pipeline are given in Exhibit 29. The construction activities would employ a maximum of about 6000 men in any given year. Some duplication of work force may occur. For instance some workers listed under river crossing construction in Exhibit 29 may also be included under pipeline construction. Communication tower construction will require an estimated 15-21 workers per tower but the construction crews would be utilized for other construction activities and are not listed separately in Exhibit 29. It is expected that an additional work force of 10 to 20 percent would be needed for survey, inspection, right-of-way acquisition, engineering and other support functions.

d. Cost - Capital cost data for construction of the Northern Border Pipeline are given in Exhibit 30. Total estimated cost of the pipeline is given as $1.347 billion (1974 dollars) including direct and indirect costs, and allowance for funds used during construction. Escalation was not included.

3. Operation

a. Environmental Residuals - The major environmental residual produced during operation of the pipeline would be nitrogen oxides (NO_x) emitted from the gas turbine at each of the twelve compressor stations. The USDI FEIS suggests the use of a maximum gas turbine emission rate of 0.50 lb $NO_x/10^6$ Btu of gas fired. As evidenced in Exhibits 24 and 25, the combined fuel usage of the compressor stations is 34.9 MMCFD for a gas delivery of 1612.0 MMCFD in summer and 49.4 MMCFD for a gas delivery of 1826.8 MMCFD in winter. Other losses in pipeline operation are given under the heading "company use and unaccounted for losses" at 8.0 MMCFD for summer operation and 9.2 MMCFD for winter operation. The anticipated overall efficiency of pipeline transmission is therefore 97.4% and 96.9% for summer and winter, respectively.

Using the fuel usage data, the suggested maximum NO_x emission rate, and a heating value for natural gas of 1000 Btu/SCF a combined total of approximately 730 lb NO_x/hr in summer and approximately 1030 lb NO_x/hr in winter would be emitted from the twelve compressor stations. Due to the fact that the compressor stations will utilize pipeline quality fuel in operation, emission of hydrocarbons, carbon monoxide, particulates, and sulfur oxides is expected to be negligible according to information in the FEIS.

b. Accident Frequency and Severity - Information concerning anticipated accident frequency and severity rates for the operational phase of the Northern Border Pipeline is not contained in the FEIS. However, the FEIS does indicate operational, maintenance, and emergency procedures designed to ensure safe operation of the pipeline. The extensive communication system consisting of 87 microwave communication towers is designed to monitor and control the pipeline in a safe and reliable manner. It is anticipated, therefore, that full-time maintenance personnel will not be required for stationing at facilities along the pipeline route. It is anticipated, however, that maintenance personnel will visit compressor and delivery sites periodically as required by operating conditions. Other facilities would be checked on an established schedule. Personnel would be located along the system to reach any area in case of emergency. Periodic maintenance would be conducted for all machinery with moving parts both on a periodic and scheduled time-of-use basis. The pipeline would be monitored for corrosion control and surveillance would be conducted to determine erosion damage and right-of-way encroachment.

The pipeline would contain 100 block valves with automatic self-actuated gas operators. The pipeline can, therefore, be isolated in segments in the event of an emergency failure. Additional safety measures in the proposed design include gas detectors equipped with alert and alarm mechanisms in gas transmission facility buildings, safety devices to prevent overpressuring natural gas at the compressor station, and additional safety devices which will isolate the compressor stations if fire or explosive gas mixtures are detected.

An operations and maintenance manual for the pipeline system would be issued. This manual would detail plans for emergencies and system malfunctions. Operating personnel would have access to maps and diagrams as aids in shutting down and isolating the system.

c. Manpower Requirements - Preliminary plans call for staffing two division offices and seven district offices for operation and maintenance of the pipeline. Approximately 200 employees would be required to operate the system.

d. Cost - No estimates of anticipated operating costs are available in the USDI FEIS for the Northern Border Pipeline. Annual payroll for operating and maintenance personnel was estimated at $300 million with an average wage of $15,000 per year.

B. Refugio-Waha Pipeline

The information in this section is summarized from the Refugio-Waha Pipeline Project, Final Environmental Impact Statement (FEIS) issued by the Federal Power Commission, Bureau of Natural Gas, Docket No. CP73-260.*

1. Description

a. Pipeline - El Paso Natural Gas Company's (El Paso's) proposed Refugio-Waha pipeline project would consist of approximately 418.5 miles of 24-inch diameter natural gas pipeline with five natural gas fired, gas turbine-

* Subsequent to the preparation of this section, personal communication with El Paso Natural Gas Company representatives in February 1977 revealed that plans for the Refugio-Waha pipeline project have been cancelled.

driven centrifugal compressor stations located at 80- to 90-mile intervals along the pipeline. The proposed pipeline would transport an average of 0.3725 bcfd (maximum capacity - 0.425 bcfd) of natural gas from an existing Transcontinental Gas Pipeline Corporation (Transco) pipeline in Refugio County, Texas to El Paso's existing 36-inch diameter main transmission pipeline near El Paso's Waha Treatment and Dehydration Plant near Coyanosa, Texas. The gas would become available to El Paso by displacement resulting from a proposal to import liquefied natural gas (LNG) from Algeria into the United States at Gloucester, New Jersey. Transco would receive the LNG in New Jersey and divert gas in Texas to El Paso in exchange for the LNG. The natural gas delivered by the pipeline would be used to supply projected demand by El Paso's customers in New Mexico, Arizona and California.

The first compressor station near Refugio, Texas would consist of two compressor units with a total rating of 24,100 hp. Support facilities for this station would include fuel and starting gas facilities with gas measurement regulators, cooling equipment, instrument air compression, storage tanks for instrument air, make-up oil, and water; a combination office, shop, and auxiliary building; standby electric generating facilities, a water well (if no local source is available) and a minimum of two houses to be used as living quarters for operating personnel. Transmission pressure along the pipeline would be maintained by four 6,654 hp compressor stations, each consisting of two 3,327 hp units and support facilities similar to the Refugio Compressor Station. Additional above-ground installations along the proposed pipeline would include 20 to 30 sectionalizing block valves spaced at 15- to 20-mile intervals, standard rectifier installations, cathodic test points and bond installations.

b. Terrain - The proposed pipeline would be located in fifteen Texas counties beginning in Refugio County and extending in a north-northwesterly direction through the counties of Goliad, Bee, Karnes, Live Oak, Atascosa, Medina, Bandera, Kerr, Real, Edwards, Sutton, Crockett, and Pecos terminating in Reeves County. For approximately the first 140 miles the pipeline would cross the West Gulf section of the Gulf Coastal Plain Province, a former continental shelf of low topographic relief. From east to west the pipeline would cross the Hockley, Oakville, Nacogdoches, and Balcones Escarpments, an area of rolling hills usually no more than 100 feet above the adjacent land.

For the next 250 miles, beginning at the Balcones Escarpment the pipeline would cross the Edwards Plateau section of the Great Plains Province with an increase in elevation from 1,000 feet at the base to 2,400 feet at the summit, about 50 miles inland. The Edwards Plateau is a gently sloping plain furrowed by streams.

From the Edwards Plateau the pipeline would continue for about 25 miles through the Pecos Valley section of the Great Plains Province ending at Waha. The Pecos Valley is a long trough 5 to 30 miles wide cut by the Pecos River.

Land usage in the area to be crossed by the proposed pipeline is predominantly agrarian, with the market value of agricultural sales about evenly divided between crops and livestock. Total land requirements for right-of-way activities would be about 3100 acres with an additional 400 acres required for access roads, borrow pits, holding ponds and storage areas. Permanent aboveground facilities other than right-of-way would occupy about 40 acres.

c. Construction Procedures - Construction of the proposed pipeline would mainly be accomplished by the conventional lay method within a 60-foot right-of-way cleared of all vegetation. Construction would begin in January of 1977 and be completed in July of the same year. The conventional lay method requires the use of ditching machines to excavate a trench sufficiently wide and deep to accommodate the 24-inch diameter pipe and adequate soil cover when the pipeline is in position. This technique removes subsoil and topsoil together and places it along one side of the trench for use as backfill.

Farmland would be trenched using the double-ditching method in which topsoil is removed first followed by the removal of the subsoil. Separate storage and replacement of the topsoil prevents mixing with the subsoil. Also, in irrigated farmland, water settled compaction around the pipeline and pneumatic tamping of the surface would be used to prevent subsidence of backfill and to reduce topographic alteration. Land compacted by heavy equipment would be plowed and disced upon completion of construction.

Blasting would be used for excavation in rocky areas. Soil to be used as "padding" material would be excavated from borrow pits. Each mile of blast excavated right-of-way would require a borrow pit of one to one and one-half acres and six feet in depth.

Pipeline crossings of twenty paved roads and six railways would utilize the bore and casement method. Four permanent and 45 intermittent streams would be crossed within a narrowed right-of-way using a trenching technique designed for a minimum impact for each individual crossing. Existing pipelines to be crossed would be exposed by hand and machine trenching and would be properly supported.

Water for hydrostatic testing of the pipeline would be obtained from local sources and stored in one-acre holding ponds from two to four feet in depth. Each five-mile section of the pipeline would require about 670,000 gallons of test water which would be returned to nearby sources or, in dry areas, would be reused for testing successive sections of the pipeline.

Construction of the Refugio Compressor Station would require clearing of eight to ten acres while each of the four smaller compressor stations would require about eight acres. Each site would be cleared, graded, and surfaced with free draining material to a depth of six to ten inches.

All trees and other vegetation cleared from the right-of-way would be stacked and either burned or removed to a disposal site. No trees or shrubs would be allowed to grow on a 20-foot wide grass covered center strip of right-of-way to allow access for maintenance. The remaining 20-foot wide strips on each side of the 60-foot right-of-way would be planted with small native shrubs.

Borrow pits, water holding ponds, and temporary access roads would be restored to their original state or left for the use of the landowner, if so desired. Where access roads cross fences, gates would be installed and kept locked.

2. Construction

a. Environmental Impacts (Qualitative)* - Construction of the proposed pipeline project would require the clearing of a total of about 3500 acres of land. Clearing of the land would temporarily expose the soil to wind and water erosion until revegetation of the ground cover occurs. In some areas erosion will remove soil, with resulting delay in the reestablishment of vegetation.

The construction of temporary access roads may result in minor topographic changes. These road areas would be restored to their original state, if the landowner so desires. The use of explosives for excavation may also result in minor changes in land features in rocky areas. Spoil produced by blasting would be used as backfill or be graded into the right-of-way. Blasting should not affect any natural landmarks in the area.

The conventional trenching methods to be used for most of the pipeline would result in the mixing of topsoil with less fertile subsoils, but would improve soil aeration and permeability. Farmlands would be trenched using the previously described double-ditching technique to avoid mixing of the topsoil and subsoil.

The temporary effects of the proposed construction on wildlife would result from disruption of soil, destruction of vegetation and wildlife habitat, increased dust, noise, vehicular traffic and human presence.

* The environmental impacts associated with construction activities were summarized from the FEIS.

The effects of construction on the aquatic habitat and water quality would result from disruption of streams and rivers at pipeline crossings, water use for hydrostatic testing, and surface runoff from cleared areas. These effects would be confined to small areas and would be only temporary.

Rare or endangered species would be affected by construction to varying degrees depending on the particular species and the steps taken to avoid adverse effects on each. Since the area to be disturbed is only a small part of the total habitat, there should be no threat to any of the less range-restricted species. Included in this group are the: red wolf, Mexican wolf, desert fox, ocelot, cougar, southern bald eagle, peregrine falcon, and whooping crane.

Rare or endangered aquatic species found in the area include the: American alligator, Valdina Farms salamander, Texas blind salamander, and the following fish: toothless blindcat, widemouth blindcat, Comanche Springs pupfish, Clear Creek gambusia, Pecos gambusia, and fountain darter. Care in the selection of sources of test water would prevent any adverse effects on these species.

The burrowing owl, black-capped vireo, and golden-cheeked warbler would all be affected by loss of habitat due to construction. Adverse effects on the vireo and warbler can be reduced by avoiding the scrub-oak and juniper-oak habitats they respectively require.

Attwater's greater prairie chicken could be adversely affected if the tall-grass prairies it resides in were destroyed. The black-footed ferret could be adversely affected by effects on its sole prey, the black-tailed prairie dog. Adverse effects on the prairie dog, ferret, and prairie chicken could be avoided by careful placement of the pipeline to reduce the impact on the required habitat.

Temporary increases in the emission of air pollutants and noise from vehicles and construction machinery would have only minimal effects on the area immediately adjacent to the construction activities.

b. Accident Frequency and Severity - There is a potential for accidents resulting from construction of the proposed pipeline. Construction related accidents could occur in any phase of the project and would be no more frequent than any other industrial-type construction involving trenching, blasting, and use of heavy equipment.

c. Manpower Requirements - Construction of the proposed pipeline would require up to 1200 workers, divided into spreads of 150 to 300 workers each. These work crews would cover about 15 miles of pipeline in about ten days completing the pipeline in seven months.

The Refugio Compressor Station would require a crew of about 100 workers for a five-month period, while the four smaller compressor stations would each require crews of about 50 workers for four to five months.

d. Cost - The cost of the proposed pipeline project, consisting of approximately 418.5 miles of 24-inch diameter pipeline, five gas turbine-driven centrifugal compressor stations housing ten compressor units, with a combined output of 50,716 horsepower and miscellaneous appurtenant facilities, is estimated to be $87,999,014.

3. Operation

a. Environmental Residuals (Quantitative) - Since only 40 of 3,100 acres of right-of-way would be devoted to aboveground facilities, the effects of operation and maintenance on land use would be minimal.

The use of natural gas as fuel for the compressors would result in regular emissions of nitrogen dioxide (NO_2). The NO_2 emission rates of the proposed compressor stations would be approximately 6 lb/hr for each of the four 6,654 hp stations and approximately 43 lb/hr for the 24,100 hp Refugio station.

b. Accident Frequency and Severity - Post construction accidents would generally be related to pipeline failure. There were 43 reportable pipeline failure incidents* for El Paso's transmission and gathering lines from 1968 through 1972. Twenty of these were due to testing of pipelines involving controlled stressing above the normal maximum operating pressure. Of the remaining 23 operational incidents, approximately 60 percent were due to material failure, construction defects, or corrosion, while about 40 percent were caused by outside forces, such as damage to the buried pipeline by excavating equipment, damage from floodwaters, and sabotage. The average occurrence of all reportable pipeline incidents during this period, including testing, was 0.699 incidents per 1,000 miles of pipeline per year as compared to an industry-wide average of 1.233 incidents per 1,000 miles of pipeline per year.

In the same five-year period, the accidents on El Paso's pipeline system resulted in five fires and three explosions with two fatalities and three injuries. The frequency rate of injuries was 5.77 injuries per million man-hours, while the overall industry average was 8.38. About 79.3 percent of El Paso's operational incidents from 1968 through 1972 occurred in rural or underdeveloped areas.

c. Manpower Requirements - Operational crews would consist of one or two employees living at each compressor station camp. These crews would perform routine maintenance required for normal operation. They would also conduct periodic inspections of the right-of-way to check for malfunctions and to cut back woody growth that might impair access to the pipeline.

* Reportable incidents are defined as those which result in a death or injury requiring hospitalization, require the removal from service of any segment of transmission pipeline, result in gas ignition, cause an estimated total property damage of $5,000 or more, or are regarded as significant accidents even though none of the above criteria are met.

d. Cost - Costs of operating and maintaining the proposed pipeline project over a 25-year life are summarized in Exhibit 31.

V SUMMARY

The proposed Dakota Transportation Project of Great Lakes Gas Transmission Company (Great Lakes) would transport 0.275 bcfd of substitute natural gas (SNG) from a coal gasification plant in North Dakota to an existing Great Lakes natural gas pipeline in Minnesota. The 365-mile long 30-inch diameter, high pressure pipeline would require no compressor stations but would include five microwave communications towers, a series of main line valves, and a district headquarters. The pipeline would follow existing railroad right-of-way almost entirely and would encounter little topographic variation. Pipeline construction procedures appear to be typical of the methods used by the industry.

The Dakota Transportation Project would be constructed in a single phase from April or May through November in 1980, but certain areas would be constructed during winter months to mitigate impacts on wetland areas. Environmental impacts related to construction activities are expected to be minor and short-term due to the almost exclusive use of existing railroad right-of-way. The Great Lakes report indicates that disturbance of vegetative cover, alteration of the soil profile and soil productivity, and disturbances to waterfowl nesting and brood rearing along the proposed route are the greatest concerns. Construction of the pipeline would require 1,748 persons for the four main line spreads. Manpower requirements for the special spreads have not been established. The total capital cost of the pipeline project is estimated at $102.7 million in 1974 dollars.

Since no compressor stations would be required, environmental residuals resulting from the operation and maintenance of the proposed SNG pipeline should be minimal. Ten employees would be required to operate the pipeline. Total cost of service after possible credits is estimated at $23,582,000 in 1974 dollars for the first year of operation (1981).

In 1975 the transmission of natural gas consumed an estimated 414,200 million cubic feet of natural gas. It is estimated that a total of approximately 595,000 tons/yr of nitrogen oxides, 76,000 tons/yr of carbon monoxide, and 222,000 tons/yr of hydrocarbons were emitted from natural gas transmission pipeline compressor operations in 1973. Estimates of emission of sulfur oxides and particulates were not available in the literature.

In 1975 five deaths due to occupational exposure to gas pipeline transmission and gathering failures were reported. There was one death recorded due to nonoccupational exposure. Available data in the literature did not permit calculation of the numbers of deaths/million man-hours. However, a factor of 0.37 deaths and permanent disabilities/million man-hours was reported for the pipeline gas segment of the petroleum industry for the year 1973. An average 6.37 disabling injuries/million man-hours was reported for natural gas transmission companies in 1975. These injuries resulted in 785 man-days lost/million man-hours in 1975.

Manpower requirements for the existing United States natural gas pipeline network were estimated at 0.12 men/mile of pipeline. The transmission component of operation and maintenance expenses for gas transmission companies in 1975 was given in the literature as $529,000,000 and $132,000,000 respectively.

New large scale pipelines recently proposed for expansion of the existing United States pipeline network include the Northern Border Pipeline segment of the Arctic Gas Pipeline and the Refugio-Waha pipeline project in Texas.* The Northern Border Pipeline is unique in two principal respects, its size and length. Delivery volume of gas would range from 1612 MMCFD to 1827 MMCFD. The pipeline would be 1619 miles long traversing all or portions of ten states. Formed by a partnership of affiliates of six natural gas transmission companies, the pipeline would include installation of 12 compressor stations, 13 gas measuring stations, 87 microwave communication towers, and 100 block valves. Terrain over which the pipeline passes is generally characterized by a lack of topographic relief. Construction procedures

* Plans for the Refugio-Waha pipeline project have been cancelled, see footnote on p. 31.

do not appear significantly different than those generally employed within the industry for pipeline construction.

Construction of the Northern Border Pipeline is expected to begin in May, 1978 with operation scheduled for July 1, 1980. Construction would occur primarily in the summer months. Environmental impacts associated with construction should not be significantly different than for any other large scale pipeline. Information contained in the FEIS indicates that soil productivity problems due to mixing of the soil profile and disruption of tile drain fields in addition to the crossing of some prime waterfowl habitat are the major considerations. Capital cost of the pipeline is estimated at $1.347 billion (1974 dollars) not including escalation. Construction activities could employ up to 6000 men in any given year.

Environmental residuals resulting from pipeline operation are expected to be limited to emission of nitrogen oxides at compressor stations along the pipeline route. Approximately 200 men will be required to operate the pipeline including the staffing of division and district offices.

The proposed Refugio-Waha Pipeline of El Paso Natural Gas Company (El Paso) would consist of 418.5 miles of 24-inch diameter natural gas pipeline, five compressor stations and 20 to 30 sectionalizing block valves. The pipeline would transport from 0.3725 to 0.425 bcfd of natural gas from an existing Transcontinental Gas Pipeline Corporation (Transco) pipeline to an existing El Paso pipeline. The gas would become available to El Paso in exchange for liquefied natural gas (LNG) delivered from Algeria to the United States at Gloucester, New Jersey. Transco would receive the LNG in New Jersey and deliver displaced natural gas to El Paso in Texas. The pipeline would extend through fifteen counties in Texas, encountering rolling hills, a plateau area, and a large river valley. Pipeline construction procedures appear to be typical of the methods used by the industry.

The Refugio-Waha Pipeline would be constructed in about seven months, from January through July of 1977. Environmental impacts of construction identified in the FEIS include destruction of vegetative cover and wildlife habitat, disruption of soil, and temporary effects on air and water quality along the proposed route.

Construction of the pipeline would require up to 1200 workers, divided into spreads of 150 to 300 workers each. The total capital cost of the project is estimated to be $87,999,014.

Environmental residuals resulting from the operation and maintenance of the proposed pipeline would be mainly the emissions of nitrogen oxides due to the operation of compressors at the five compressor stations along the proposed route. Operation of the pipeline would require one or two employees at each of the five compressor stations.

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2. Gas Facts. American Gas Association, 1975.

3. Environmental Impacts Efficiency and Cost of Energy Supply and End Use. Hittman Associates, Inc., Hit-593, Volume I. November, 1974.

4. Urban, C. M. and K. J. Springer. Study of Exhaust Emissions from Natural Gas Pipeline Compressor Engines. Project PR-15-61. Southwest Research Institute. February, 1975.

MATERIAL REQUIREMENTS FOR A TYPICAL
MAIN LINE PIPELINE CONSTRUCTION SPREAD *
DAKOTA TRANSPORTATION PROJECT

Item	Quantity	Percent Obtained within 30 Miles of Construction Site
Diesel Fuel (gal.)	572,600	100
Gasoline (gal.)	143,100	100
Lube Oil (gal.)	7,900	100
Grease (lbs.)	3,400	100
Welding Rod (lbs.)	144,300	0
Steel (tons)	7,900	1
Asphalt (tons)	1,800	0
Sand (yds.)	2,100	100
Cement (tons)	100	100
Gravel (yds.)	4,100	100
Skids and Timbers (tons)	60	0

*Construction of the pipeline would require four main line spreads.

Source: Dakota Transportation Project. Great Lakes Gas Transmission Company. Application for a Certificate of Public Convenience and Necessity. Before the Federal Power Commission. Docket No. CP75-283. Volume III. March, 1975. pp. 1-27.

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EXHIBIT 1
SL—3600

CONSTRUCTION COST ESTIMATE
PIPELINE DAKOTA TRANSPORTATION PROJECT
(1974 DOLLARS)

Item	Material	Installation	Total
Right-of-Way and Damages	$ -	$ 1,284,800	$ 1,284,800
Pipe	50,787,300	34,689,600	85,476,900
Coat and Wrap	1,387,600	-	1,387,600
Road and Railroad Crossings - Cased	119,500	222,000	341,500
Concrete Pipe Weights	2,187,200	2,353,200	4,540,400
Main Line Valve Assemblies	821,800	714,600	1,536,400
Scraper Traps	136,300	118,500	254,800
Radiographic Inspection	-	963,600	963,600
Engineering and Supervision*	-	3,409,100	3,409,100
Total Direct Cost			$ 99,195,100
Organization and Management, 1%			992,000
Subtotal			$ 100,187,100
Allowance for Funds Used During Construction, 2-1/2%			2,504,700
Total Estimated Cost of Construction			$ 102,691,800

*Included as a direct cost in environmental report.

Source: Dakota Transportation Project. Great Lakes Gas Transmission Company. Application for a Certificate of Public Convenience and Necessity. Before the Federal Power Commission. Docket No. CP75-283. Volume I. March, 1975. Exhibit Z-2. pp. 3.

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EXHIBIT 2
SL—3600

CONSTRUCTION COST ESTIMATE – DISTRICT
OPERATING HEADQUARTERS AND COMMUNICATION TOWERS
DAKOTA TRANSPORTATION PROJECT (1974 DOLLARS)

Item	Material	Installation	Total
District Operating Headquarters	$ 493,500	$ 37,500	$ 531,000
Engineering and Supervision*	-	25,000	25,000
Total Direct Cost			$ 556,000
Organization and Management, 1%			5,600
Subtotal			$ 561,600
Allowance for Funds Used During Construction, 2-1/2%			14,000
Total Estimated Cost of Construction			$ 575,600
Communication Towers	122,000	-	122,000
Engineering and Supervision*	-	6,100	6,100
Total Direct Cost			$ 128,100
Organization and Management, 1%			1,300
Subtotal			$ 129,400
Allowance for Funds Used During Construction, 2-1/2%			3,200
Total Estimated Cost of Construction			$ 132,600

*Included as a direct cost in environmental report.

Source: Dakota Transportation Project. Great Lakes Gas Transmission Company. Application for a Certificate of Public Convenience and Necessity. Before the Federal Power Commission. Docket No. CP75-283. Volume I. March, 1975. Exhibit Z-2. pp. 4.

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EXHIBIT 3
SL-3600

SUPPORTING DETAIL TO OTHER COST OF SERVICE ITEMS RELATED TO THE SYNTHETIC NATURAL GAS PIPELINE FACILITIES — DAKOTA TRANSPORTATION PROJECT
($\times 10^3$ \$, 1974)

Item	Annual Amount
Transmission Expenses	
Payroll Costs:	
10 Additional Employees' Salaries	$ 125
Pipeline and Other Expenses:	
Supplies and Expenses	86
Total Transmission Expenses	$ 211
Administrative and General Expenses	
Allocated Expenses	$ 218
Depreciation	
Transmission Plant @ 4%	$4,120
Communication Facilities @ 10%	15
General Plant @ 9%	23
Total Depreciation	$4,158
Property and Other Taxes	
Ad Valorem Taxes:	
North Dakota	$1,547
Minnesota	405
Total	$1,952
Payroll Taxes	9
Total General Taxes	$1,961

Source: Dakota Transportation Project. Great Lakes Gas Transmission Company. Application for a Certificate of Public Convenience and Necessity. Before the Federal Power Commission. Docket No. CP75-283. Volume I. March, 1975. Exhibit Z-3. pp. 3.

COST OF SERVICE
SYNTHETIC NATURAL GAS PIPELINE FACILITIES
DAKOTA TRANSPORTATION PROJECT
($X\ 10^3$ $, 1974)

Item	Year		
	1981	1982	1983
Transmission Expenses	$ 211	$ 211	$ 211
Administrative and General Expenses	218	218	218
Return	12,204	11,319	10,451
Income Taxes	5,004	5,004	5,004
Depreciation	4,158	4,158	4,158
General Taxes	1,961	1,961	1,961
Total Cost of Service Before Possible Credits	$23,756	$22,871	$22,003
Possible Credits - Return on Accumulated Deferred Income Taxes	174	513	829
Total Cost of Service After Possible Credits	$23,582	$22,358	$21,174

Source: Dakota Transportation Project. Great Lakes Gas Transmission Company. Application for a Certificate of Public Convenience and Necessity. Before the Federal Power Commission. Docket No. CP75-283. Volume I. March, 1975. Exhibit Z-3. pp. 1.

NATURAL GAS INDUSTRY SYSTEM AND STRUCTURE

A. System

1. Field and Gathering - A network of pipelines (mains) transporting natural gas from individual wells to compressor station, processing point, or main trunk pipelines.

2. Transmission - Pipelines (mains) installed for the purpose of transmitting gas from a source or sources of supply to one or more large volume customers or a pipeline installed to interconnect sources of supply. In typical cases transmission lines differ from gas mains in that they operate at higher pressures, are longer, and the distance between connections is greater.

3. Distribution - Generally, mains, services, and equipment which carry or control the supply of gas from the point of local supply to and including the sales meters.

B. Structure

1. Transmission Company - Company which obtains the major portion of its gas operating revenues from the operation of a gas transmission system and/or from main line sales to industrial customers. For purposes of American Gas Association statistics, a transmission company obtains at least 95 percent of its gas operating revenues from sales for resale and/or transportation of gas for others and/or main line sales to industrial customers and classifies at least 95 percent of mains (other than service pipe) as field and gathering storage, and/or transmission.

2. Distribution Company - Company which obtains the major portion of its gas operating revenues from the operation of a retail gas distribution system, and which operates no transmission system other than incidental connections within its own system or to the system of another company. For purposes of American Gas Association statistics, a distribution company obtains at least 95 percent of its gas operating revenues from sales to ultimate customers and classifies at least 95 percent of mains (other than service pipe) as distribution.

3. Integrated Company - A company which obtains a significant portion of its gas operating revenues from the operations of both a retail gas distribution system and gas transmission system. For purposes of American Gas Association statistics, an integrated company obtains less than 95 percent but more than 5 percent of its gas operating revenues from either its retail or transmission operations or does not meet the classification of mains established for distribution or transmission companies.

4. Combination Utility - Utility which supplies both gas and some other utility service (electricity, water, traction, etc.). For purposes of American Gas Association statistics, a combination utility derives at least 5 percent but less than 95 percent of its total operating revenues from gas operations.

Source: Gas Facts - American Gas Association, 1975, pp. 193-203.

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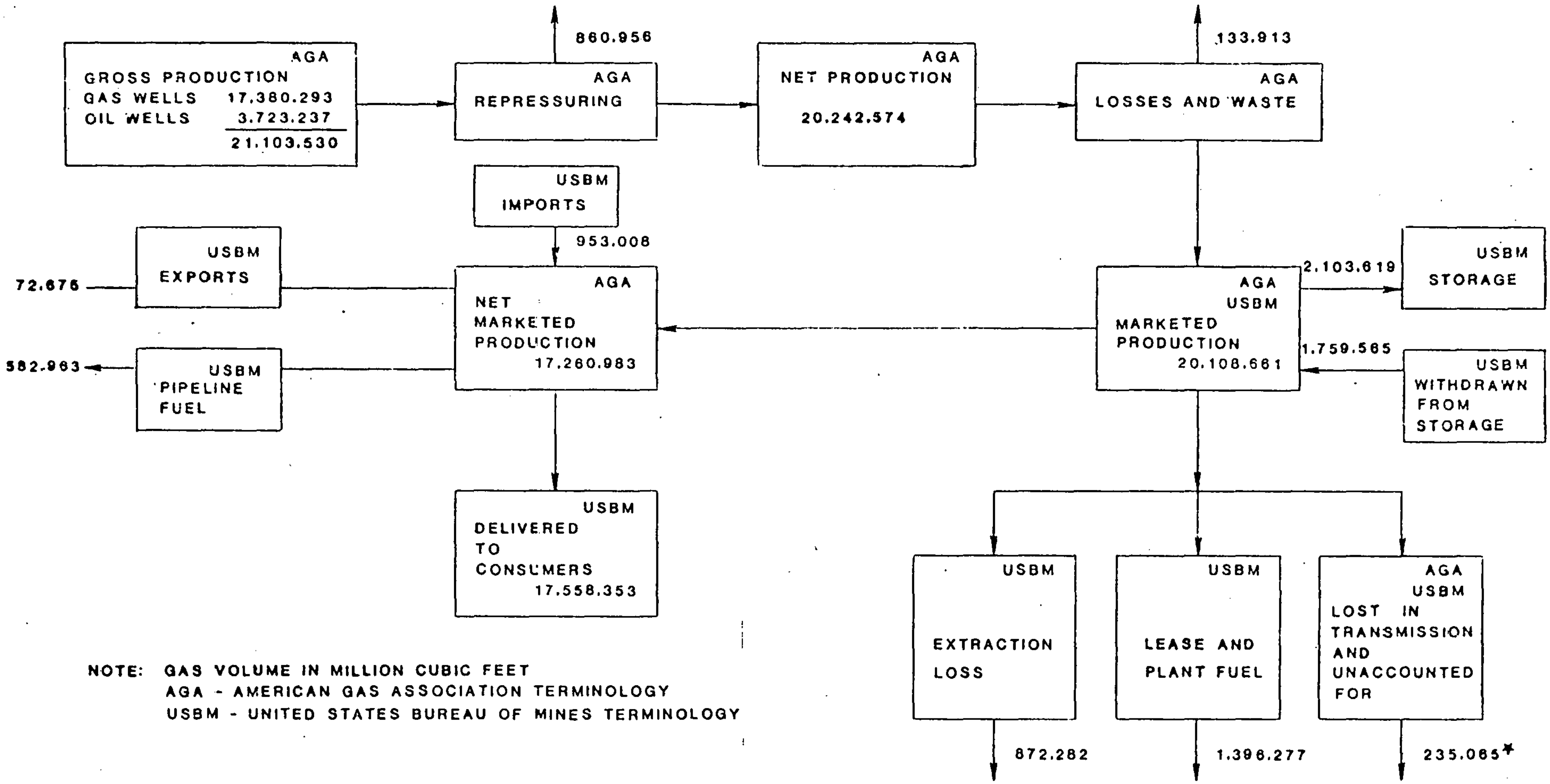
SL-3600



NOTE: GAS VOLUME IN MILLION CUBIC FEET
AGA - AMERICAN GAS ASSOCIATION TERMINOLOGY
USBM - UNITED STATES BUREAU OF MINES TERMINOLOGY

SOURCE: GAS FACTS, AMERICAN GAS ASSOCIATION. 1975. PP. 22.
MINERALS YEARBOOK, VOLUME 1. METALS, MINERALS, AND FUELS.
UNITED STATES DEPARTMENT OF THE INTERIOR. 1973. PP. 795 AND 814 - 815.

* REPORTED AS 235,068 BY AGA

GAS VOLUME FLOW DIAGRAM, 197[illegible]

SARGENT & LUNDY ENGINEERS

PIPELINE FUEL REQUIREMENTS, 1975

Total Pipeline Fuel (million cubic feet)	528,963
Transmission Compressor Horsepower (thousand hp)	12,069
Total Compressor Horsepower (thousand hp)	15,413
Estimated Transmission Pipeline Fuel (million cubic feet)	414,200

Sources: Mineral Industry Surveys. Natural Gas Annual. U.S. Department of the Interior Bureau of Mines. October 4, 1976

Gas Facts American Gas Association, 1975 pp. 49

ENVIRONMENTAL RESIDUALS
PIPELINE GAS TRANSMISSION AND DISTRIBUTION

	(tons/10^{12} Btu of gas processed)
A. Water Pollutants	None
B. Air Pollutants	
Particulates	0
Nitrogen Oxides	103*
Sulfur Oxides	0
Hydrocarbons	0
Carbon Monoxide	0
Aldehydes etc.	0

*Assumes operation of compressor stations by gas engines. If gas turbines are utilized 2.82 tons/10^{12} Btu of gas processed should be substituted.

Source: Environmental Impacts Efficiency and Cost of Energy Supply and End Use. Hittman Associates, Inc. HIT-593. Volume I. November, 1974. pp. V-1 - V-17.

NO_X EMISSIONS FROM NATURAL GAS PIPELINE OPERATION, 1967

	Fuel Consumption (million cubic feet/year)	Emission Factor ($lb/10^6$ cubic feet)	NO_x Emission (10^3 tons/yr)
Gas Engine	436,000	7300	1,596
Gas Turbine	140,000	200	14
	576,000		1,610

Source: Control Techniques for Nitrogen Oxides From Stationary Sources. U.S. Dept. of Health, Education, and Welfare. March, 1970. pp. 7-29.

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EXHIBIT 10
SL—3600

EMISSION FACTORS
GAS TURBINES AND GAS ENGINES

	Nitrogen Oxides ($lbs/10^6$ Btu)	Hydrocarbons ($lbs/10^6$ Btu)	Carbon Monoxide ($lbs/10^6$ Btu)	Sulfur Oxides ($lbs/10^6$ Btu)	Particulate ($lbs/10^6$ Btu)
Gas Turbine*	0.4	0.042	0.115	0.005	0.014
Gas Engine	12.6**	0.0012	Not Given	0.0006***	Not Given

*Emission factors are based on electric utility turbines. Composition of natural gas fuel not given.

**Emission factor given above is for a gas engine at 1000 hp. Quantity of NO_x emitted varies greatly with the load on the engine. For instance, the emission factor is 3.0 lbs $NO_x/10^6$ Btu for a gas engine at 100 hp.

***Not based on test data. Natural gas sulfur content of 2000 grains/10^6 ft^3 of gas.

Source: Compilation of Air Pollutant Emission Factors. Second Edition. U.S. Environmental Protection Agency. AP-42. March, 1975. pp. 3.3.1-1 to 3.3.1-3 and pp. 3.3.2-1 to 3.3.2-2.

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ENVIRONMENTAL RESIDUALS RESULTING FROM COMPRESSOR OPERATION, 1973 AMERICAN GAS ASSOCIATION MEMBER COMPANIES AND SUBSIDIARIES

	Installed Horsepower (hp)	Operation (bhp-hrs)	Emissions (tons/yr) Nitrogen Oxides	Carbon Monoxide	Hydrocarbons
Gas Engines	7,663,000	$4.5x10^{10}$	553,000	66,700	215,000
Gas Turbines	3,332,000	$1.8x10^{10}$	27,800	6,900	1,300
TOTALS	10,995,000	$6.3x10^{10}$	581,000	74,000	216,000

*For gas engines and gas turbines rated over 1000 hp

Source: Urban, C. M. and K. J. Springer - Study of Exhaust Emissions from Natural Gas Pipeline Compressor Engines. Southwest Research Institute - Project PR-15-61. Prepared for American Gas Association February, 1975 pp. 33.

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ENVIRONMENTAL RESIDUALS RESULTING FROM COMPRESSOR OPERATION, 1973 GAS UTILITY INDUSTRY

Environmental Residual	Emissions* (tons/yr)
Nitrogen Oxides	784,000
Carbon Monoxide	100,000
Total Hydrocarbons	293,000

*Calculated from survey values by ratio of total installed compressor horsepower for the gas utility industry (14,858,000) to installed compressor horsepower for the survey (10,995,000).

Source: Urban, C. M. and K. J. Springer - Study of Exhaust Emissions from Natural Gas Pipeline Compressor Engines. Southwest Research Institute. Project PR-15-61, Prepared for American Gas Association February, 1975. pp. 33.

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EXHIBIT 13
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ENVIRONMENTAL RESIDUALS, 1973
PIPELINE GAS TRANSMISSION

Environmental Residual	Emissions from Gas Transmission * (tons/yr)
Nitrogen Oxides	595,000
Carbon Monoxide	76,000
Total Hydrocarbons	222,000

*Calculated by ratio of installed horsepower to total installed horsepower for the gas utility industry times estimated emissions for gas utility industry in 1973.

Derived from data presented in: Urban, C. M. and K. J. Springer - Study of Exhaust Emissions from Natural Gas Compressor Engines. Southwest Research Institute - Project PR-15-61. Prepared for American Gas Association, February, 1975 pp. 33.

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EXHIBIT 14
SL—3600

OCCUPATIONAL HEALTH STATISTICS
PIPELINE GAS INDUSTRY

Industry	Deaths & Permanent Total Disabilities** (No./10^6 Manhours)	Permanent Partial Disabilities*** (No./10^6 Manhours)	Deaths & Permanent Disabilities (No./10^6 Manhours)	Temporary Total Disabilities + (No./10^6 Manhours)	All Disabling Injuries (No./10^6 Manhours)	Mandays Lost From All Disabling Injuries (No./10^6 Manhours)
Automobile++	0.02 (1974)*	0.20 (1974)	0.22 (1974)	1.36 (1974)	1.58 (1974)	204 (1974)
Pipeline Gas+++	NA	NA	0.37 (1974)	NA	6.48 (1973)	1,199 (1973)
Petroleum	0.08 (1973)	0.09 (1973)	0.17 (1973)	6.56 (1973)	6.73 (1973)	690 (1973)
Gas Industry	0.03 (1974)	0.07 (1974)	0.10 (1974)	8.99 (1974)	9.08 (1974)	357 (1974)
Underground Coal Mining++	0.58 (1974)	1.23 (1974)	1.81 (1974)	33.63 (1974)	35.44 (1974)	5,154 (1974)
All Industry	NA	NA	0.34 (1974)	9.86 (1974)	10.20 (1974)	614 (1974)

NA = not available

* Figures in parenthesis indicate year of data.

** Combined sum of deaths and permanent total disabilities. A death is defined as any fatality resulting from work. A permanent total disability is any disability other than death which permanently and totally incapacitates a worker from following any gainful occupation, or which results in the loss of or the complete loss of use of, any of the following in one accident: a) both eyes; b) one eye and one hand, arm, leg, or foot; or c) any two of the following not on the same limb; hand, arm, leg, or foot.

*** Permanent partial disability is any disability other than death or permanent total disability which results in the complete loss or loss of use of any member or part of a member of the body, or any permanent impairment of functions of the body or body part.

\+ A temporary total disability is any disability which does not result in death or permanent impairment which renders the disabled person unable to perform a regularly established job on one or more full calendar days following the day of injury.

++ Included for information purposes only. The automobile industry and underground coal mining industry had the lowest and highest number of disabling injuries per million manhours in 1974 respectively. Caution should be exercised in making comparisons between industries. See text for further explanation.

+++ Includes only pipeline gas industries owned by petroleum companies.

SOURCES: Work Injury Rates. National Safety Council, 1975.

Personal Communication. National Safety Council, January, 1977.

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EXHIBIT 15
SL-3600

OCCUPATIONAL HEALTH STATISTICS
NATURAL GAS TRANSMISSION COMPANIES

Year	All Disabling Injuries (No./10^6 Manhours)	Mandays Lost From All Disabling Injuries (No./10^6 Manhours)
1970	5.02	686
1971	5.70	634
1972	5.88	762
1973	5.67	1,287
1974	6.12	333
1975	6.37	785

SOURCE: Gas Facts. American Gas Association, 1975, pp. 192.

1975 FATALITIES IN MAJOR INDUSTRIES

Industry	No. of Deaths	Deaths/100,000 Workers
Agriculture	2,100	58
Construction	2,200	61
Government	1,700	12
Manufacturing	1,500	8
Mining, Quarrying, Oil and Gas Wells	500	63
Service	1,800	9
Trade	1,200	6
Transportation and Public Utilities	1,600	33
Gas Industry	21	11
All Industries	12,600	15

SOURCE: Gas Facts. American Gas Association, 1975, pp. 191.

GAS PIPELINE TRANSMISSION AND GATHERING FAILURES, 1975

Cause of Failure	Number	No. of Fatalities: Occupational	No. of Fatalities: Non-Occupational	No. of Injuries: Occupational	No. of Injuries: Non-Occupational
Corrosion	44	3	1	2	4
Damage by Outside Forces	237	0	0	0	5
Construction Defect or Material Failure	88	1	0	5	0
Other Causes	25	1	0	1	0
Total	394	5	1	8	9

Source: Minerals Yearbook. Volume I. Metals, Minerals, and Fuels. United States Department of the Interior. 1973. pp. 809.

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EXHIBIT 18
SL—3600

EMPLOYEES AND PAYROLL INVESTOR–OWNED
NATURAL GAS TRANSMISSION COMPANIES

Year	Total Employees	Payroll ($ x 10^6)			
		Construction	Operation	Miscellaneous	Total
1960	31,400	22.0	166.1	11.7	199.8
1965	29,600	30.6	187.5	10.3	228.4
1970	32,400	44.9	266.7	20.4	332.0
1975	37,200	53.8	470.4	50.0	574.2

Source: Gas Facts, American Gas Association, 1975, pp. 190.

ESTIMATE OF OPERATING MANPOWER REQUIREMENTS
FOR GAS TRANSMISSION EXISTING U.S.
NATURAL GAS PIPELINE NETWORK

Year	Estimated Transmission* Operating Employees	Transmission Pipeline Mileage	Manpower/Mile
1960	26,100	183,700	0.14
1965	24,300	211,300	0.12
1970	26,000	252,200	0.10
1975	30,500	262,600	0.12

NA = Not Available

*Estimate obtained by ratio of operating payroll to total payroll times total investor-owned natural gas transmission companies.

Source: Gas Facts, American Gas Association, 1975, pps. 49 and 190.

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OPERATING EXPENSES, 1975
INVESTOR OWNED NATURAL GAS
TRANSMISSION COMPANIES

	Dollars	% of Operating Revenues
Operation Expenses	8,463,000,000	71.1
Maintenance Expenses	187,000,000	1.6
Depreciation, Retirements, Depletion etc.	896,000,000	7.5
Taxes	1,014,000,000	8.5
Total Operating Expenses	10,560,000,000	88.8

SOURCE: Gas Facts. American Gas Association, 1975, pp. 152 and 153.

OPERATION AND MAINTENANCE COST BREAKDOWN, 1975
INVESTOR–OWNED NATURAL GAS TRANSMISSION COMPANIES

Expenses	Operation (dollars)	Maintenance (dollars)
Gas Purchased	7,284,000,000	0
Other Production and Purchasing Expenses	127,000,000	41,000,000
Storage	103,000,000	11,000,000
Transmission	529,000,000	132,000,000
Distribution	0	*
Customer Accounts	3,000,000	0
Sales	4,000,000	0
General & Administrative	414,000,000	3,000,000
	8,463,000,000	187,000,000

* Less than $500,000

SOURCE: Gas Facts. American Gas Association, 1975, pp. 158.

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EXHIBIT 22
SL–3600

OPERATION AND MAINTENANCE COST
TRANSMISSION COMPONENT, 1975
EXISTING U.S. NATURAL GAS PIPELINE NETWORK

Total Operating Expenses (dollars)	10,560,000,000
Operation Expenses (dollars)	8,463,000,000
Transmission Component (dollars)	529,000,000
Maintenance Expenses (dollars)	187,000,000
Transmission Component (dollars)	132,000,000

Source: Mineral Industry Surveys. Natural Gas Annual, U.S. Department of the Interior Bureau of Mines, October 4, 1976.

NATURAL GAS DELIVERY POINTS AND DELIVERY VOLUMES NORTHERN BORDER PIPELINE

Delivery Point	Milepost	Location	Delivery Volume (MMCFD) * Summer	Winter
Northern Natural Gas Co. I	520	South Dakota	27.1	30.8
Northern Natural Gas Co. II	742	Minnesota	80.8	91.8
Northern Natural Gas Co. III	809	Iowa	99.1	112.5
Michigan Wisconsin Pipe Line Co.	1061	Illinois	206.0	233.5
Natural Gas Pipeline Co. of America	1138	Illinois	166.9	189.2
Panhandle Eastern Pipeline Co.	1294	Indiana	166.3	188.5
Columbia Gas Transmission Corp. I	1443	Ohio	558.7	632.7
Columbia Gas Transmission Corp. II	1573	Pennsylvania	108.6	123.0
Columbia Gas Transmission Corp. III	1618	Pennsylvania	32.6	36.9
Texas Eastern Transmission Corp.	1619	Pennsylvania	165.9	187.9
			1612.0	1826.8

*14.7 psia, 60°F

Source: Alaska Natural Gas Transportation System. Final Environmental Impact Statement. North Border. U.S. Dept. of the Interior. March, 1976.

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EXHIBIT 24
SL—3600

COMPRESSOR STATIONS
NORTHERN BORDER PIPELINE

Compressor Location	Approximate Milepost	Horsepower Rating	Fuel Usage (MMCFD)	
			Summer	Winter
Montana	127	30,000	4.0	5.3
North Dakota	238	30,000	3.9	5.3
North Dakota	355	30,000	3.7	5.3
South Dakota	469	30,000	3.8	5.5
South Dakota	581	30,000	3.6	5.3
Minnesota	691	30,000	3.4	5.1
Iowa	801	30,000	3.0	4.5
Iowa	915	30,000	2.3	3.3
Illinois	1027	30,000	2.1	3.0
Illinois	1138	13,500	1.3	1.7
Indiana	1262	13,500	2.3	2.6
Ohio	1384	13,500	1.5	2.5
			34.9	49.4

Source: Alaska Natural Gas Transportation System. Final Environmental Impact Statement. North Border. U. S. Department of the Interior. March, 1976

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LAND REQUIREMENTS
NORTHERN BORDER PIPELINE

	Construction (R.O.W. (acres)	Permanent R.O.W. (acres)
Pipeline	19,626	10,584
Compressor Stations*		500
Communication Towers		248
Mainline Block Valves		6
Delivery-Measuring Stations		26
Stream Crossings	165	
Major River Crossings	200	
Pipe Stockpiles	600	
Access Roads	145	152
	20,736	11,516

*Includes sufficient land area for the 12 required compressor stations and 13 future compressor stations if capacity is increased at a future date.

Source: Alaska Natural Gas Transportation System. Final Environmental Impact Statement. North Border. U.S. Dept. of the Interior. March, 1976.

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LAND USE
NORTHERN BORDER PIPELINE

Land Use Category	Miles	%
Urban (residential, industrial, commercial)	4	0.2
Agriculture		
Cultivated	1,231	76.0
Range	259	16.0
Woodland	74	4.6
Rights of Way (roads, railroads, utility)	27	1.7
Waterways and Floodplains	24	1.5
	1,619	100.0

Source: Alaska Natural Gas Transportation System. Final Environmental Impact Statement. North Border. U.S. Dept. of the Interior. March, 1976.

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SUMMARY OF MAJOR MATERIALS AND SUPPLIES TO BE CONSUMED OR UTILIZED DURING CONSTRUCTION NORTHERN BORDER PIPELINE

Material or Supply	Amount Consumed or Utilized
Steel (10^6 tons)	1.1
Welding Rods (10^6 pounds)	4.5
Concrete (10^3 tons)	375.0
Diesel Fuel (10^6 gallons)	14.4
Gasoline (10^6 gallons)	6.5
Lube Oil (10^3 gallons)	215.2
Grease (10^3 pounds)	151.0

Source: Alaska Natural Gas Transportation System. Final Environmental Impact Statement. North Border. U.S. Dept. of the Interior. March, 1976.

CONSTRUCTION MANPOWER
NORTHERN BORDER PIPELINE

	Manpower
Pipeline	5330 total
River Crossings	1060 total
Compressor Stations*	36/station
Communication Towers	(included above)

*A peak work force of approximately 60 men will be employed for a 1-month period.

Source: Alaska Natural Gas Transportation System. Final Environmental Impact Statement. North Border. U.S. Dept. of the Interior. March, 1976.

COST DATA (1974 DOLLARS)
NORTHERN BORDER PIPELINE

	Material	Erection	Total
Pipeline*	638,300,000	236,200,000	874,500,000
Compressor Stations	46,900,000	13,200,000	60,100,000
Right of Way			47,800,000
Measurement Stations	3,700,000	2,500,000	6,200,000
Communication System	9,700,000	2,900,000	12,600,000
Misc. Direct Costs**			11,700,000
Total Direct Costs			1,012,900,000
Engineering and Construction Management			37,600,000
Misc. Indirect Costs***			20,100,000
Contingencies			62,700,000
Allowance for Funds Used During Construction			213,700,000
Total Indirect Costs			334,100,000
Total Cost			1,347,000,000

*Includes 1138 miles of 42 inch pipe, 305 miles of 36 inch pipe, 176 miles of 24 inch pipe and material and erection costs for 12 major river crossings.

**Includes charges for land in fee, survey and mapping, and operation and maintenance equipment.

***Includes commitment fees for short and long term debt, and a filing fee (classified for the purposes of this Exhibit as an indirect cost).

Source: Alaska Natural Gas Transportation System. Final Environmental Impact Statement. North Border. U.S. Dept. of the Interior. March, 1976.

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OPERATION AND MAINTENANCE COSTS
REFUGIO – WAHA PIPELINE

Description	Annual
Taxes, Other Than Income Taxes, Principally Ad Valorem	$ 1,320,000
Annual Payments for Labor, Materials, and Expenses to Operate and Maintain the Project:	
Transmission Expenses	625,000
Administrative and General Expenses	219,000
Total	$ 2,164,000

Source: Refugio - Waha Pipeline Project. Final Environmental Impact Statement. Federal Power Commission. Docket No. CP73-260. April, 1975. pp. 78.

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