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The Viability of Imported Liquefied Natural Gas as an Energy Resource

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THE VIABILITY OF IMPORTED
LIQUIFIED NATURAL GAS
AS AN ENERGY RESOURCE

by

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Major Research paper submitted in partial fulfillment
of the requirements for the degree of Master of Marine
Affairs.

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Abstract of

THE VIABILITY OF IMPORTED LIQUIFIED NATURAL GAS AS AN
ENERGY RESOURCE

As the United States enters the 1980's, the need for secure and efficient energy sources is rapidly moving to the forefront of our foreign and domestic policies. It is apparent that our existence, as well as that of our allies, is closely tied to the ability to secure energy resources. The importation of Liquefied Natural Gas (LNG), by specially designed ships, from oil exporting nations to energy consuming nations has been a highly touted energy resource. While the importation of LNG may be a viable energy resource for many industrialized nations it does present unique problems for American energy resource planning. The United States has embarked on a national energy program that stresses independence and efficiency and LNG importation seems to fail on both of these accounts.

HYPOTHESES:

United States importation of LNG is not a cost effective energy resource due to: (1) dependence on foreign sources, (2) transportation costs including "hidden" expenses involving shipping subsidies, (3) safety regulations, and (4) pricing schemes by exporting nations as well as those mandated by federal regulations.

PREFACE

In August of 1977 my ship, the U.S.S. Julius A. Furer (FFG-6), was returning to her homeport of Charleston, South Carolina after a two month cruise to Great Britain to celebrate the Queen's Silver Jubilee when we were ordered to lay to, even as we sighted the Cooper River Bridge. After several minutes of comments and questions by the crew, the reason for the prolongation of our case of channel fever became readily apparent. A large white sphere, which barely cleared the bridge, was being towed to sea. Being a Naval Aviator, and a bit perturbed at our delay, I immediately commented on the heritage and diminished mental condition of anyone who would foul the seas with an object that wasn't flat enough for even a helicopter to land upon. I soon learned that the object of my displeasure was one of the independently constructed spheres that later would be put in a ship's hull to transport Liquified Natural Gas.

Despite my less than ideal introduction to the Liquified Natural Gas industry, I was intrigued by the engineering and scope of the concept and decided that LNG would be an interesting and contraversial subject for a major paper. In constructing this paper, one of the major problems that confronted me was the constant state of flux of the U.S. LNG industry. In the year that I have been following the subject with an eye towards serious research, I have seen the major contract negotiations stalled and abandoned because of the

inability to achieve a mutually agreeable price, three \$100 plus million ships were found unsafe by the Coast Guard, and U.S. LNG tankers are either being laid up or leased to foreign shippers.

The major problem in researching the subject was not in finding accurate technical data, valid energy forecasts, or information concerning the safety of transportation of LNG, but rather the hard facts concerning economic viability of the entire scheme. Obviously I could have taken the easy way out and "proved" that LNG importation is not a viable energy resource because it has fallen on such hard times but I believe that there are even more fundamental difficulties with the LNG importation industry and these problems will be discussed in the text and summarized.

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EVOLUTION OF THE LNG INDUSTRY

PART I

INTRODUCTION

Background. Natural gas usage in the United States has increased to the point where it has become our number one domestic energy resource. Today natural gas supplies roughly twenty-six percent of our nations total energy usage.¹ Table 1 illustrates natural gas consumption in comparison to the other major energy resources:

Table 1

Resource	Consumption (Quads)
Imported Oil	15.2
Domestic Oil	20.0
Natural Gas	21.0
Coal	15.8
Nuclear	2.9
Other	3.1
Total U.S. Consumption	78.0 Quads
Data from U.S. Dept. of Energy, compiled by M.B. Hunsiker	

The United States has roughly eight percent of the world's proven natural gas reserves; approximately 201 Quads. A Quad is defined as one quadrillion British Thermal Units, (BTU) or 10^{15} BTU and is a term which is used extensively to measure primary energy reserves and consumption. In order for the reader to gain an appreciation of the energy of a Quad, the following equivalent are provided: a Quad equals 40 million tons of coal, 24 million tons of petroleum, one trillion (10^{12}) cubic feet of natural gas, or 500,000 barrels per

day of oil for a full year. While this figure may seem staggering, one must realize that America used 78 quads in 1980, and almost 56 Quads came from our domestic natural resources. We consumed 20 Quads, roughly 10 percent, of the estimated 201 Quads of our own natural gas reserves last year alone. Why has natural gas become the premium fuel of our economy?

Natural Gas Developments. Natural gas is a generic term usually applied to a mixture of predominantly hydrocarbon gases found in subsurface rock reservoirs. Natural gas is usually made up of 85 to 95 percent methane and various concentrations of ethane, propane, and butane. Most Americans are familiar with what is generally termed associated gas, which is usually the volatile portion of crude oil found in varying proportions wherever crude oil is discovered. Non-associated gas is totally unrelated to liquid oil accumulations and it is also a major energy resource. One of the most important factors in the world's gas supply has been the large amounts of wastage through the process of "flaring off" natural gas in fields that have a low gas to oil ratio. Unless a pipeline was nearby or there was an exceptionally large supply of gas, it was simply uneconomical to try to store or transport the gas. Thus, all of the gas that was not used for reinjection, to maintain the oil extraction pressure, was simply ignited at the well head. It is estimated that Saudi Arabia flared amounts exceeding 14,000 million cubic meters a year - the equivalent of 12 million

tons of crude oil.²

In the United States the flaring off of unwanted gas is virtually non-existent because of a tremendous capital investment of almost one million miles of distribution pipelines. Presently, high pressure, high volume transmission pipelines link all of the lower 48 states, and pipelines are available to link all associated and non-associated fields. This vast distribution system is actually a double edged sword. While efficient distribution has assured that all potential resource areas can be served, it has also led to a tremendous demand for large industrial and domestic services.

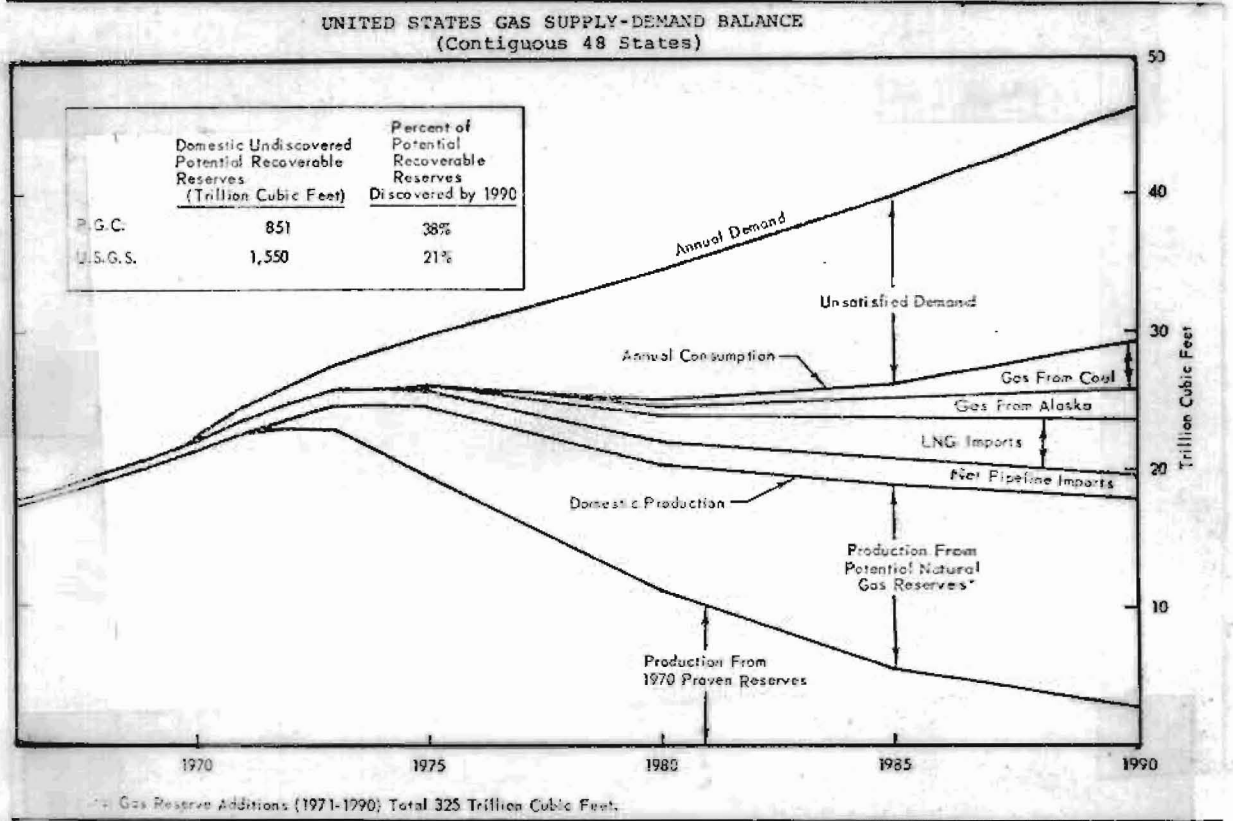
Federal Gas Policies. For many years the federal government held down the price of natural gas to unrealistic levels, resulting in little incentive to explore for new gas resources. This first became obvious to Americans in 1969 when natural gas suppliers were forced to refuse requests for new industrial and domestic services in much of the country. This original gas shortage was a harbinger of things to come and in 1976 and 1977 critical gas shortages forced Congress to enact the Natural Gas Policy Act of 1978. With this act, Congress hoped to allow the price of newly discovered natural gas, natural gas discovered later than 1969, to gradually increase to a price that would peg natural gas prices to the oil BTU equivalent by 1985.³ The major problem with this act was that Congress assumed imported oil would cost 15 dollars per barrel in 1985 and already most imported oil is

selling in excess of 38 dollars per barrel. Prior to the Natural Gas Policy Act of 1978 which introduced decontrol, it simply was not economical for developers to explore for new reserves at a price that was over 30 percent below market equivalent.

Since 1978 explorations have revealed vast new fields in the West and Gulf Coast. Nevertheless, actual production of natural gas has exceeded new discoveries by approximately 40 percent. Most of the new discoveries are in deep wells, over 15,000 feet, but again this phenomenon was almost mandated by Congress because the act allows gas drillers to charge up to 6 dollars per million BTUs for new deep gas compared to 2 dollars per million BTUs for new shallow gas.⁴ The gas development industry has found it more profitable to concentrate its capital on deep wells, hoping for a greater return. The complexity of the Natural Gas Policy Act has caused developers to bypass shallow gas reserves and actually has created somewhat of a shortage. Despite the fact that production is still outstripping discoveries most sources believe we will be able to continue current natural gas production levels for about 30 years. Table 2 gives a graphic description of how most current production levels will continue to be met, but it is interesting to note that demand will continue to rise.

Table 2

SOURCE: FPC, National Gas Supply and Demand, 1971-1980.



Decontrol, tax incentives, and conservation will not put more gas in the ground. Because of natural gas' high caloric value and extremely clean burning properties it has been the fuel of choice for industry and domestic use. These proer-ties would still make natural gas an extremely attractive fuel even if it were not currently priced 20 to 30 percent below imported oil of equivalent BTU capabilities. These qualities, coupled with the tremendous investment we have in distribution systems, make it mandatory that we explore all possibilities for securing reliable and plentiful gas supplies.

There are many unconventional gas production resource schemes under study. Among the most promising are, extrac-tion from Devonian Shale, Tight Sands, Geopressurized zones,

and synthetic production from coal. All of these methods have promise but they are years away from practical and economic feasibility.

LNG Development. One method of increasing natural gas supplies to the United States is the importation of Liquefied Natural Gas (LNG) in specially designed ships from oil exporting nations. Many argue that LNG will supply our needs until the other unconventional methods of natural gas production become feasible. Others argue that LNG importation makes us more dependent on foreign energy sources and that the entire process is too costly in energy usage and capital investment. Many others are concerned about the safety features of such a potentially dangerous process. While the potential safety aspects cannot be totally ignored, it must be realized that LNG operations have an enviable safety record and as long as we are involved in an energy shortage our economy will demand that we explore and utilize all potential energy sources. While the public may be concerned about potential disasters the most likely result will be stringent safety regulations, costly procedures for training and operation, and sophisticated equipment. Practically speaking, it would be difficult to restrict the usage of an energy resource based solely on a worst-case scenario. It appears that the importation of LNG will most likely continue to increase despite potential safety problems. The most important aspect of LNG importation to the United States is the

cost effective aspect of this energy intensive import resource.

Although LNG has been produced and utilized for years, the American public has only recently become aware of its role in our energy mix. This has been a result of increased public awareness and media attention to our energy shortage. The sheer size of the receiving terminals and transport vessels has caught the public's attention. The idea for liquification of natural gas to reduce its volume for efficient transportation was first patented in 1914.⁵ It was not until the 1940's that the process became commercially feasible and the first "peak shaving" facilities were constructed.

Characteristics of LNG. One property of natural gas that makes the liquification process so difficult is the fact that natural gas cannot be liquified by simply increasing the pressure. It must be cooled below its critical temperature of minus 100 degrees Fahrenheit and even then the pressure must be on the order of 800 PSI to maintain a liquid state.⁶ This creates considerable problems because of the expense of designing and producing transportation containers that would be capable of holding large quantities of LNG at high pressures and cool temperatures. The high pressures of the container would also present an unacceptable safety risk if a leak should occur. The safest and most cost-effective solution is to cool the natural gas to minus 260 degrees Fahrenheit and maintain 4 to 10 PSI internal pressure. The low pressures assure that leaks would not be as catastrophic.

The actual process of cooling gases below minus 240 degrees Fahrenheit is termed "cryogenics" and the process has been used for years for such common gases as oxygen, nitrogen, and helium for industrial processes.⁷ By cooling natural gas to its liquid state we can convert 600 cubic feet of free gas at atmospheric pressure to one cubic foot of liquid. This reduction in volume is what makes the transportation and storage of LNG feasible.

Peak Shaving. The earliest practical use of LNG was for "peak shaving" purposes. LNG is often stored to meet peak winter demand for residential heating. Usually a commercial user's demand will remain relatively constant by volume percentage regardless of weather conditions, however domestic customer demand fluctuates with the temperature. This increased demand placed on the distribution system by cold weather is often quite high and some type of temporary additional supply is usually required. In the construction of long-distance natural gas pipelines the usual practice is to size the pipeline larger than the average yearly demand rates and this allows the gas distributor to store LNG during the summer months. The distribution system can then meet peak demands by increasing the normal capacity 15 to 20 percent by operating all of the compression equipment throughout the distribution system at the maximum possible flow rate and release regasified LNG into the pipelines. This "peak shaving" system ensures adequate supply for the increased demand but the costs of liquification of the excess gas, storage in extensive insulated tanks, and regasification in winter are high.

pensive insulated tanks, and regasification is quite high.

For many years "peak shaving" facilities relied on the excess domestic gas supply of low demand cycles to stock their tanks. However, the maximum amount of LNG which can be produced at any one liquification site is limited to approximately 20 percent of the quantity of gas which drops from pipeline pressure to low pressure because of the need to maintain volume in the pipelines.⁸ Today, LNG "peak shaving" plants vary in size from small satellite plants resembling large golf balls with a capacity of 10,000 barrels, the equivalent of 35 million cubic feet of natural gas, to very large multi-tank facilities with the largest tanks having a capacity of 580,000 barrels or 2 billion cubic feet of natural gas.⁹ Each tank has the capacity to heat a city of 75,000 people for two months.

The importation of LNG for "peak shaving" facilities began for the United States in 1968 when the Boston Gas Company began importing shipments of LNG from Algeria. The United States began to export LNG in 1969 under long term contracts for gas from Alaska to Japan.¹⁰ Today LNG is used in the United States and other industrialized nations not only for "peak shaving" but also as an actual base load for domestic pipelines.

International Considerations. Ninety-five percent of all natural gas which crosses international borders is transported via pipeline.¹¹ The development of cryogenics has

allowed transportation of LNG in specially designed ships to nations which are beyond the economic range of pipeline construction. Presently the United States imports natural gas from Canada and Mexico at rates roughly equivalent to the BTU content of oil. At the same time we are importing relatively small quantities of LNG via ships from Algeria. Most Western European nations and Japan also import LNG via tankers and these nations appear to be making plans to import as much as the market conditions will allow. One of the basic questions which must be addressed is: Does the importation of LNG make economic sense for the United States or are we simply trying to compete with all users in a scarce energy market? Obviously, this type of question strikes at the very heart of a free market system, but when the government and the citizens, through taxation and subsidization, must foot part of the costs they should have an input to ensure that the enterprise is in their best interests and not simply a profit scheme for a few companies. The decision makers must consider the tremendous capital costs, subsidies, safety aspects, and energy alternatives to decide what is the best course of action and not just a misguided desire to compete or generate profits for a few companies.

Foreign Dependence. Despite the obvious need to develop and manage all practical energy resources the United States must also consider the adverse impacts of dependence on foreign sources. In plain and simple terms, we are the leader

of the free-world and our policies and actions must be based upon extremely high standards. Much of the world looks to America to set the example of economic prosperity based on a free market economy and trade between all nations. We must avoid even the perception of being forced into policy decisions based upon a dependence on foreign energy imports. The thought of the world's foremost economic and political power being hamstrung by dependence on unsecure imports would have catastrophic repercussions throughout the world economy. In short, if the United States cannot solve its energy problem the rest of the world, particularly developing nations, cannot look forward to economic prosperity or a stable world. (See Appendix I)

Presently the United States imports natural gas via pipeline from Canada and Mexico at prices ranging from \$3.45 to \$4.47 per million BTU. Comparing this to the BTU oil equivalent, the prices range from \$27.50 to \$33.60 a barrel.¹² While this price may seem reasonable it does not reflect the tremendous capital funds involved in pipeline distribution which are significantly higher than oil refinery costs. One of the major advantages to pipeline importation is the fact that the money stays in the North American economic sphere, hopefully raising the economy and encouraging the development of our neighboring countries. While it may seem that we are becoming dependent on just two sources of imported natural gas we should also recognize the fact that

strong trade relationships with our neighbors will enhance our security and the stability of our neighbors.

By restricting our natural gas importation to pipelines we may also benefit our allies by avoiding costly competition for scarce natural resources. Many European nations and Japan have significant energy resource problems and they are planning on imported LNG as a major contributor to their energy mix. The United States should not avoid the LNG competition simply out of altruism but at the same time we should not enter the arena simply from a spirit of competition and economic regard for a few corporations. We need to study LNG importation and make a decision based upon economic viability and national interest.

Today we can see vast changes in the world-wide LNG industry. The foreign producers are engaged in a crusade to raise the price of natural gas to an oil BTU equivalent. Already Algeria has achieved a pricing contract with France that will raise the price to \$5.00 per million BTU.¹³ The completion of pipelines to Italy and Spain has allowed Algeria to continue to export natural gas while negotiating favorable contracts with European purchasers of LNG. Italy and Spain are quite content to receive as much natural gas as the Algerians will send and the Algerians no longer have to depend on a single mode of gas exportation.

One American company, El Paso Natural Gas, has recently terminated its LNG operations because of an inability to

achieve a favorable price contract with Algeria. El Paso was by far the largest American importer of LNG and the company is now left with nine large LNG tankers and two operating terminals for regasification.

Natural gas exporting nations realize that decontrol of domestic gas in the United States has allowed prices to rise and their resource value has also risen on the American market. Like all gas producers they are glad to see the price of gas rise, but the distributors like El Paso prefer to see the price of natural gas lower to ensure that consumer conservation does not deplete their profits. The distributors must always keep a significant amount of natural gas in the pipelines or storage facilities to ensure safe and uninterrupted flow. This gas earns them nothing and conservation with high prices can seriously disrupt their business. At the same time competition among European nations and Japan for natural gas has given exporters a favorable market.

Algeria has announced that it will no longer pursue LNG exportation as a long range national economic policy. The pipelines to Europe have assured her a market and all of the expense of further distribution will be passed on to the importing nation or company. Scarce capital and high interest rates have made the construction of liquification facilities very expensive and the exporting nations would rather simply sell their gas via pipeline without the dependence on foreign capital and technology to keep their liquification

facilities operating and expanding. As pipelines reach more producing nations the trend away from liquification facilities at the export terminal will undoubtedly increase. The Persian Gulf area can be expected to move towards pipeline transport in the near future if and when the political situation stabilizes. However, major LNG export facilities can be expected to continue and actually increase in nations such as Nigeria and Indonesia.

As the distance increases from exporting liquification facility to importing terminal the transportation costs will increase, primarily as a result of the number of LNG tankers needed to maintain a "moving pipeline." In order to operate an efficient receiving terminal the tankers must arrive at a frequency that will allow planned continuous operation of the storage and gasification facilities. The tankers must also be able to receive their cargo on time and at the predetermined quantity. Presently, LNG tankers must spend 50 percent of their actual voyage time in ballast. These extensive operations make reliable supply contracts very important to any nation that plans on using imported LNG as a significant contributor to its energy needs.

Presently most European nations are striking bargains with exporting nations that are significantly higher than oil BTU equivalents simply to ensure long term contracts (up to 20 years) with guaranteed quantities.¹⁴ Obviously these nations are banking heavily on increasing energy costs

and a continuing energy shortage. American companies are not allowed to enter into these long-term, high-priced contracts because Congress has mandated that they must purchase their natural gas for importation at the lowest cost available. Thus, the exporting nations have no guarantee that the American companies would be able to legally fulfill their contractual obligations. This legal restriction has hampered American entry into some markets but has also served to avoid a multi-national contract bidding auction with only one beneficiary: the exporting nation.

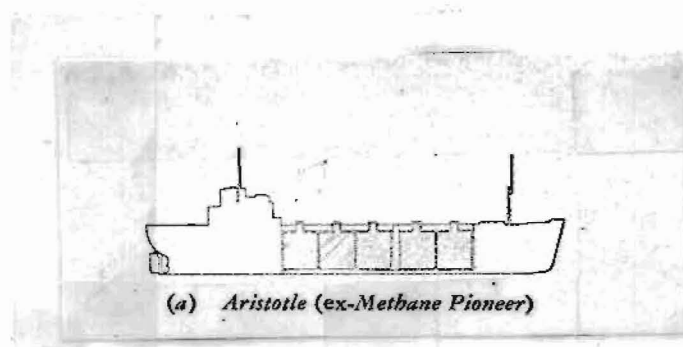
The American LNG companies argue that even though LNG is imported from foreign sources, it will actually cut our dependence on any one source of foreign energy by increasing the number of nations from which we import energy. At first glance, this argument makes some sense, unfortunately most nations that export LNG are also members of OPEC and a prudent person would assume that their LNG exporting policies would be closely tied to their oil policies. American LNG companies also argue that when a nation invests vast sums of capital in liquification facilities and port improvements that the nation would be less likely to provoke importers because of the revenues needed to operate the facilities and pay off capital investments. However, the industry is being less than candid by not also pointing out that for some projects as much as 90 percent of the initial capital is foreign investment.¹⁵ Much of this may be petro-dollars

but it is foreign capital investment nonetheless.

American LNG companies also argue that these facilities offer a market for American technology and management expertise. If we look further into this theory some flaws become apparent. Many of the nations which have developed LNG exporting facilities are already swimming in petro-dollars and have little real need for more state income according to their economic plans. The LNG facilities were promoted and developed as joint ventures by the companies involved and the exporting nations. One of the major selling points of these joint ventures was that the liquification and port facilities would provide an industrial base to their economies and also provide a diversified job market for local populations. The complexities of these plants has made these promises all but disappear. The plants are so complex and vast that proper management and maintenance by foreign technicians is a must. In addition most parts needed to maintain and operate the plants must be imported from the industrialized nations at high costs. Everything from complicated electronic components and valve assemblies to the tires for maintenance trucks must usually be imported. The local population is often reduced to menial maintenance tasks or feather-bedding management positions with little real production authority. This often leads to inefficient management and strained working relationships. Most exporting nations have developing economies which generally require basic

industrialization before moving into the high technology spheres of natural gas liquification and the like.

Transportation Costs. LNG importation is basically an energy transportation and distribution industry. The first ocean transport of LNG occurred in 1959 when the Methane Pioneer, a converted dry cargo ship, successfully transported 5,000 cubic meters of LNG from Lake Charles, Louisiana to Canvey Island at the head of the Thames Estuary in England.¹⁶ The Methane Pioneer remained in service for two years and made several successful voyages. (Fig. 1)



It became obvious that in order to realize any economies of scale LNG tankers would have to increase in size to roughly an equivalent of the Very Large Crude Carriers (VLCC). In addition the number of vessels devoted to a particular project must be sufficient to ensure a stable supply of LNG at the receiving terminal and little delays at the exporting liquification facility. Most large LNG tankers require approximately 24 hours to offload and turnaround, while loading

time may exceed 48 hours. In order to be efficient these vessels must maintain a rigid schedule. The average round trip time for the large LNG tankers from Arzew, Algeria to the East Coast of the United States is approximately 20 days. If the Federal Power Commission's forecasts of LNG importation as outlined in table 2 are true, this will mean that the United States LNG importation industry will require approximately 100 LNG tankers of the 125,000 cubic meter capacity and 6 to 8 receiving terminals.¹⁷ This will mean that an LNG tanker will call at each terminal every 40 hours. The capital investment in 100 ships with price tags of 125 million dollars a piece is staggering.

The actual shipborne transportation of the LNG product is not the major cost. The energy costs for the liquification are the highest portion of the LNG process, approximately 15 percent of the caloric value of the gas which is finally liquified is used just for that process.¹⁸ The entire liquification, transportation, and regasification process is less than 70 percent energy efficient. Approximately 8 to 10 percent of the energy value is used during the transportation by ship. This is not wastage however, because the tankers "boil off" LNG to use in their engines when they are on the high seas. The United States does not allow the vessels to use LNG for propulsion when entering an American harbor and this has caused an increased expense for dual fuel boilers for vessels expecting to operate in our

waters.

While the transportation of LNG in large expensive tankers may seem extravagant, the actual percentage of the transportation cost as related to the well-head price of natural gas will go down with each increase in gas prices. American LNG importers are confident that decontrol of natural gas will allow the domestic and pipeline prices to raise to a point where imported LNG will appear to be an attractive alternative.

Subsidies. Merchant shipping has always played a tremendous role in the economic health of America and the federal government has maintained a strong interest in the promotion of the maritime transportation industry. The LNG industry is no exception. Despite the conflicting regulations governing gas price controls and energy independence the Federal Government has actively supported and subsidized the construction of many LNG Tankers.

The Merchant Marine Act of 1936 as ammended in 1970 (Public Law 91-469) has made United States flag construction more attractive than ever before. The Maritime Administration is now authorized to pay construction - differential subsidies to reduce the cost difference between building a ship in a U.S. shipyard and the costs of building the vessel in a foreign yard. This cost difference cannot be greater than 50 percent, and LNG tanker construction costs usually only vary about 25 percent higher than foreign construction

costs. (See table 3)

TABLE 3

Vessel type	Construction costs	
	U.S.	Europe
125,000 cubic meters		
MOSS	\$90 mil	\$67 mil
MEMBRANE	100 mil	80 mil

These costs illustrate that American shipyards are generally more competitive when constructing high-technology sophisticated ships. The current construction differential subsidy barely makes VLCC construction viable in U.S. yards and there is so much overtonnage in almost all types of shipping the subsidies have not brought the amount of work that was anticipated to American shipyards. Table 4 illustrates the LNG construction subsidies of FY 79.

Table 4

LNG Construction Subsidies FY 79

OWNER	SHIPBUILDER	TOTAL COST	CDS
		(millions \$)	(millions \$)
El Paso Columbia	Avondale	106	17.5
El Paso Cove Point	Avondale	100	16.5
El Paso Savannah	Avondale	103	17.0
Lachmar	General Dynamics	155	40.0
Lachmar	General Dynamics	155	40.0

Source: Annual report of the Maritime Administration for fiscal year 1979. July 80.

Unfortunately, the Reagan administration is said to be favorably considering the withdrawal of all CDS funds as a

belt - tightening measure on the federal budget.¹⁹ This would seriously effect LNG tanker construction in American shipyards. The Office of Management and Budget has suggested the complete elimination of the 107 million dollar Carter proposal for CDS.²⁰ They feel that since only a few ships are built using CDS, the withdrawl of funding would not seriously affect American shipyards and the increase in naval shipbuilding should more than offset any impacts. Strangely enough, the American shipyards have not vigorously opposed this proposal to date, however, the maritime unions and shipowners have strongly opposed a reduction in CDS funding.

One of the adverse effects of CDS funding can be seen by the large percentage of American flag LNG tankers that are currently employed as LNG storage facilities or layed up and out of service. The construction subsidies allow the shipowners to take the tankers out of service at any time and accumulate depreciation time at a straight line rate of 4 to 5 percent annually. When one considers that the owners only paid for roughly two thirds of the vessel and the remainder was financed under loan guarantees from Title XI at low interest rates, it becomes obvious that the owners are not losing money when they lay up the LNG tankers for a short period of time. As the time increases other costs relating to the receiving terminals and ship maintenance begin to effect the company.

Title XI Loan Guarantees. Title XI of the Merchant

Marine Act authorizes federal ship financing guarantees to American shipowners who construct ships in American shipyards. As of the end of fiscal year 1980 over 6.4 billion dollars of financing guarantees by the federal government were in force. Of this total, approximately 1.4 billion dollars covered the construction of 16 LNG tankers and there are pending applications for 17 more LNG tanker guarantees for an additional 1.6 billion dollars.²¹ It is important to note that this is not money that the federal government has spent, it is a guarantee to the lenders that the federal government will pay the loans if the shipowner defaults. Actually the program has been very successful with only 12 defaults in the history of the Title XI guarantee program.²² Under Title XI the shipowners are eligible for government mortgage guarantees, ranging from 75 to 87.5 percent of the vessel cost. In addition, they may be eligible for direct government loans with a downpayment of 25 percent and some LNG tankers have even received funds under section 509 for national defense features.²³ These features include such items as increased shaft horsepower, nuclear, biological, and chemical washdown capabilities, increased turbo generating capacity, large boom cranes, and at-sea fueling stations. The federal government subsidizes American flag vessels for these features so that they can be used during time of war or crisis but the use of LNG tankers in a convoy or war zone would hardly seem prudent.

Operating Subsidies. The Merchant Marine Act authorizes the Maritime Administration to pay operating - differential subsidies, (ODS), to American shipping companies in order to help offset the higher price of operating an American flag vessel. These ODS funds are available for essential trade routes and essential cargoes. Currently LNG tankers do not receive ODS funding and unless the government makes a determined commitment to import LNG as a vital part of our energy mix, it is unlikely that LNG shipowners will benefit from this program.

Because of the relatively small crew and the high level of training involved it is unlikely that LNG shippers will rely on ODS to help defray labor costs. LNG tanker operations require highly skilled crewmen, not only to navigate and run the vessel, but also to ensure that the cargo is held in a proper cryogenic state. The operators of LNG tankers seem more than willing to pay premium wages to attract experienced crews and reduce any possible liability to the owner should the vessel be involved in a mishap.

Safety Considerations. If LNG should spill from its tank, either ship or shore-based storage tank, it will vaporize quickly and become highly volatile. Until LNG is regasified for distribution in domestic pipelines it has no odor, hence a leak is difficult to detect. LNG will only burn on the surface of the liquid, however if it is not kept cryogenically it will quickly vaporize (evaporate) at normal temper-

atures. The resulting vapor is highly volatile when mixed with air and since it will most likely be cooler than the surrounding air it will be more dense and settle towards the ground.

On October 20, 1944, at the East Ohio Gas Company in Cleveland, the first "peak shaving" plant using LNG in the United States, a storage tank containing 4,200 cubic meters of LNG collapsed.²⁴ The resulting explosion and fire killed 130 people, injured over 200 more, and resulted in property damage of 7 million dollars.²⁵ Much of the spilled LNG was contained in dikes at the site, however, some leaked into streets, storm sewers, and basements and exploded. The explosion flared back to the site and soon the rest of the LNG ignited. This catastrophe set back LNG operations in the United States for almost 20 years even though the actual cause of the accident was never determined.

Natural gas in its liquid state represents a tremendous concentration of potential energy. Because LNG is transported and stored at such low temperatures, heat is always flowing into the container and the pressure will increase. This means the vapor must be removed or the container must be mechanically cooled. Any breakdown in cooling capability necessitates a venting or burn off operation to keep the pressures inside the tanks at an acceptable level. Because the vaporized LNG has no odor the venting and burn off must be carried out precisely.

All tanks, including shipboard type, are heavily insulated to reduce the amount of mechanical cooling that is necessary. Indeed, when the El Paso Paul Kayser ran aground this past June near Gibraltar she was powerless for several days, but her sister ship, El Paso Sonatrach, salvaged the cargo even though cryogenic conditions were lost for approximately 24 hours.²⁶ While this speaks well of the insulating capabilities of LNG tankers it also was a stroke of luck that there was another empty cryogenic carrier within one days range.

If the LNG had spilled on the water most tests indicate that it would have rapidly vaporized and presented an immediate hazard to the vessel and others within approximately 10 miles. The cold gas in contact with water and water vapor would form a visible fog that could be detonated by any means. If the LNG vapor is ignited, the flame will travel towards the source of the leak.²⁷

In 1968 the Bureau of Mines conducted tests on the volatility of LNG spills on open water and discovered the possibility of a flameless explosion. This violent vaporization could cause ignition of the LNG very close to the leak source and rupture the entire structure, releasing all of the LNG at once.²⁸

Tank Construction. There are several types of storage tanks for LNG facilities: single steel tanks with outer insulation, dual tanks with steel outer tanks, and concrete tanks. Most LNG tanks in the United States are built above

ground and rely on a dike system to contain any spills. The General Accounting Office has found that these above ground tanks do not represent the safest technology. They claim that above ground tank farms are subject to earthquake, tornado, and flood damage.²⁹ There is also a great deal of concern over the fatigue effects on the tanks of storing the cryogenic material over a long period of time. The GAO has recommended that all LNG storage facilities be built underground or at least constructed to the standards applied to nuclear facilities.³⁰

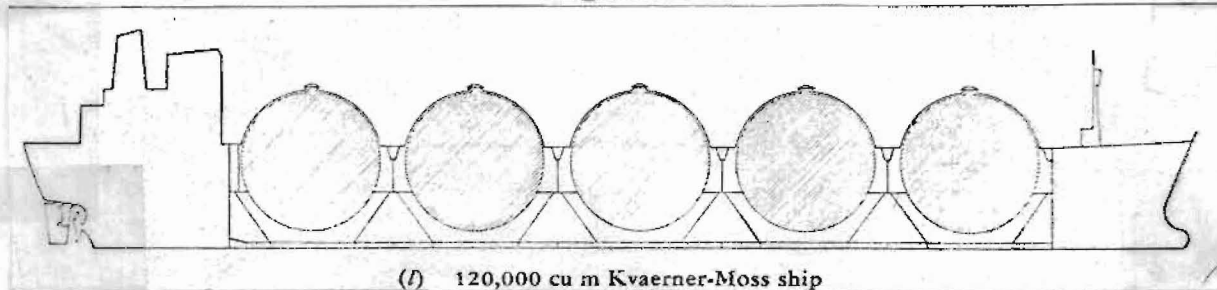
Ship Design. All LNG tankers are constructed with a double hull design to reduce the possibility of rupture of the LNG tanks. This practice proved its worth in the recent grounding of the El Paso Paul Kayser. The ship ran aground near Gibraltar at 16 knots and opened 12 bottom tanks to the sea. A gash approximately 500 feet long was put in the bottom but she did not lose any LNG.³¹

LNG tankers are usually equipped with bow thrusters, precision navigation, bridge control of engines, and collision avoidance systems in addition to the normal safety and operating equipment. They are constructed to strict IMCO standards and are structurally the safest link in the LNG chain.

There are two basic types of LNG ocean transport tankers in use today. The first type is often called the Moss - Rosenberg design which utilizes several free standing tanks

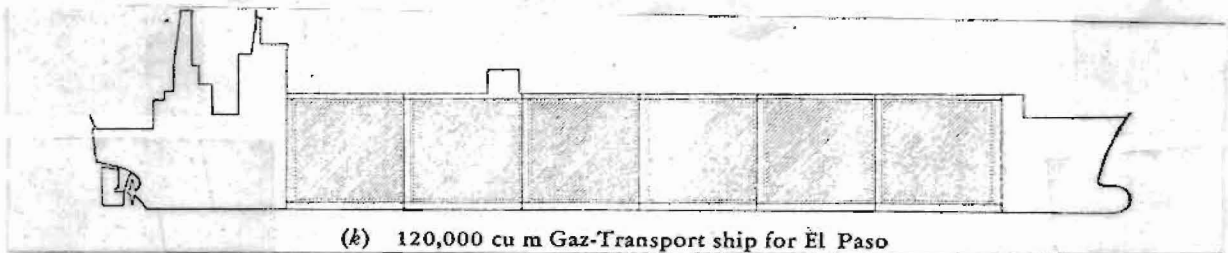
that are completely independent of the hull structure. (Fig.2)

Figure 2



Heavy insulation is applied to the exterior of the tank or the interior of the ship's hull. The second major type of LNG tanker is the membrane design. (Fig. 3)

Figure 3



In this type the ship's hull supports the insulation, which is load-bearing and separated from the cargo by a metal lining. This type of vessel does allow a more efficient use of cargo space but they have had difficulties. Three of these LNG tankers have been rejected by the Coast Guard because of cracks developing in the polyurethane foam insulation.³²

IMCO requires that the LNG tankers have a primary barrier, which is actually the tank, constructed of nickel alloy to withstand the cold temperatures. In addition to the primary barrier a secondary barrier must be able to hold the cargo for at least 15 days before any remaining LNG could

contact the hull of the ship. The IMCO Code for the Construction and Equipment of Ships Carrying Liquid Gas in Bulk of November 12, 1975 has ensured that all tanker vessels have enough redundancy and strict construction standards that they will leak before there could be a failure of the tanks. The Coast Guard conducts a rigorous inspection program and all vessels must submit a Letter of Compliance before entering a U.S. port. All LNG ocean tankers are subjected to vigorous design and construction requirements, testing, and material requirements such as crack-arresting steel deck and hull plates, gas-free detectors, and extensive venting. These requirements make LNG vessels very expensive to construct, operate, and maintain but anything less could be catastrophic.

Liability. Most of the LNG tankers are owned or leased by separately incorporated subsidiaries of a parent firm and the LNG receiving facilities are owned by different legal subsidiaries.³³ This presents a problem for parties seeking to collect for damages. Current limitations of liability statutes could make it impossible for collection since the single ship asset company would be bankrupt. If a major accident should occur there would be such extensive damage that the undercapitalized shipowner or charterer would most likely be unable to satisfy the claims. Since the vessel or the LNG facility would most likely be worthless the claimants would have a long and complex legal action with the insurance company. Currently liability coverage for LNG terminals

ranges from 50 million dollars to 190 million dollars per incident.³⁴ These funds could be quickly exhausted in a major accident where loss of life was a result. In the case of foreign ships the claimants may be unable to secure any legal recourse at all. The lack of strict liability statutes may result in the federal government becoming the party of last resort and tax money could be spent to satisfy claims.

Siting. LNG import terminals do present a potential safety hazard and should be located away from major urban centers. Currently only Boston has a large LNG import terminal in a large urban area and it is unlikely that any future development will take place in urban areas. The LNG import terminals at Cove Point, Md. and Elba Island, Ga. offer an acceptable risk to large urban areas. That is not to say that there are not large LNG and LPG storage facilities in urban areas. Most large cities have at least one facility within a potentially dangerous area, but they are not marine related.

When one considers the lengthy and costly siting process, with zoning requirements and Environmental Impact Statements it becomes apparent that a great deal of cost must accompany the planning of a site. Sites must be selected for their safety from flooding and earthquakes as well as their proximity to major distribution facilities. The average marine terminal for the importation of ocean transported LNG costs approximately 200 million dollars before start up.³⁵ The siting

process for LNG terminals is a complicated polyglot of federal, state, and local regulations.³⁶ Agency jurisdiction is not clearly defined and each LNG facility is considered on an individual case basis. The proposed facility at Cojo, California has been plagued by cost overruns of over 170 million dollars while battling environmentalists, land developers, indians, and the state government, even after meeting federal standards.³⁷ The expenses incurred obtaining permission to construct and operate a large marine LNG terminal will be passed on to the consumer in one fashion or another even if the facility is never constructed.

Sabotage. LNG is an extremely volatile substance with the potential to destroy wide areas if it is ignited in a proper fashion by saboteurs. Many malicious groups have the weapons and explosives to take over a major facility and actually hold an entire city as hostage. While this may be a worst-case scenario we should also realize that small facilities and LNG trucks are also vulnerable to terrorist activities. A small amount of LNG, if placed in a strategic location, could present security forces with a dilemma of unequal proportions. While trucks and transportable containers may represent the most likely terrorist targets, the large facilities and ocean LNG tankers cannot be overlooked. The GAO has found that all LNG facilities lack adequate security, construction safeguards, or contingency plans, and that the prevention of sabotage is not being investigated

properly despite the fact that large industrial sites and energy companies have often been the targets of sabotage in the past.³⁸

The GAO has recommended that the following programs be evaluated for use at LNG facilities:

"Physical barriers, guards, guard dogs, random roving patrols, and alarm systems.

-Area surveillance devices and intrusion detection systems; including terrestrial, in-water, and waterfront systems.

-Specialized and redundant communications and lighting systems.

-Hardening of specific structures to reduce the ease of damage and control forceful entry.

-Traffic control, air and underwater surveillance, unique security procedures and countermeasures for waterfront and shore facilities.

-Security escorts for ships, trucks, and tank cars.

-Personnel screening procedures and visitor clearance and control."³⁹

The implementation of these recommendations would be extremely costly and again the costs would be passed on to the consumer with no guarantee that sabotage could be prevented. Indeed some may argue that these extraordinary security procedures may actually attract terrorists.

Coast Guard Safety Requirements. The Port and Tanker Safety Act of 1978, (46USC 391a), gives the U.S. Coast Guard the responsibility for the safety of all U.S. flag LNG tankers in any waters, and foreign LNG tankers in U.S. waters.

The Coast Guard is also responsible for all standards for LNG tanker construction, maintenance, and operation.⁴⁰ The Coast Guard's official position on LNG operations is contained in "CG-478 LNG and LPG - Views and Practices, Policy and Safety." Basically they consider LNG to be a hazardous cargo requiring special consideration such as stringent construction inspections and biennial inspections for LNG tankers. Foreign vessels must obtain a Letter of Compliance, (LOC), and any change in owners or registry invalidates the current LOC. The Coast Guard feels that strict construction criteria and a strong inspection program play an important role in preventing any maritime LNG accident.

The Coast Guard inspection procedures for the arrival of a LNG shipment begin about 24 hours before the ship's arrival with an inspection of the port facility. This inspection ensures that the facility is prepared for the arrival, that the necessary equipment is safe and operable, and that adequate fire fighting equipment is prepared. At least two personnel are taken by helicopter or boat to the LNG tanker where they inspect the vessel for documentation, hull condition, navigation capability, cargo security, piping, venting, engine condition, and steering. The ship inspection takes approximately two and one-half hours and the results are radioed to the Captain of the Port who grants approval for the LNG vessel to enter the port.

All U.S. LNG port transportation is conducted during daylight hours with a Coast Guard helicopter and chase boat monitoring the channel for hazards or other traffic. Many ports require that other ocean vessels over certain DWT be kept out of the channel and traffic area when an LNG tanker with cargo is entering a port. The entire inspection and escort operation requires approximately 25 Coast Guard personnel for each shipment. The costs of this operation are borne by the taxpayer, but there have been recommendations that the LNG industry pay for the services; in which case the consumer will bear the costs. (See Appendix III, IV)

Personnel Training. Recognizing that the operation of LNG tankers and the associated cargo transfer procedures require qualified personnel, the Coast Guard has established minimum requirements for the Master, Chief Mate, Chief Engineer, First Assistant Engineer, and the "person in charge" of the shore facility. Most of the training is accomplished at maritime schools such as the Calhoun MEBA Engineering School, and the Coast Guard accepts completion of these schools as evidence of training. In addition, the Coast Guard conducts a four — day training course on LNG at Yorktown, Va. but this is primarily utilized by Coast Guard personnel and officers receive a 12 - week survey course.⁴¹ Presently the Coast Guard and IMCO are attempting to standardize training requirements for all ship's personnel involved with LNG transport. Most of the LNG companies require that their personnel complete extensive training

courses run by the parent company or safety consultants such as Marine Safety International.⁴² The most extensive training is conducted by the companies who have a vested interest in the safe and orderly transport of the cargo. The Coast Guard schools are designed for their personnel in order to provide a minimum level of training for their inspectors and officers.

Impact on Port Activity. Because of the strict traffic control regulations that must occur when LNG movements are scheduled for a port, other vessels and shippers must delay or advance their movements by as much as eight hours. On the surface this does not seem to be an unreasonable restriction, however, if LNG does expand to as much as 15 percent of our gas supply, it will mean arrivals at least every two and one-half days at each of the 6 to 8 East Coast ports. This could conceivably cause a major impact on vessel traffic both in the port area and in the waters adjacent to major marshalling areas. It is impossible to accurately forecast the actual impact on other shipping with the limited data available at this time.

Pricing Policy. The federal government through the Federal Power Commission which is now the Federal Energy Regulatory Commission, (FERC), has complete statutory authority over the sale of natural gas in interstate transport. During the years of federal price controls the price of natural gas was held down while the exploration companies

had to drill deeper and look offshore and the companies were unable to pass along these increased prices to the user.

Natural gas demand rose because of its low price and clean - burning qualities and the nation was faced with a gas shortage.

Now that the energy crises is recognized the FERC has proposed a two-phased incremental pricing policy linked to the Natural Gas Policy Act of 1978 which will decontrol the price of natural gas. The FERC plans to put the monetary burden on large industrial boiler users for the first phase. In effect they will be paying more for the natural gas they use than residential customers. The second phase would allow price increases to all industrial users of natural gas with the exception of hospitals, schools, and "other public service customers." The FERC explains its policy:

"The intent of incremental pricing, as conceived by legislators whose constituents stood to suffer from across the board decontrol of gas prices, is to alleviate the economic burden that normally would occur to small businesses, small industries and residences...since residential users have traditionally payed more than industrial users it should be industry who pays for new increases."⁴³

It is ironic to note that the gas distributors are totally opposed to this form of incremental pricing, arguing that it would not be "fair" for some users to pay more for the same product, when for years they charged small residential users much more than large industrial users because of the "increased economies of scale." Natural gas companies want

to see the costly new gas averaged in with the existing domestic supply and continue business as usual.

The pricing policy of LNG is very political and it is difficult to envisage either side gaining a clear decision. A two to threefold rapid price increase in natural gas would be catastrophic to most users but industry must also receive enough return to continue to invest in distribution and exploration. The LNG operation will continue to be controlled strictly by federal regulations governing the price that the exporter may receive, the return that the shipping company may make, and the final price that the distribution company may charge. All of this regulation makes the LNG industry costly to administer and subject to political whims with little regard for its use as a long-term contributor to our energy needs.

Developments. The future of the importation of LNG is in a constant state of flux because of the international situation and stability of potential exporters, the lack of clear directions on the part of government officials, and the potential safety and environmental problems associated with LNG. It appears as if Western Europe has made a long-term commitment to imported LNG and Royal Dutch Shell and British Petroleum have made major financial commitments to the construction of the world's largest liquification plant in Bonny, Nigeria. Japan has completed long-term contracts with Indonesia and has recently agreed to contracts at 5

dollars per million BTU for the importation of Alaskan LNG from Kenai.⁴⁴

The United States is currently importing only a small amount of LNG for "peak shaving" operations but El Paso has recently hired former Deputy Secretary of State Warren Christopher, of Iranian fame, to negotiate a contract with the Algerian nationalized gas company, Sonatrach.⁴⁵ This will most likely lead to a considerable increase in LNG importation.

At the present time there is severe overtonnage in the ocean LNG fleet but if the proposed liquification facilities in Nigeria, UAE, and Venezuela are completed as planned there will probably be a severe shortage of tankers by 1985 and U. S. companies may charter or sell their LNG fleets to support foreign LNG operations if the U.S. does not decide to import large quantities for base load distribution. It appears that the U.S. decision will have to be made by federal policies, the current policies do not give enough guidance for capital investment or foreign contract confidence. Until a firm policy is set, the U.S. LNG import industry will probably continue haphazardly until 1985.

Conclusions;

LNG importation to the United States is not cost effective because:

-We can import natural gas from Canada, Mexico, and Alaska.

-Our pipeline distribution system is

extensive enough to distribute any imported gas to the areas which require natural gas.

-Capital used in the LNG importation industry could be used in the construction of the Alaskan pipeline, other distribution systems, coal gasification, or other industrial revitalization.

-U.S. shipyards can continue to build LNG tankers and American companies can charter or sell the vessels without necessarily having our own LNG importation industry.

-The LNG tanker and facility inspection program carried out by the Coast Guard is an unnecessary expense to taxpayers.

-The siting of LNG facilities will involve costly legal battles that will burden the taxpayer and consumer.

-The U.S. will not achieve its goal of energy independence by increasing energy imports.

-Port activities will suffer unreimbursable expenses because of traffic restrictions during LNG operations.

-The costs of protection from sabotage will be passed to the consumer.

-Federal regulations and controls will be costly.

-U.S. competition for a world LNG market may drive prices to totally uneconomical limits. One need only look at the oil market to see the ramifications.

-The foreign sources of LNG are tied to OPEC with the exception of the Soviet Union.

-The importation of LNG will benefit only a small segment of industry while raising the price of natural gas to all users.

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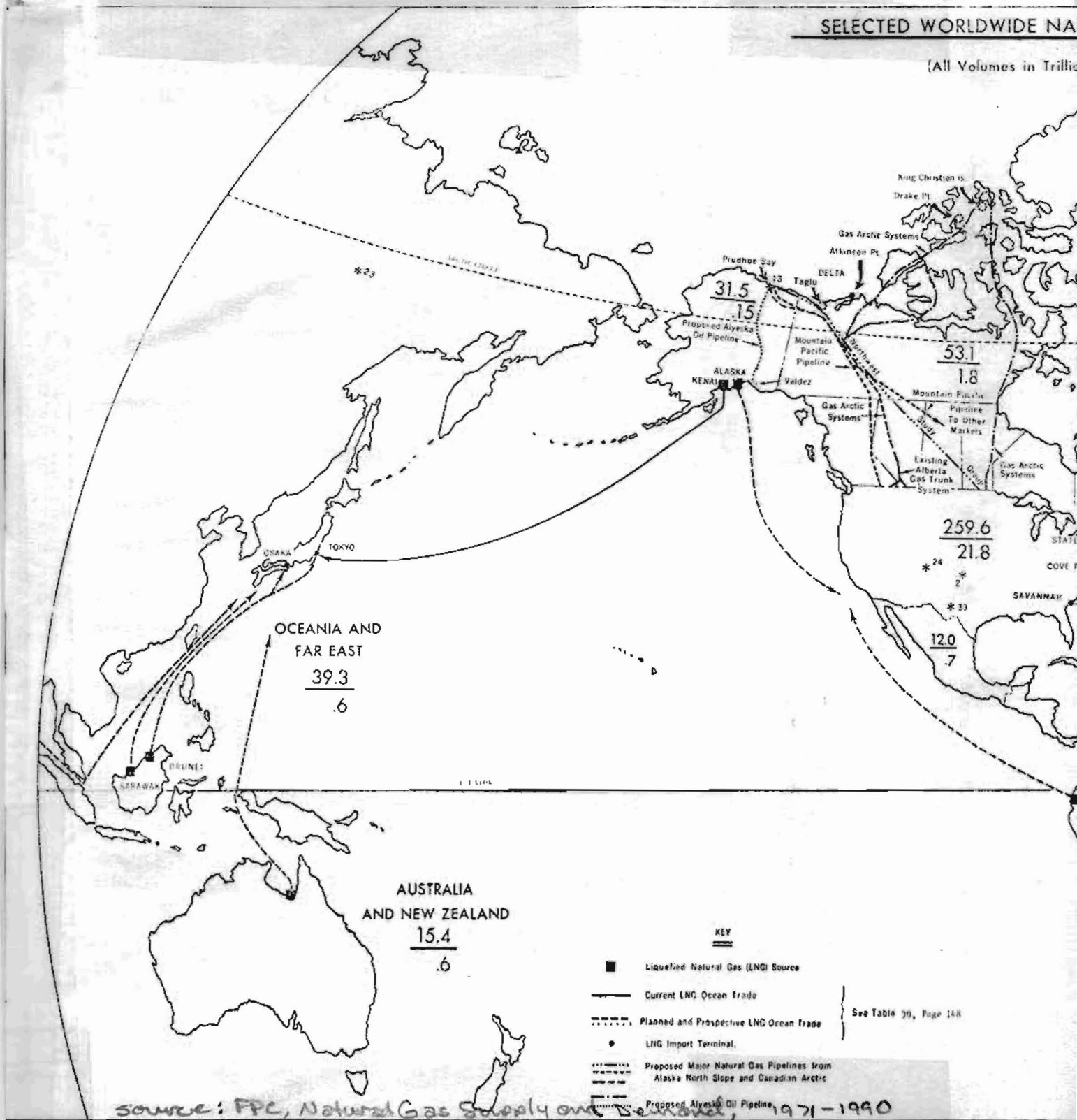
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APPENDIX I

SELECTED WORLDWIDE NATURAL GAS

(All Volumes in Trillion

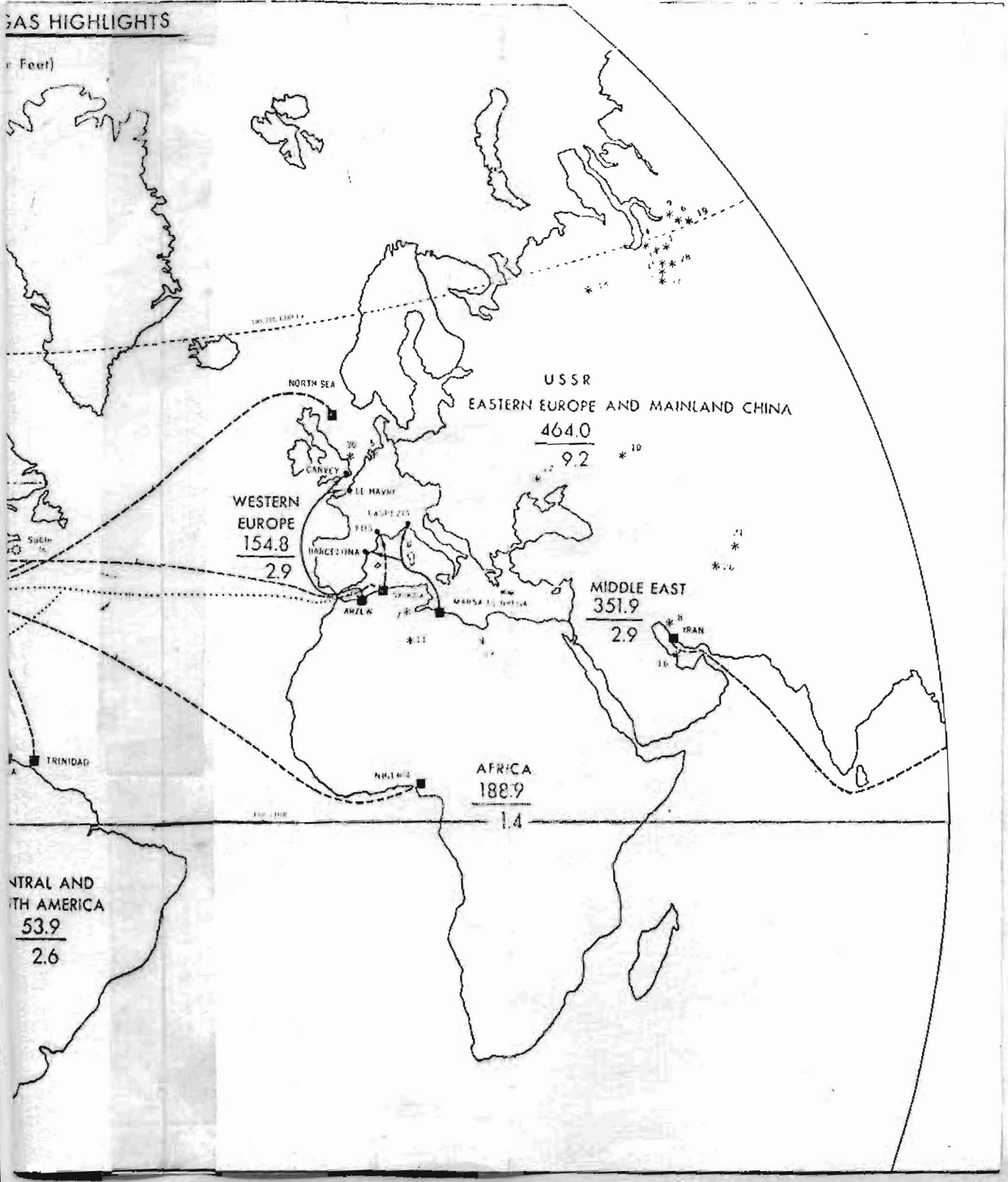


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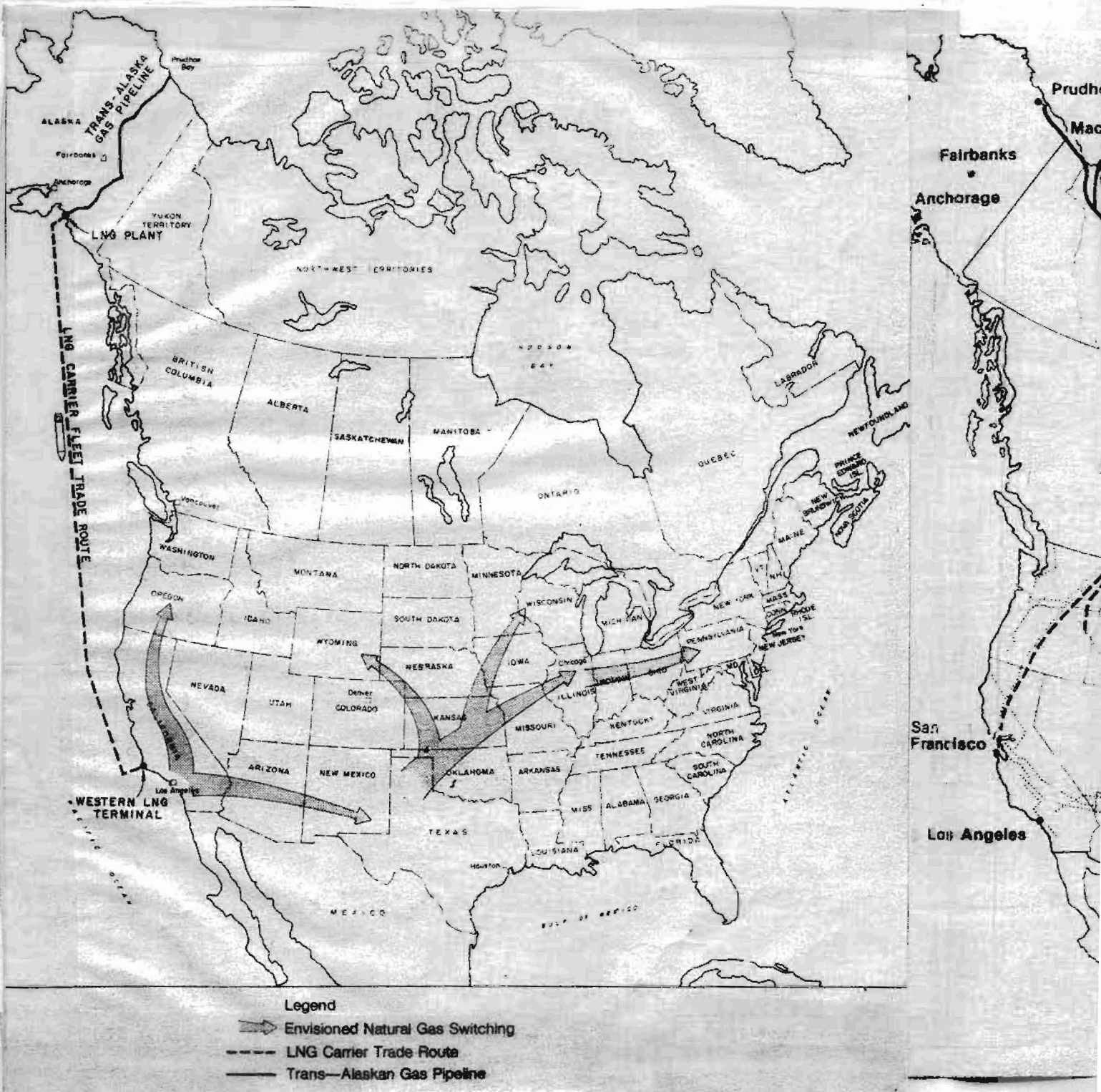
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GAS HIGHLIGHTS

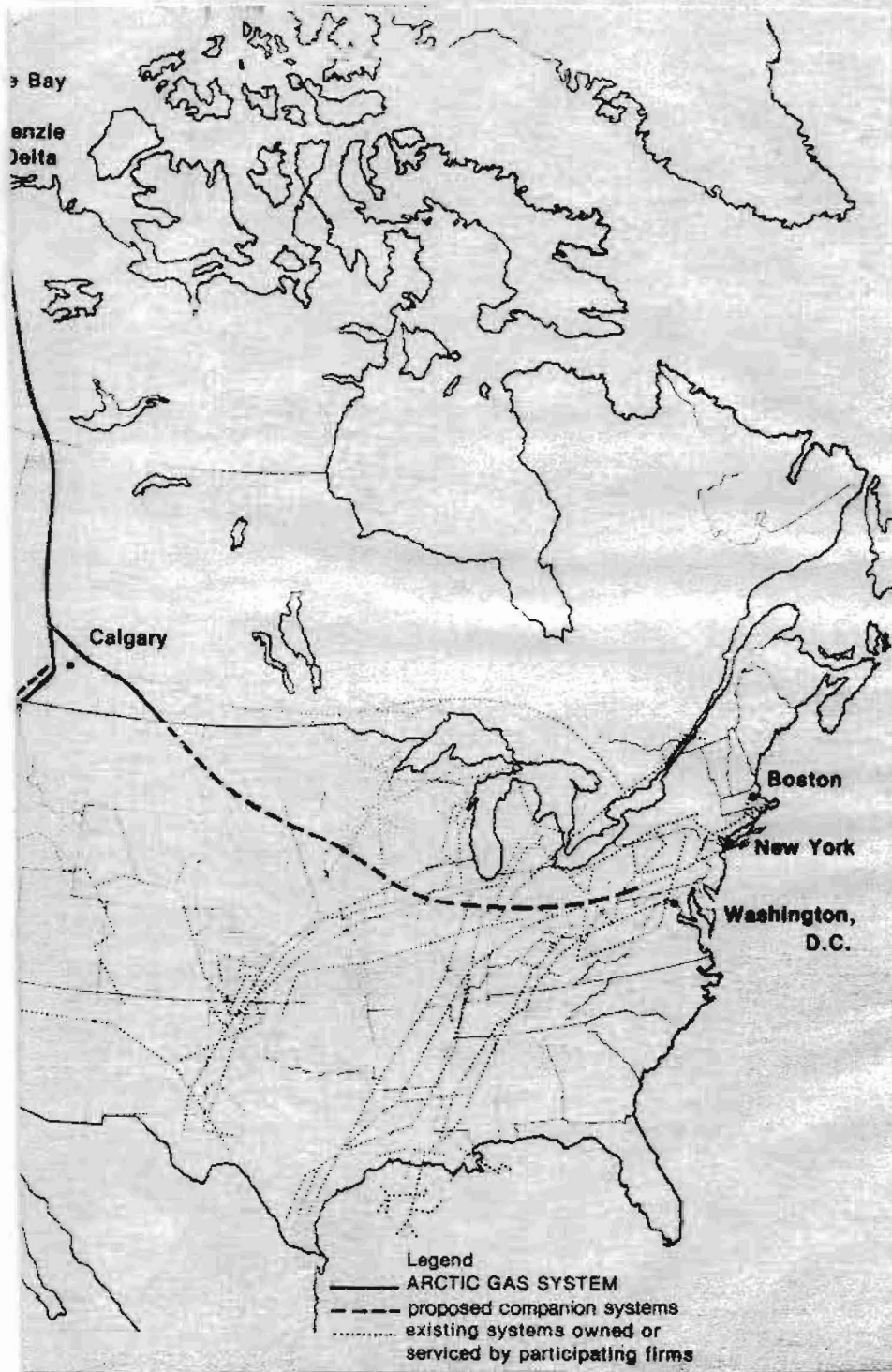
(in Feet)



APPENDIX II



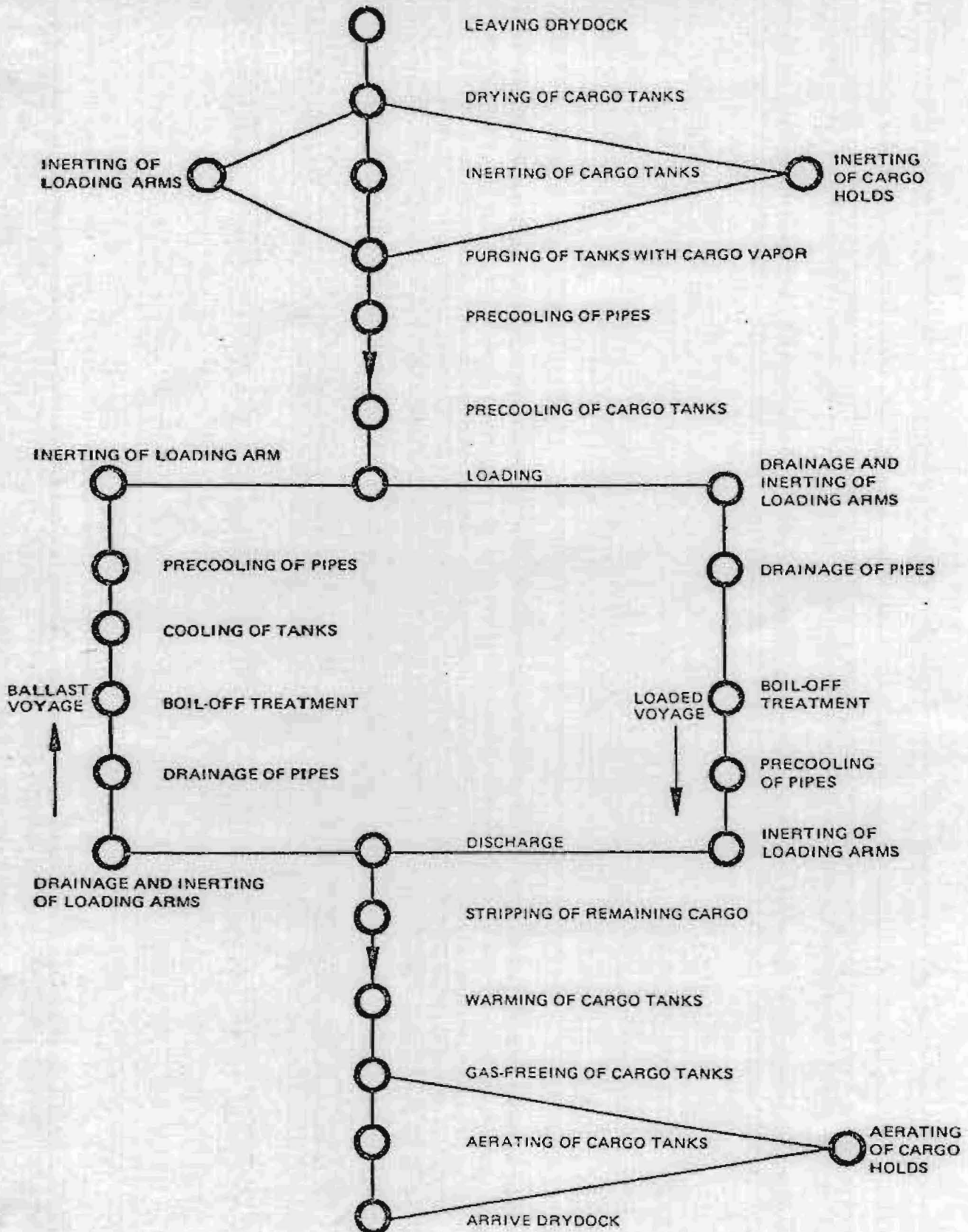
SOURCE: Oil and Gas Journal. Comparison of Alternate Natural Gas Transportation Systems for Alaskan Fields.



*Comparison of ARCTIC SYSTEM
 Gas Transportation System for Alaska*

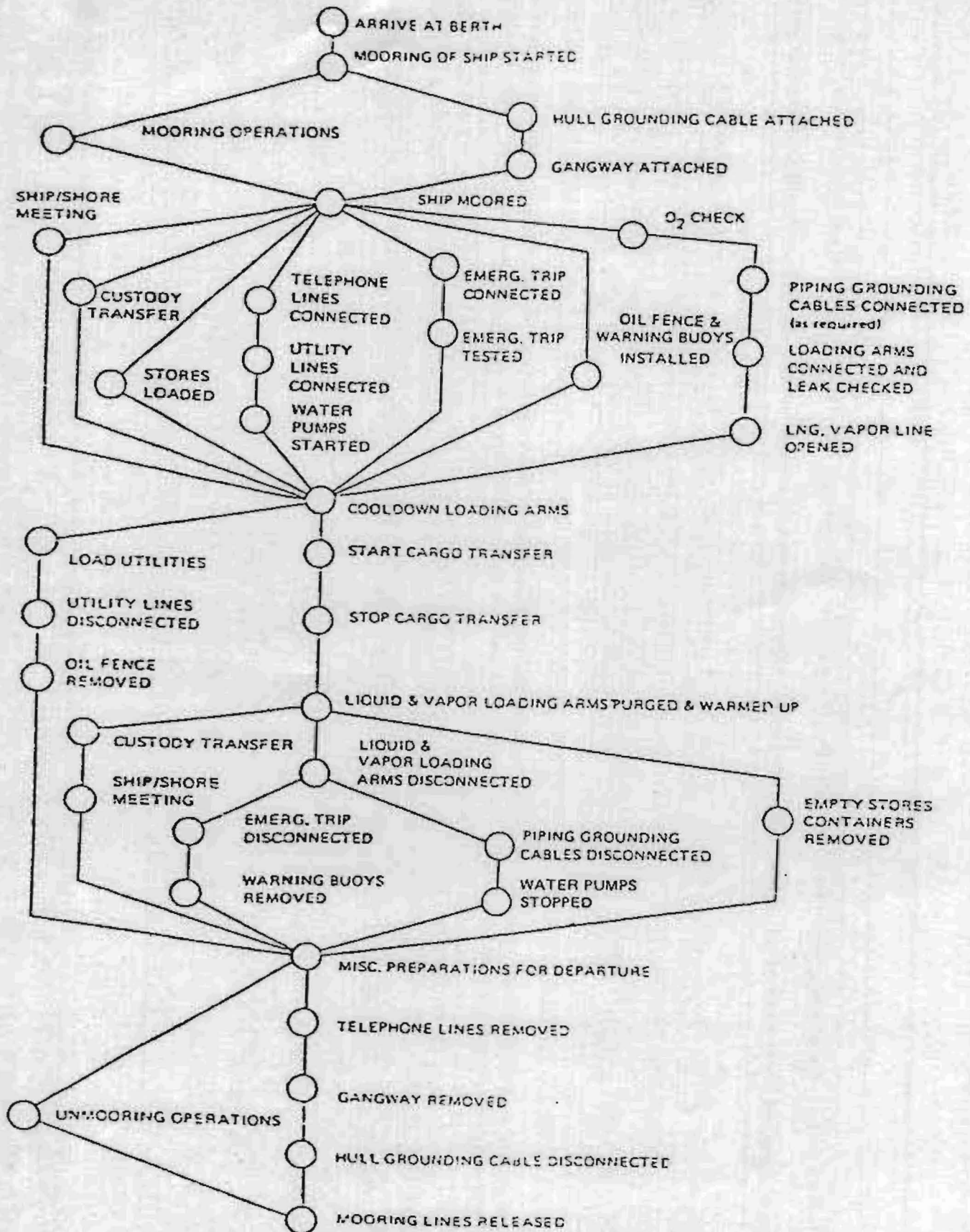
APPENDIX III

TYPICAL LEG CARGO OPERATION SCHEDULE



SOURCE: U.S.G.A.O. Liquefied Energy Gases Safety.

APPENDIX IV
TYPICAL CARGO TRANSFER SEQUENCE



SOURCE: U.S.G.A.O. Liquefied Energy Gases Safety.