DOE/R4/10088--T1

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24 December 1981

PRODUCTION MANAGEMENT COMPANY

U.S. Department of Energy
ATTN: Contracts/Grants
1655 Peachtree Street, NE
Atlanta, Georgia 30309

Dear Sirs;

Enclosed is the final technical report on Grant No. DE-FG44-80R410088.00.

Although the information on equipment was quite difficult to obtain and took much longer than anticipated, I was able to meet the primary goal (determination of feasibility) and to execute all but one of the objectives (survey of potential customers). It was precisely because of the result of the feasibility analysis that it was decided that such a survey at this time would not be productive.

Because the survey task was not performed, there remains more than \$2,700 in the grant savings account, including interest. Please instruct me as to its disposition.

Yours truly,

D.W. Rogers
President

DOE/R4/10088--T1

DE84 000373

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FINAL REPORT

LIQUEFACTION OF REMOTE SOURCES OF NATURAL GAS

GRANT NO. DE-FG44-80R410088.00

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By

D.W. Rogers

December 1981

*Copy sent
to P.O.
1-28-82*

zshp
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I. INTRODUCTION

BACKGROUND

In the mid-1970s there occurred some short but severe interruptions of natural gas supplies to industry and widespread curtailment of new connections for residences.

The reason for these virtually unprecedented measures is generally accepted to be the government-imposed artificially low wellhead price paid for natural gas, which made it economically undesirable to tap known reserves — much less explore for additional reserves.

In the context of the nationwide policy of ensuring residential supplies to existing customers, the interruption of supplies created severe concern in both the industrial and construction industries to the point that conversion to alternate fuels became commonplace. Conversion, however, had its own set of road blocks in the form of oil shortages and/or environmental regulations. Consequently, some industries purchased their own in-the-ground gas supplies to guarantee availability.

The prospect of interruption was particularly abhorrent to those industrial and processing operations that could not (for reasons of gas quality or access to alternatives) consider conversion. In spite of reassuring words about the gas "bubble" from executives of the gas industry, apprehension persisted among those who had been affected by curtailment and those who feared a recurrence.

The pervasive atmosphere of concern generated wide interest in providing solutions to supply problems — whether real or imagined. One such possible solution was the subject of a grant proposal from Production Management Corporation (PMC).

The PMC proposal was based upon three assumptions: (1) that gas supplies were sufficiently unreliable to pose a threat to some existing plants and would certainly inhibit the construction of new plants that required natural gas in their operations; (2) that recent technological developments in cryogenics made it potentially feasible to liquefy natural gas and transport it to industrial users, where it would be re-gasified and serve as a direct substitute for pipeline gas; and (3) that sufficient supplies of gas from "shut-in" wells might be available in remote areas of Appalachia to make it economically feasible to supply nearby existing or new plants.

THE OBJECTIVE

In the context of the above assumptions and industrial-economic environment, PMC proposed to determine the technical and financial feasibility of liquefying remote reserves and transporting the liquefied product to users.

METHODOLOGY

The proposed methodology included efforts to (1) identify any prohibitive or limiting laws and/or regulations; (2) identify sufficient unutilized reserves in remote areas to justify further investigation; (3) identify existing portable liquefaction equipment (or an interested manufacturer that could supply the needed equipment) to obtain cost and performance data; (4) determine site preparation, supply and production costs for use in assessing economic feasibility; and (5) identify potential users.

II. LAWS AND REGULATIONS

Examination of the extensive variety of laws and regulations applicable to the production and transportation of liquefied natural gas revealed no barrier to the proposed process. However, the sheer magnitude of Federal and state agencies involved and the number of permits required (see table below) makes it clear that the amount of time and money required for planning and permitting such a project should be a major consideration in determining economic feasibility.

Although strictly an educated guess, it appears that a minimum of one man-year of expert assistance would be desirable at an estimated cost of \$50,000.

Table 1

Laws and Regulations Applicable to Production and Transportation of Liquefied Natural Gas

FEDERAL PERMITS

I. Natural Resources

a. Earth Movement

Permit to construct along a navigable waterway; U.S. Army Corps of Engineers (Con).

b. Water Discharge

NPDES Wastewater Discharge Permit; EPA Water Enforcement Branch (Oper).

II. Human Resources

a. Social Security

Social Security Withholding Payments; IRS (Con, Oper, Postop).

b. Withholding Tax

Federal Employer's Registration Certificate; IRS (Con, Oper, Postop).

III. Capital Equipment

a. Plant Communications

Two-way radio license for commercial use; FCC (Oper).

b. Air Obstructions

Notice of Proposed Construction or Alteration; U.S. DoT, FAA (Con).

IV. Transportation

a. Interstate Commerce.

Interstate Commerce Certification; ICC (Oper).

V. Miscellaneous

a. Business Registration

Registration Statement for public offering of stock; SEC (Pcon).

b. Business Tax

Federal Corporate Income Tax (also for partnership or individual proprietor-business income tax); IRS (Oper).

STATE PERMITS

I. Natural Resources

a. Earth Movement

Approval of Construction in a Floodway; DNREP, Division of Water Resources (Con).

b. Water Withdrawal

1. Water withdrawal permit, over 10,000 gallons per day; DNREP, Division of Water Resources (Oper).

2. Approval for new individual water supply, if not receiving flow from existing lines; DNREP, Division of Sanitary Engineering (Oper).

c. Water Discharge

Permit to discharge, manufacturing and mining; DNREP, Division of Water Quality (Oper).

d. Solid Waste

Landfill application; DNREP, Division of Hazardous Materials and Waste Management (Con, Oper, Postop).

e. Hazardous Waste

Permission to dispose of special and/or hazardous waste at a permitted disposal site; DNREP, Division of Hazardous Materials and Waste Management (Con, Oper, Postop).

f. Air

Permit for Air Contaminant Source; DNREP, Division of Air Pollution Control (Con, Oper, Postop).

II. Human Resources

a. Workmen's Compensation

Request for Workmen's Compensation Certificate; DoL (Con, Oper, Postop).

- b. Withholding Tax
Withholding Application; DoR (Con, Oper, Postop).
- c. Radioactive Material Handling
Kentucky Radioactive Material License; DHR, Radiation Control Branch (Con, Oper, Postop).
- d. Unemployment Insurance
Report to Determine Employer Liability; DHR, Bureau for Social Insurance (Con, Oper).

III. Capital Equipment

- a. Boilers
Inspection and certification of boilers; DHBC, Office of State Fire Marshal (Con, Oper).
- b. Plumbing
Approval of Plumbing Plans in Plant; DHBC, Division of Plumbing (Con).
- c. Building Plans
Approval of building plans prior to construction; DHBC, Division of Labor Standards (Con).
- d. Right-of-Way Encroachment
Encroachment permit; DoT, Bureau of Highways (Con).
- e. Air Obstructions
Permit to Construct or Alter a Structure; DoT, Kentucky Airport Zoning Commission (Con).
- f. Siting
Certificate of Convenience and Necessity and Certificate of Environmental Compatibility; Energy Regulatory Commission (Con).

IV. Transportation

- a. Industrial Hauling
Industrial Hauling Permit; DoT (Oper).
- b. Vehicle Identification
Uniform Vehicle Identification Cards; DoT, Division of Motor Carriers (Oper).
- c. Public Convenience and Necessity
Certificate of Public Convenience and Necessity; DoT, Division of Hearings (Oper).
- d. Irregular Route Certification
Irregular Route Certificate; DoT (Oper).

- e. Motor Fuel Use Tax
Highway Motor Fuel User License; DoT(Oper).
- f. Motor Fuel User Bond
Highway Motor Fuel User Bond, DoT (Oper).
- g. Injury and Liability Insurance
Certificate of Injury and Liability Insurance; DoT (Oper).
- h. Commercial Vehicle Insurance
Vehicle Insurance Sticker; DoI (Oper).
- i. Combustible Liquids
 - 1. Flammable and Combustible Liquid Tank Vehicle Permit; DHBC, Division of Fire Prevention (Oper).
 - 2. Flammable and Combustible Liquid Certificate of Condition, DHBC, Division of Fire Prevention (Oper).
- j. Apportioned Truck Registration
Certificate of Apportioned Registration and Title; DoT (Oper).
- k. Vehicle Registration and Licensing
License Plates; DoT (Oper).
- l. Overweight/Overdimension
Application for Special Permit for Overweight and/or Overdimension Vehicles; DoT (Oper).

V. Miscellaneous

- a. Business Registration
 - 1. Partnership Registration, Statement of Assumed Name Form; Secretary of State (Pcon).
 - 2. Domestic Incorporation Registration; Secretary of State (Pcon).
 - 3. Foreign Incorporation Registration, Certificate of Authority to Operate; Secretary of State (Pcon).
- b. Business Tax
Corporate Income and License Tax Returns; DoR (Con, Oper).
- c. Sales and Use Tax
Retail Sales and Use Tax Permit; DoR (Oper).

III. EQUIPMENT

With leads supplied by Dr. Lowell Elder of Columbia Gas, six possible suppliers of appropriate liquefaction equipment were identified:

J.F. Pritchard and Co. of Kansas City
Chicago Bridge and Iron of Oak Brook, Ill.
Air Products and Chemicals of Allentown, Pa.
Linde A.G., New York (Low Tempco Division)
Air Liquids France of Paris
Airco Cryogenics of Irvine, Ca.

The attached letter was sent to the research director of each of these companies. Airco was the only company that seemed sufficiently interested to tolerate the many phone calls and letters necessary to identify the proper equipment and obtain an estimate of its cost. This may be because Airco was (coincidentally) examining the possibility of modifying a piece of proven equipment (a nitrogen liquefier) for the purpose of liquefying natural gas.

The following excerpt from a letter written by Mr. Glenn H. Gaisombhe provided the capacity, cost and delivery information we sought but left it up to us to infer operating characteristics and other necessary information from the stacks of nitrogen liquefaction data and brochures they provided (see attached examples).

Bound into the catalog is also a brochure describing a 6.4 ton per day nitrogen liquifier. This particular plant has not been modified for well service applications yet but is an example of a reliable, proven plant with many installations. We are working with BOC to define the specific changes and a complete description will be forthcoming of a unit tailored specifically for remote/portable/limited attendance operation. In the meantime we can confirm that a \$1,000,000.00 budget for plant, storage and power source is appropriate. This breaks down as follows:

6.4 Ton Well Service Liquifier	\$685,000.00 ex-works
13,000 gal. (44 ton) Storage Tank	\$150,000.00 installed
300KW M-G Set	\$150,000.00 installed

Delivery looks like 11-12 months. The tank and M-G set are available in London or Europe but you can use the USA prices for budgeting.

It appears evident that the appropriate basic equipment can be made available within a year from at least this one source at a cost of at least \$1,000,000.

It is estimated that additional equipment (transport tractor trailer, safety equipment, communications) will cost \$250,000.

Based upon round-the-clock operations with a two-man crew, a driver and a manager, the estimated annual operating costs would be approximately \$200,000.

Maintenance, supplies and services costs would approximate another \$50,000 per year.

Site preparation costs will vary, of course, according to such factors as proximity to existing roads, terrain, and proximity to existing wells. (The amount of line that must be laid.) Obviously, sufficient level space must be made for the liquefaction unit, storage tank, personnel shelter, and collector unit. Also, access roads might well be needed. The estimated average site preparation cost is \$100,000 including erecting the storage tank and other facilities.

In summary, capital costs are estimated at \$1,350,000, and annual operating costs are estimated at \$250,000 plus royalties.

IV. ECONOMIC ANALYSIS

Based upon the capacity of existing portable equipment, maximum production per day would be 6.4 tons or approximately 3,500 gallons (about 300,000 cubic feet). If the liquefied product were to sell competitively with natural gas, it could not sell for more than \$0.35 per gallon. At \$0.35 per gallon, the daily gross income would be \$1,225. Thus, maximum annual gross would be \$447,000 (see Table 2).

Although LPG sells for about \$0.80 per gallon with 91,500 Btu per gallon and gasoline at up to \$1.50 per gallon with 115,000 Btu per gallon, it would appear that the need for capital investment at the user's end and the lower Btu per gallon (84,000) — not to mention the lack of an established market — would tend to hold the price of LNG in the \$0.35 to \$0.50 per gallon range. Maximum gross at \$0.50 would be about \$640,000.

Thus it can be seen (Table 2) that with royalties of \$1.00 per 1,000 feet and LNG sale price of \$0.35 per gallon, annual maximum gross profit (without debt service) would be about \$88,000. At \$0.50 per thousand the gross would be \$280,000, still not enough to meet debt service on \$1,500,000 at 20 percent.

It seems clear that the price of LNG would have to approach \$0.70 per gallon (not unreasonable on a Btu basis but non-competitive with pipeline gas) before the venture would become potentially feasible.

Obviously, lower royalties and interest rates would lower the point at which such a venture becomes attractive. However, it is just as obvious that a steady and predictable demand and a constant production rate are not achievable. Something like line 4 in Table 2 would seem to be a more realistic annual average.

It now seems evident that three critical developments are required to make liquefaction feasible.

- 1) Technology — The development of portable equipment with significantly greater output (say 10-12 tons per day) would have considerable impact on feasibility — particularly if the purchase price did not exceed \$1.5 million.
- 2) Markets — Critical to feasibility is the development of a stable market for the product. As long as pipeline gas is available, existing users are no longer likely candidates for liquefied product, leaving only municipalities and new plants in areas not served by pipeline as possibilities.

Table 2

**Maximum Annual Gross Income
(based upon 3,500 gal/day for 365 days)**

Scenario	Price (\$/gal)	x	Gal/Yr	=	Total Income	—	Operating Cost	—	Royalties @ \$1.00/MCF*	—	Debt Service @ 20%	=	Max Net.
1	\$0.35	x	1,277,500	=	\$447,125	—	250,000	—	109,000	—	300,000	=	-212,000
2	0.50	x	1,277,500	=	638,750	—	250,000	—	109,000	—	300,000	=	-20,000
3	0.70	x	1,277,500	=	894,250	—	250,000	—	109,000	—	300,000	=	285,000
(Based upon 3,500 gal/day for 300 days)													
4	0.70	x	1,050,000	=	735,000	—	250,000	—	109,000	—	300,000	=	126,000
5	1.00	x	1,050,000	=	1,050,000	—	250,000	—	109,000	—	300,000	=	391,000

* assumes purchase of "old gas"

- 3) Price — Obviously, price has a major impact on feasibility in any enterprise. This is particularly true when other elements such as equipment and labor costs and limited markets are virtually unalterable. As shown on line 5 of Table 2, for example, if the price per gallon were to approach \$1.00, the economic feasibility would be greatly enhanced.

V. REMOTE SOURCES OF NATURAL GAS

With the assistance, advice and counsel of the staff at the Kentucky Geological Survey, an extensive examination was made of drilling records and production information available on capped wells and otherwise unexploited areas of significant discovery in Appalachian Kentucky.

We were advised that there exists no separate file of capped wells and that it would be necessary to review every drilling record to determine the location of such wells. Consequently, we altered our approach to pick selected areas that were out of the reach of existing pipelines but near known sources of gas; such as Southern Breathitt County and Wolfe and Morgan Counties. (See enclosed map.)

Even so, our initial focus on areas distant from existing pipelines gave disappointing results from two important aspects: (1) older records, which includes most of the capped wells, frequently failed to specify flow rates, and the wells that did show flow rates were inadequate to justify exploitation by themselves, and (2) records of capped wells showed that wells were too distant from one another to expect that existing wells would provide the opportunity to tap several in the same area to obtain the needed flow.

During this phase of the study, it became evident that over the years very few drillers showed an interest in gas — if the well failed to show favorable signs of oil (even with significant gas show) more often than not, it was shut in or capped, without an effort to reach promising gas-bearing strata.

Some of the more conscientious oil drillers (such as E.C. Dyer) would run lines from such wells to local homes. Some are still using this gas after 30 years.

It became evident that only two choices were left open to our investigation: (1) re-focus the review of drilling records to producing areas served by pipelines where there are sufficient proven reserves to justify gasification installation (even though in direct competition with pipeline operations); or (2) re-direct the effort to determine the feasibility of installations based upon new drilling efforts. Even though the latter option holds considerable promise, it was decided that such an approach was beyond the scope, if not the spirit, of the grant proposal. Consequently, efforts were resumed to identify potential existing sources in already developed fields.

Results of the revised approach were more positive, as shown by Table 3. As encouraging as the results were, it seemed prudent to stop and take a realistic look at the whole project vis a vis decontrol, equipment capacity, and economics.

The sharp increase in drilling that resulted from partial decontrol affected the near-term and medium-term prospects of liquefaction dramatically. The prospect of increasing supplies of natural gas (which soon became reality) made it unlikely that anyone served by pipeline would make the necessary investment in conversion equipment — even if the price were competitive and long-term guarantees of supply could be made.

Table 3
Selected Results of Analysis of Drilling Records

Breathitt County

Location	Driller/Operator	Depth	Flow	Date	Status/Comments
N-73-1	Sun River Oil	1394	250 M	1919	Capped
N-73-9	Sun River Oil	1390	200 M	N/R	N/R
N-73-9	L.C. Young	1492	N/R	1964	Capped. Shot from 1491-1507; Increased flow 3X.
N-73-10	Henshaw	1376	75 M	N/R	N/R
N-73-14	Louis Diamond	1370	200 M	N/R	Pay zone in coniferous
N-73-17	L.C. Young	1248	40 M	1962	N/R
N-73-17	L.C. Young	1241	100 M	1949	Open flow in coniferous. Rock pressure 485
N-73-18	Cesar McCoun	N/R	500 M	1947	Open flow
N-73-22	J.T. Walters	1316	N/R	1963	"Plenty of gas"
N-73-24	Matt Shuster	1406	150 M	1950	—
N-73-25	United Carbon	1297	267 M	1959	Final open flow 435 M after acid & fractioning
M-73-8	Floyd Gross	1576	335 M	N/R	N/R
L-73-4	Swiss Oil	1561	200 M	1929	450
M-73-21	Swiss Oil	N/R	110 M	1929	360 plugged

Wolfe County

Location	Driller/Operator	Depth	Flow	Date	Status/Comments
N-73-1	Sun River Oil	1394	250 M	1919	Capped
N-73-2	L.C. Young	N/R	310 M	1963	Shot with 45 qts. Nitro — Shut in
N-73-4	Holly Creek Prod. Co.	1365	235 M	1964	Based on report by Oilfield Research, Inc.

Location	Driller/Operator	Depth	Flow	Date	Status/Comments
N-73-4	Holly Creek	1285	88 M	1965	Shot with 80 qts. Open flow
N-73-4	Holly Creek	1410	50 M	1966	Plugged
N-73-5	L.C. Young	1360	1 MM	1961	N/R
N-73-6	L.C. Young	1346	260 M	1961	N/R
N-73-7	Holly Creek	1289	53 M	1966	Capped. Reopen permit 1966.
N-73-14	Petroleum Expl.	1319	90 M	1932	Shot
N-73-15	Prather Drilling	1432	360 M	1964	Plugged
N-73-15	United Carbon	N/R	622 M	1957	Shot & fractured
N-72-1	L.C. Young	1416	390 M	1954	N/R
N-72-1	T.E. Grinsdale	1365	175 M	1963	325 lbs pressure
N-72-10	John Moore	1430	165 M	1954	Shot

Magoffin County

P-78-12	Adams Farm	640	150 M	1923	N/R
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Johnson County

P-80-15	Oliver Jenkins	2439	900 M	1946	Shot 540 lbs
P-80-15	Oliver Jenkins	2421	250 M	1948	Shot
P-80-15	S.C. Allen	1925	800 M	1943	Sulfur content
P-80-15	Oliver Jenkins	2334	70 M	1945	Shot
0-79-10	Rolla Dixon	814	368 M	1944	Rock pressure 260 lb. Open flow.
0-79-10	Rolla Dixon	1501	100 M	1945	Shot — open flow
0-79-10	Swamp Branch Oil	362	105 M	1928	100 open flow
0-79-10	Swamp Branch Oil	852	92 M	1928	
0-80-3	Temple Oil	1590	215 M	1928	

0-80-3	Richmond Oil	962	140 M	1945	Acidized — shut in
0-80-4	Gibson	602	304 M	1927	
0-80-4	Richmond Oil	1525	160 M	1944	Shot & tubed
0-80-4	Tom Branch Oil	N/R	400 M	1927	175 open flow
0-80-4	Swamp Branch Oil	N/R	290 M	1928	Shot & tubed
0-80-5 & 6	Swamp Branch Oil	760	143 M	1928	N/R
0-80-5	Swamp Branch Oil	945	200 M	1928	Tubed
0-80-6	Swamp Branch Oil	695	1 MM	1928	N/R
0-80-6	Swamp Branch Oil	755	250 M	1928	Tubed & shut in
0-80-7	Geo. Rice Farm	N/R	210 M	N/R	N/R
0-80-7	Geo. Rice Farm	780	310 M	N/R	N/R
P-79-1	Inland Gas	2391	94 M	1950	Plugged
P-79-1	Inland Gas	1875	33 M	1953	Plugged
P-79-4	Mid-South Oil	2213	100 M	1931	N/R
P-79-4	Lou. G&E	N/R	1.5 MM	N/R	
P-79-4	Bedrock Oil	2183	560 M	1930	Tubed & shut in
P-79-4	Bedrock Oil	1580	431 M	1930	N/R
P-79-20	Bedrock Oil	1545	280 M	1946	Shut in

Morgan County

P-74-3	Hazel Green Oil	N/R	800 M	N/R	Gas for 15 years until drowned out
P-74-2	Hazel Green Oil	N/R	40 M	N/R	N/R

N/R means not recorded.

CONCLUSIONS & RECOMMENDATIONS

It is with considerable disappointment that we conclude that the liquefaction of natural gas in remote areas of Appalachia is not economically feasible as long as an adequate and reliable supply of pipeline gas is perceived to be available for the foreseeable future and the price per Btu of pipeline gas remains so far below other fuels. Following are the bases for this conclusion:

- The cost/price ratio is inadequate to justify the necessary investment until natural gas approaches the price of other fuels.
- Production rates of currently available equipment are too low relative to equipment cost and likely product price.
- Reliable long-term wells of sufficient volume are relatively rare except in developed gas fields – all of which are served by pipeline.
- The expenses associated with liquefaction at both the producer's and user's ends are sufficiently great to discourage investment unless perhaps, a company or town (municipal utility) not served by pipeline would buy an existing field (or develop one) of sufficient size and long-term reliability to justify the investment. (Such situations, however, would likely result in a large, "permanent" liquefaction unit backed up by a very large storage unit at the facility to be served.)
- Reliability of supply is a major consideration. On the one hand, the enterprise requires a relatively constant demand for the maximum daily output. On the other hand, such demand carries the obligation to meet that demand under any and all conditions (weather, equipment breakdown, strikes, etc.). Because the liquefied product is more expensive to store, a large and costly storage tank would be needed to meet all contingencies. Thus, the least that would be required is a redundant system ready to operate as needed.

Although these arguments are discouraging for the project as proposed, there did arise during the course of this investigation two variations on the basic theme, one or both of which might offer the opportunity to achieve the purposes of this project. These are discussed below.

It is conceivable that a pipeline company (even one of the smaller, localized ones) could erect a stationary liquefaction unit at its main distribution site and offer liquefied product as an expansion of its normal activities. On its face, such an arrangement does not satisfy the conservation aspect of the project. However, if such a market were established in this way, the next step might well be to set up portable units (when units with sufficiently high production rates become available) as we have envisioned and use the stationary unit as backup for contingencies and for peak demand. Such an arrangement could eliminate the problems of supply and reliability described above and provide the scale of operations that would make the investment attractive.

Another variation, although departing from the liquefaction process, might offer an opportunity similar to the one described above for an even lower capital cost. This approach involves the production of propane and butane using portable and/or stationary units. The existing markets for the product, its storability, and its transporability make this approach potentially attractive to lease holders of a number of non-contiguous small gas fields in an area such as Appalachia. Another obvious advantage of this approach is that redundancy or large-scale operations are not crucial.

It is our recommendation that these alternate approaches to tapping the smaller, remote fields be encouraged through the distribution of technical information on liquefaction and stripping processes to utilities, intrastate pipeline companies, and engineering schools. Because there exists no non-proprietary single body of information oriented specifically to the potential producer, preparation of the type of detailed and reliable process and equipment information needed will no doubt require considerable effort and expert judgement. Perhaps, a good school of engineering/geology could be interested in such a challenge.

Dear Sir,

I am currently conducting an analysis of the feasibility of liquefying natural gas in the field with portable equipment. The report of my findings will go to the U.S. Department of Energy.

I understand that your company has considerable expertise in the liquefaction of natural gas and the manufacture of equipment for that purpose.

I am most anxious to include in my analysis any information you can provide on existing or planned portable liquefaction equipment. Furthermore, I would be most appreciative of any analytical work you may have done to determine:

- Existing and potential markets for portable equipment
- Operational requirements including manpower, additives such as ethanol, ancillary equipment such as trucks and storage, equipment cooling requirements, minimum reserve requirements for economic operation, etc.
- Gas quality problems (removal of impurities) and possible solutions.

I am, of course, interested in either negative or positive results of such analyses, as well as your informed opinions.

I will certainly give credit in my report for any information you provide unless, of course, you wish otherwise. I will be pleased to send you a copy of my report, if you wish.

If you have any questions, please call me.

Sincerely,

D.W. Rogers
President

[Handwritten signature]
G.G.

March 25, 1980

Mr. Glen Garsombke
Marketing Dept.
Airco Cryogenics
Division of Airco, Inc.
1900 S.E. Main Street
Irvine, California 92713

REFERENCE: Our BE-34310 - NG-500, NLG-500,
NG-700, NLG-700, N-1000 & N-1500 Plants

Dear Mr. Garsombke:

With regard to our recent telephone conversation concerning our nitrogen producing plants, we are pleased to enclose preliminary information and budget prices on the following plants:

<u>PLANT MODEL</u>	<u>BUDGET PRICE EX FACTORY</u>
Model NG-500	\$268,500.00
Model NLG-500	\$288,310.00
Model NG-700	\$403,300.00
Model NLG-700	\$437,800.00
Model N-1000	\$570,000.00
Model N-1500	\$630,300.00

— 3.5 TONS/DAY

Refer to the enclosed Design Basis and Utilities sheets for further information.

Present delivery for either of the above plants is 11 to 12 months.

I would be happy to meet with you at your convenience to discuss details and firm up exact requirements. Please contact me, and we can arrange a meeting.

Continued.....

SUPERIOR AIR PRODUCTS CO.

2001 Jernee Mill Rd., Sayreville, N. J. U. S. A. 08872

Airco Cryogenics

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March 25, 1980

Thank you for your interest in Superior Air Products, and I
look forward to working with you in the near future.

Very truly yours,

SUPERIOR AIR PRODUCTS CO.

Dale A. Crum

International Sales Representative

DAC:bd

Enc: Design Basis & Utilities
for NG-500, NLG-580, NG-700, NLG-700,
N-1000, and N-1500 Plants

Supairco Brochures

DESIGN BASIS & UTILITIES
MODEL NLG-700 NITROGEN PLANT

3.5 TONS/DAY

This plant is designed to produce:

gaseous nitrogen supplied at 75 PSIG
 and near ambient temperature with a
 purity of 99.999% inert.

9,500 SCFH

OR

gaseous nitrogen supplied at 75 PSIG
 and near ambient temperature with a
 purity of 99.999% inert

2,700 SCFH

AND

liquid nitrogen supplied at 75 PSIG
 subcooled with a purity of 99.999% inert

4,050 SCFH

The plant may be operated at various intermediate settings.

Standard cubic foot is measured at 68°F and one atmosphere absolute.

Plant design is based on atmospheric conditions of 85°F, 50% relative humidity, one atmosphere absolute, 85°F cooling tower water and normal atmospheric air containing a maximum of 350 PPM carbon dioxide.

UTILITIES

Electric Power

<u>ITEM</u>	<u>INSTALLED HP</u>	<u>AVERAGE OPERATING KW GAS ONLY</u>	<u>AVERAGE OPERATING KW GAS & LIQUID</u>
Compressor Motor #1	150	83.5	88.4
Compressor Motor #2	150	83.5	88.4
Generation Heater	30 KW	8.0	8.0
Refrigeration Unit	30	-----	<u>21.0</u>
<u>TOTAL AVERAGE OPERATING KW</u>		175.0	205.8

DESIGN BASIS & UTILITIES CONT'd: (NLG-700)

SUPPLY VOLTAGE

All equipment is designed to operate with electric power at 440 volts, 3 phase, 60 cycles. In addition, a supply of 110 volts, single phase power is required for operation of the control circuits.

Cooling Water at 85°F
and 10°F temperature rise: 90 GPM

NOTES

1. No instrument air is required.
2. All operating power requirements are given in kilowatts and denote the power consumption as measured at the device. The power requirements are subject to a tolerance of plus or minus 4%.
3. Based on data from similar plants, sound level will not exceed 90 dBA during normal operation.

PLANT DEFROSTING

Defrosting is required before initial plant start-up, after extended periods of operation and after extended periods of plant shutdown. Defrosting consists of passing hot dry air through the low temperature sections of the plant to remove any moisture or carbon dioxide that may have accumulated.

DEFROST = 8 TO 12 HRS

THEN START-UP = 8 TO 12 HRS

CONTIN. W/O DEFROST - 12 MONTHS

DESIGN BASIS & UTILITIES
MODEL NLG-500 NITROGEN PLANT

This plant is designed to produce:

Gaseous nitrogen supplied at 75 PSIG
and near ambient temperature with a
purity of 99.999% inert.

6,700 SCFH
190 S.M.3/hr.

OR

Gaseous nitrogen supplied at 75 PSIG
and near ambient temperature with a
purity of 99.999% inert.

1,950 SCFH
55.2 S.M.3/hr.

AND

Liquid nitrogen supplied at 75 PSIG
subcooled with a purity of 99.999% inert

2,850 SCFH
80.7 S.M.3/hr.

The plant may be operated at various intermediate settings.

A standard cubic foot is measured at 68°F and one atmosphere absolute.

Plant design is based on atmospheric conditions of 85°F, 50% relative humidity, one atmosphere absolute, 85°F cooling tower water and normal atmospheric air containing a maximum of 350 PPM carbon dioxide.

UTILITIES

Electric Power

<u>ITEM</u>	<u>INSTALLED HP</u>	<u>AVERAGE OPERATING KW GAS ONLY</u>	<u>AVERAGE OPERATING KW GAS & LIQUID</u>
Air Compressor Motor	200	117.0	131.3
Regeneration Heater	18 KW	5.7	5.7
Refrigeration Unit	30	-----	21.0
<u>TOTAL AVERAGE OPERATING KW</u>		122.7	158.0

SUPPLY VOLTAGE

All equipment is designed to operate with electric power at 440 volts, 3 phase, 60 cycles. In addition, a supply of 110 volts, single phase power is required for operation of the control circuits.

DESIGN BASIS & UTILITIES CONT'd:

Cooling water at 85°F and

10°F temperature rise:

72 GPM

NOTES

1. No instrument air is required.
2. All operating power requirements are given in kilowatts and denote the power consumption as measured at the device. The power requirements are subject to a tolerance of plus or minus 4%.
3. Based on data from similar plants, sound level will not exceed 90 dBa during normal operation.

PLANT DEFROSTING

Defrosting is required before initial plant start-up, after extended periods of operation and after extended periods of plant shutdown. Defrosting consists of passing hot dry air through the low temperature sections of the plant to remove any moisture or carbon dioxide that may have accumulated.

Approximate times are as follows:

Time required for defrosting:	8 hours
Time until nitrogen produced after defrosting:	8 hours
Time of continuous operation without defrosting:	12 months

DESIGN BASIS & UTILITIES
MODEL NG-700 NITROGEN PLANT

This plant is designed to produce:

Gaseous nitrogen supplied at 75 PSIG
and near ambient temperature with a
purity of 99.999% inert.

9,500 SCFH

OR

Gaseous nitrogen supplied at 75 PSIG
and near ambient temperature with a
purity of 99.999% inert.

7,500 SCFH

AND

Liquid nitrogen supplied at 75 PSIG
subcooled with a purity of 99.999% inert

900 SCFH

The plant may be operated at various intermediate settings.

A standard cubic foot is measured at 68°F and one atmosphere absolute.

Plant design is based on atmospheric conditions of 85°F, 50% relative humidity, one atmosphere absolute, 85°F cooling tower water and normal atmospheric air containing a maximum of 350 PPM carbon dioxide.

UTILITIES

Electric Power

<u>ITEM</u>	<u>INSTALLED HP</u>	<u>AVERAGE OPERATING KW GAS ONLY</u>	<u>AVERAGE OPERATING KW GAS & LIQUID</u>
Air Compressor Motor #1	150	83.5	88.4
Air Compressor Motor #2	150	83.5	88.4
Regeneration Heater	30 KW	8.0	8.0
<u>TOTAL AVERAGE OPERATING KW</u>		175.0	184.8

SUPPLY VOLTAGE

All equipment is designed to operate with electric power at 440 volts, 3 phase, 60 cycles. In addition, a supply of 110 volts, single phase power is required for operation of the control circuits.

DESIGN BASIS & UTILITIES CONT'd: (NG-700)

Cooling water at 85°F and
10°F temperature rise: 90 GPM

NOTES

1. No instrument air is required.
2. All operating power requirements are given in kilowatts and denote the power consumption as measured at the device. The power requirements are subject to a tolerance of plus or minus 4%.
3. Based on data from similar plants, sound level will not exceed 90 dBa during normal operation.

PLANT DEFROSTING

Defrosting is required before initial plant start-up, after extended periods of operation and after extended periods of plant shutdown. Defrosting consists of passing hot dry air through the low temperature sections of the plant to remove any moisture or carbon dioxide that may have accumulated.

Approximate times are as follows:

Time required for defrosting:	8 hours
Time until nitrogen produced after defrosting:	8 hours
Time of continuous operation without defrosting:	12 months

DESIGN BASIS & UTILITIES CONT'd: (N-1000)

Cooling tower water at 85°F
and 10°F temperature rise: 120 GPM

NOTES:

1. No instrument air is required.
2. All operating power requirements are given in kilowatts and denote the power consumption as measured at the device. The power requirements are subject to a tolerance of $\pm 4\%$.
3. Based on data from similar plants, sound level will not exceed 86 dba during normal operation.

PLANT DEFROSTING

Defrosting is required before initial plant start-up, after extended periods of operation and after extended periods of plant shutdown. Defrosting consists of passing hot dry air through the low temperature sections of the plant to remove any moisture or carbon dioxide that may have accumulated.

Approximate times are as follows:

Time required for defrosting:	12 hours
Time until nitrogen produced after defrosting:	18 hours
Time of continuous operation without defrosting:	12 Months

DESIGN BASIS AND UTILITIES

MODEL N-1500 NITROGEN PLANT

The plant will be designed to produce high purity nitrogen of a minimum of 99.999 mol % inert as follows:

Gaseous nitrogen supplied at 100 PSIG and near ambient temperature 15,000 SCFH

OR

Gaseous nitrogen supplied at 100 PSIG and near ambient temperature 14,565 SCFH

AND

Liquid nitrogen supplied at 100 PSIG subcooled 435 SCFH

The plant may be operated at various intermediate settings.

A standard cubic foot is measured at 68°F and 14.7 PSIA.

Plant design is based on atmospheric conditions of 85°F, 50% relative humidity, 14.7 PSIA, 85°F cooling tower water and normal atmospheric air containing a maximum of 350 PPM carbon dioxide.

UTILITIES

Electric Power

<u>ITEM</u>	<u>SUPPLY VOLTAGE</u> <u>3 PH, 60 HERTZ</u>	<u>INSTALLED</u> <u>H.P.</u>	<u>AVERAGE</u> <u>OPERATING KW</u>
Air Compressor	440	150	117.20
Water Chiller	440	10	6.00
Chilled Water Pump	440	1	.75
Chilled Water Pump	440	1	-----
Expander Lube Oil Pump	440	1	.80
Expander Lube Oil Pump	440	1	-----
Lube Oil Heater	110	2 KW	-----
Regeneration Heater	440	40 KW	11.00
Defrost Heater	440	6 KW	-----
Controls	110	---	2.00

TOTAL AVERAGE OPERATING KW 137.75

DESIGN BASIS & UTILITIES CONT'd: (N-1500)

Cooling tower water at 85°F
and 10°F temperature rise: 178 GPM

NOTES:

1. No instrument air is required.
2. All operating power requirements are given in kilowatts and denote the power consumption as measured at the device. The power requirements are subject to a tolerance of $\pm 4\%$.
3. Based on data from similar plants, sound level will not exceed 86 dBA during normal operation.

PLANT DEFROSTING

Defrosting is required before initial plant start-up, after extended periods of operation and after extended periods of plant shutdown. Defrosting consists of passing hot dry air through the low temperature sections of the plant to remove any moisture or carbon dioxide that may have accumulated.

Approximate times are as follows:

Time required for defrosting:	12 hours
Time until nitrogen produced after defrosting:	13 hours
Time of continuous operation without defrosting:	12 Months

Cryoplants

**Skid-mounted
oxygen-nitrogen
plant. Type SK145**

Compact skid-mounted oxygen-nitrogen plant, Type SK145

The basic plant is assembled on three self-contained and compact skids which, when simply connected together on site, comprise a complete and fully operational plant.

Skid mounted units:

- Reduce site erection and commissioning period. The plant should be on stream within six weeks of site delivery.
- Reduce civil foundations and buildings. The plant is designed for outdoor location, and skids eliminate foundations other than concrete slab.
- Reduce lengthy pipe lines, particularly liquid lines, thus reducing natural evaporation losses.
- Reduce maintenance and operation activity. All controls and equipment are easily accessible and compact.

The plant will produce oxygen or nitrogen at a minimum purity of 99.5 per cent either as liquid or gaseous products.

- **Liquid oxygen**
145 Nm³/h of liquid oxygen, equivalent to 186 litres per hour at 4 bar (g) and minus 176°C.
- **Liquid nitrogen**
165 Nm³/h of liquid nitrogen, equivalent to 296 litres per hour at 13 bar (g) and minus 174°C.
- **Gaseous oxygen**
The liquid product can be pumped and vaporised into cylinders at a rate of up to 145 Nm³/h at 203 bar (g).
- **Gaseous nitrogen**
The liquid product can be pumped and vaporised into cylinders at a rate of up to 165 Nm³/h at 203 bar (g).

- **Skid No. 1**
Air compressor — standard machine.
Electric motor drive — 260 kW.
Interconnecting pipework.
Control panels.
- **Skid No. 2**
Freon pre-cooler.
Water separator.
Molecular sieve purifier unit comprising two adsorber vessels working alternately.

● Skid No. 3

- Main exchanger.
- Upper and lower column.
- Condenser/reboiler.
- Subcooler.
- Expansion turbine with oil brake and cooler.
- Mild steel casing 'cold box'.
- Interconnecting pipes, valves, fittings.
- Insulation.
- Instrument panel.

● Skid No. 4

- Cooling water tower skid.
- Additional freon cooler to increase plant capacity.
- Cylinder filling equipment for oxygen.
- Cylinder filling equipment for nitrogen.

● Skid No. 5

Air is compressed in a 3 stage reciprocating oil free compressor (2) to 35 bar (g) and is cooled in water cooled interstage and after-coolers, and finally reduced to 5°C in the freon cooler (3). Moisture is initially removed in the water separator (4) and the air is finally purified of moisture and carbon dioxide in the molecular sieve unit (5A/B) to less than 1 vpm impurities. Manual changeover of the molecular sieve vessels is carried out every eight hours.

The purified compressed air enters the cold box at a temperature of between 5 to 7°C and is further cooled in the main exchanger (7) against waste nitrogen, and expanded to about 13 bar (g) through the main expansion valve into the lower column (8). The lower column (8) separates the incoming air into rich liquid which collects at the bottom of the column, and poor liquid which

Both liquids are subcooled to below their saturation temperature in the subcooler (11) against cold waste nitrogen, before being expanded to about 4.2 bar (g) into the upper column (10) as reflux. Liquid oxygen product is taken from the reboiler bath (9) and sub-cooled against waste nitrogen in the sub-cooler (11). This cold waste nitrogen leaves the upper column and, after passing through the sub-cooler (11), enters the cold end of the main exchanger (7) where it is warmed before being expanded through the expansion turbine (6) and back into the exchanger (7). Part of the waste nitrogen is also used for reactivation and recooling of the molecular sieves.

High pressure gaseous oxygen

When high pressure gaseous oxygen is required for cylinder filling, the liquid oxygen is pumped (12) at pressure through an atmospheric vaporiser (13) into the cylinder filling manifold (14).

High pressure gaseous nitrogen

When high pressure gaseous nitrogen is required for cylinder filling, the liquid nitrogen is pumped (15) at pressure through an atmospheric vaporiser (16) into the cylinder filling manifold (17).

Liquid products

Both liquid oxygen and nitrogen can be passed directly from the plant into liquid storage.

Cryoplants

Plot plan for three basic skids for SK145

Utility requirements

The only services required are an electrical supply of not less than 380 volts, 3 phase, and a supply of good quality cooling water. The average consumption for these services is:

Power plant	298 kW
Cylinder filling	4 kW
Cooling water circulation rate at temperature rise of 11°C.	26 m ³ /hour

Commissioning

Qualified engineers are available to supervise the initial start up and commissioning of the plant, and to train the operators in the control and maintenance of the installation.

After sales service

A fast and reliable after sales and spares service is available through the BOC Group of Overseas Companies and established Agencies throughout the world.

Shipping weights and dimensions

- **Skid No. 1, compression module**

Length	4.3m
Width	3.5m
Height	3.3m
Weight	13 tonnes
- **Skid No. 2, pre-purification module**

Length	4.5m
Width	3.3m
Height	4.6m
Weight	9 tonnes
- **Skid No. 3, air separation module**

Length	8.9m*
Width	3.3m
Height	4.5m
Weight	19 tonnes

* This length becomes the overall height on site assembly.

Cryoplants Limited

Angel Road, London N18 3BW, England
Telephone 01-803 1300 Telex 263247
Cables: Cryoplants London

DESIGN BASIS AND UTILITIES

MODEL N-1,000 NITROGEN PLANT

The plant will be designed to produce high purity nitrogen of a minimum of 99.999 mol % inert as follows:

Gaseous nitrogen supplied at 100 PSIG and near ambient temperature 10,000 SCFH

OR

Gaseous nitrogen supplied at 100 PSIG and near ambient temperature 9,710 SCFH

AND

Liquid nitrogen supplied at 100 PSIG subcooled 290 SCFH

The plant may be operated at various intermediate settings.

A standard cubic foot is measured at 68°F and 14.7 PSIA.

Plant design is based on atmospheric conditions of 85°F, 50% relative humidity, 14.7 PSIA, 85°F cooling tower water and normal atmospheric air containing a maximum of 350 PPM carbon dioxide.

UTILITIES

Electric Power

<u>ITEM</u>	<u>SUPPLY VOLTAGE</u> <u>3 PH, 60 HERTZ</u>	<u>INSTALLED</u> <u>H.P.</u>	<u>AVERAGE</u> <u>OPERATING</u>
Air Compressor	440	125	80.80
Water Chiller	440	7.5	5.00
Chilled Water Pump	440	1	.75
Chilled Water Pump	440	1	-----
Expander Lube Oil Pump	440	1	.80
Expander Lube Oil Pump	440	1	-----
Lube Oil Heater	110	2 KW	-----
Regeneration Heater	440	30 KW	6.00
Defrost Heater	440	6 KW	-----
Controls	110	---	2.00
<u>TOTAL AVERAGE OPERATING, KW</u>			95.35