come under attack, and in many states, building programs for new power station have been held up because of safety reasons.

- Moreover, CO_2 emission control from major fuels is recognized as the essential issue related to the greenhouse effect, especially since demand for energy increasing.

Concern over worlds' diminishing energy resources coupled with a growing awareness of the need to protect the environment, led to an upsurge interest in natural gas and construction of special natural gas carriers.

These conflicting demands for more energy and cleaner environment present a considerable problem and natural gas promises to solve both of them, thus it was known as a glamour fuel of 1970's.

Until well into the 20th century, it was considered a nuisance and a by-product of crude oil production. Only when in remote areas of Wyoming, huge reserves of gas were discovered, nobody thought it was one of the energies with a more than promising future. The proven reserves of natural gas at the end of 2001 amounted to 170 trillion cubic meter, which are equivalent to 153-milliard toe. The petroleum reserves at the same date, amounted to 142.6 milliard toe, so, we see that the usable reserves of gas are higher than those ones of petroleum.

1.10 Need For Transportation:

- By geographic areas, it is found in particular that,
- The former USSR, found particularly, the Russian Federation and Turkmenistan have nearly one third of the world reserves.
- Iran, Qatar, Australia, Papua New Guinea, the United States, and in Africa; Algeria, Nigeria, Libya and Egypt gather more than 90% of the proven reserves of this continent.
- The OPEC countries have 45% of the world natural gas resources, much lower that those they have in crude oil reserves, which amount to 78%.

- Moreover, there are large reserves of natural gas in areas for which there is no significant market. Such hydrocarbon reserves are stranded in North Africa, West Africa, South America, Caribbean, the Middle East, Indonesia, Malaysia, Northwestern Australia and Alaska. In addition, markets for these natural gases include Japan, Taiwan, Korea, Europe and the U.S.

Therefore, there is a need for transportation of natural gases to areas where it is scarce from areas where it is in abundance.

***Illustration 1*:-**

According to the U.S. Energy Information Administration (U.S. EIA), natural gas production in the U.S. is predicted to grow from 19.1 trillion cubic feet (Tcf) in 2000 to 28.5 Tcf in 2020.The total U.S. Demand for natural gas is expected to rise from 2.8 Tcf in 2000 to about 33.8 Tcf by 2020 adjusted for forecasted gains in energy efficiency and conservation). These projections suggest that the U.S. could face a gap of 5Tcf by 2020.

Hence, she needs to import natural gas to meet her requirements.

Where natural gas supply and the intended consumer are reasonably close, pipelines can be used for transporting the gas. However, as most of the world supply is remote from the consumer areas, shipboard carriage is the only alternative. Another aspect of the carriage by pipeline is that the government and private companies are reluctant to become involved with networks, which cross the territory of the countries other than their own.

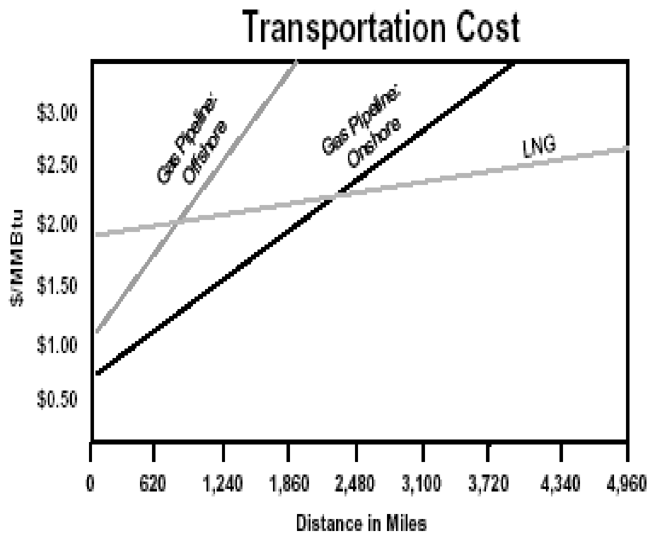
***Illustration 2*:-**

From the Russian Federation to Portugal, it is necessary to pass through at least four different countries.

Therefore it can be said that shipping transport of LNG is not only growing, but taking more and more importance, as the sea transport, offers the nations the strategic advantages such as

- Non-dependence on pipelines, built over many different lands of different nations.
- The LNG trade gives more freedom and less dependence on third parties for importers.

LNG offers greater trade flexibility than pipeline transport, allowing cargoes of natural gas to be delivered where the need is greatest and the commercial terms are most competitive. The figure below shows that as the distance over which natural gas must be transported increases, usage of LNG has economic advantages over usage of pipelines. Liquefying natural gas and shipping it becomes cheaper than transporting natural gas in offshore pipelines for distances of more than 700 miles or in onshore pipelines for distances greater than 2,200 miles.



Source: Institute of Gas Technology.

CHAPTER: 2

MODES OF TRANSPORTATION

2.1 Pipe lines:-

The efficient and effective movement of natural gas from producing regions to consumption regions requires an extensive and elaborate transportation system. In many instances, natural gas produced from a particular well will have to travel a great distance to reach its point of use. The transportation system for natural gas consists of a complex network of pipelines, designed to quickly and efficiently transport natural gas from its origin, to areas of high natural gas demand. Transportation of natural gas is closely linked to its storage, as well; should the natural gas being transported not be required at that time, it can be put into storage facilities for when it is needed.

Source: Duke Energy Gas Transmission Canada

There are essentially three major types of pipelines along the transportation route: the gathering system, the interstate pipeline, and the distribution system. The gathering system consists of low pressure, low diameter pipelines that transport raw natural gas from the wellhead to the processing plant. Should natural gas from a particular well have high sulfur and carbon dioxide contents (sour gas), a specialized sour gas gathering pipe must be installed. Sour gas is extremely corrosive and dangerous, thus its transportation from the wellhead to the sweetening plant must be done carefully.

Pipelines can be characterized as interstate or intrastate. Interstate pipelines carry natural gas across state boundaries, in some cases clear across the country. Intrastate pipelines, on the other hand, transport natural gas within a particular state. This section will cover the fundamentals of interstate natural gas pipelines, but the technical and operational details discussed are essentially the same for intrastate pipelines.

Natural gas pipelines are subject to regulatory oversight, which in many ways determines the manner in which pipeline companies must operate.

2.1.1 Interstate Natural Gas Pipelines :-

The interstate natural gas pipeline network transports processed natural gas from processing plants in producing regions to those areas with high natural gas requirements, particularly large, populated urban areas. As can be seen, the pipeline network extends across the entire country.

Pipes in Transit
Source: Duke Energy Gas Transmission Canada

Interstate pipelines are the 'highways' of natural gas transmission. Natural gas that is transported through interstate pipelines travels at high pressure in the pipeline, at pressures anywhere from 200 to 1500 pounds per square inch (psi). This reduces the volume of the natural gas being transported (by up to 600 times), as well as providing propellant force to move the natural gas through the pipeline. This section will cover the components of the interstate pipeline system, the construction of pipelines, and pipeline inspection and safety.

A Compressor Station
Source: Duke Energy Gas Transmission Canada

2.1.2 Pipeline Components:-

Interstate pipelines consist of a number of components which ensure the efficiency and reliability that is needed from a system that delivers such an important energy source year round, twenty four hours a day, and consist of a number of different components.

2.1.2.1 Pipes:-

Pipelines can measure anywhere from 6 to 48 inches in diameter, although certain component pipe sections can consist of small diameter pipe, as small as 0.5 inches in diameter. However, this small diameter pipe is usually used only in gathering and distribution systems. Mainline pipes, the principle pipeline in a given system, are usually between 16 and 48 inches in diameter. Lateral pipelines, which deliver natural gas to or from the mainline, are typically between 6 and 16 inches in diameter. Most major interstate pipelines are between 24 and 36 inches in diameter. The actual pipeline itself, commonly called 'line pipe', consists of a strong carbon steel material, engineered to meet standards set by the American Petroleum Institute (API).

Pipelines are produced in steel mills, which are sometimes specialized to produce only pipeline. There are two different production techniques, one for small diameter pipes and one for large diameter pipes. For large diameter pipes, from 20 to 42 inches in diameter, the pipes are produced from sheets of metal which are folded into a tube shape, with the ends welded together to form a pipe section. Small diameter pipe, on the other hand, can be produced seamlessly. This involves heating a metal bar to very high temperatures, then punching a hole through the middle of the bar to produce a hollow tube. In either case, the pipe is tested before being shipped from the steel mill, to ensure that it can meet the pressure and strength standards for transporting natural gas.

Line pipe is also covered with a specialized coating to ensure that it does not corrode once placed in the ground. The purpose of the coating is to protect the pipe from moisture, which causes corrosion and rusting. There are a number of different coating techniques. In the past, pipelines were coated with a specialized coal tar enamel. Today, pipes are often protected with what is known as a fusion bond epoxy, which gives the pipe a noticeable light blue color. In addition, cathodic protection is often used; which is a technique of running an electric current through the pipe to ward off corrosion and rusting.

2.1.2.2 Compressor Stations:-

As mentioned, natural gas is highly pressurized as it travels through an interstate pipeline. To ensure that the natural gas flowing through any one pipeline remains pressurized, compression of this natural gas is required periodically along the pipe. This is accomplished by compressor stations, usually placed at 40 to 100 mile intervals along the pipeline. The natural gas enters the compressor station, where it is compressed by a turbine, motor, or engine.

A Compressor Station
Source: Duke Energy Gas Transmission Canada

Turbine compressors gain their energy by using up a small proportion of the natural gas that they compress. The turbine itself serves to operate a centrifugal compressor, which contains a type of fan that compresses and pumps the natural gas through the pipeline. Some compressor stations are operated by using an electric motor to turn the same type of centrifugal compressor. This type of compression does not require the use of any of the natural gas from the pipe, however it does require a reliable source of electricity nearby. Reciprocating natural gas engines are also used to power some compressor stations. These engines resemble a very large automobile engine, and are powered by natural gas from the pipeline. The combustion of the gas powers pistons on the outside of the engine, which serves to compress the natural gas.

In addition to compressing natural gas, compressor stations also usually contain some type of liquid separator, much like the ones used to dehydrate natural gas during its processing. Usually, these separators consist of scrubbers and filters that capture any liquids or other undesirable particles from the natural gas in the pipeline. Although natural gas in pipelines is considered 'dry' gas, it is not uncommon for a certain amount of water and hydrocarbons to condense out of the gas stream while in transit. The liquid separators at compressor stations ensure that the natural gas in the pipeline is as pure as possible, and usually filters the gas prior to compression.

2.1.2.3 Metering Stations:-

In addition to compressing natural gas to reduce its volume and push it through the pipe, metering stations are placed periodically along interstate natural gas pipelines. These stations allow pipeline companies to monitor and manage the natural gas in their pipes. Essentially, these metering stations measure the flow of gas along the pipeline, and allow pipeline companies to 'track' natural gas as it flows along the pipeline. These metering stations employ specialized meters to measure the natural gas as it flows through the pipeline, without impeding its movement.

2.1.2.4 Valves:-

Interstate pipelines include a great number of valves along their entire length. These valves work like gateways; they are usually open and allow natural gas to flow freely, or they can be used to stop gas flow along a certain section of pipe. There are many reasons why a pipeline may need to restrict gas flow in certain areas. For example, if a section of pipe requires replacement or maintenance, valves on either end of that section of pipe can be closed to allow engineers and work crews safe access. These large valves can be placed every 5 to 20 miles along the pipeline, and are subject to regulation by safety codes.

2.1.2.5 Control Stations and SCADA Systems:-

Natural gas pipeline companies have customers on both ends of the pipeline - the producers and processors that input gas into the pipeline, and the consumers and local distribution companies that take gas out of the pipeline. In order to manage the natural gas that enters the pipeline, and to ensure that all customers receive timely delivery of their portion of this gas, sophisticated control systems are required to monitor the gas as it travels through all sections of what could be a very lengthy pipeline network. To accomplish this task of monitoring and controlling the natural gas that is traveling through the pipeline, centralized gas control stations that collect, assimilate, and manage data received from monitoring and compressor stations all along the pipe.

Most of the data that is received by a control station is provided by Supervisory Control and Data Acquisition (SCADA) systems. These systems are essentially sophisticated communications systems that take measurements and collect data along the pipeline (usually in a metering or compressor stations and valves) and transmit them to the centralized control station. Flow rate through the pipeline, operational status, pressure, and temperature readings may all be used to assess the status of the pipeline at any one time. These systems also work in real-time, meaning that there is little lag time between the measurements taken along the pipeline and their transmission to the control station.

This information, relayed to a centralized control station, allows pipeline engineers to know exactly what is happening along the pipeline at all times. This allows quick reactions to equipment malfunctions, leaks, or any other unusual activity along the pipeline. Some SCADA systems also incorporate the ability to remotely operate certain equipment along the pipeline, including compressor stations, allowing engineers in a centralized control center to immediately and easily adjust flow rates in the pipeline.

2.1.3 Pipeline Construction:-

As natural gas use increases, so does the need to have transportation infrastructure in place to supply the increased demand. This means that pipeline companies are constantly assessing the flow of natural gas across the U.S., and building pipelines to allow transportation of natural gas to those areas that are underserved.

Surveying the Right-of-Way
Source: Duke Energy Gas Transmission Canada

Constructing natural gas pipelines requires a great deal of planning and preparation. In addition to actually building the pipeline, several permitting and regulatory processes must be completed. In many cases, prior to beginning the permitting and land access processes, natural gas pipeline companies prepare a feasibility analysis to ensure that an acceptable route for the pipeline exists that provides the least impact to the environment and public infrastructure already in place.

Assuming a pipeline company obtains all the required permits and satisfies all of the regulatory requirements, construction of the pipe may begin. Extensive surveying of the intended route is completed, both aerial and land based, to ensure that no surprises pop up during actual assembly of the pipeline.

Installing a pipeline is much like an assembly line process, with sections of the pipeline being completed in stages. First, the path of the pipeline is cleared of all removable impediments, including trees, boulders, brush, and anything else that may prohibit the construction. Once the pipeline's path has been cleared sufficiently to allow construction equipment to gain access, sections of pipes are laid out along the intended path, a process called 'stringing' the pipe. These pipe sections are commonly from 40 to 80 feet long, and are specific to their destination. That is, certain areas have different requirements for coating material and pipe thickness.

'Stringing' the Pipe
Source: Duke Energy Gas Transmission Canada

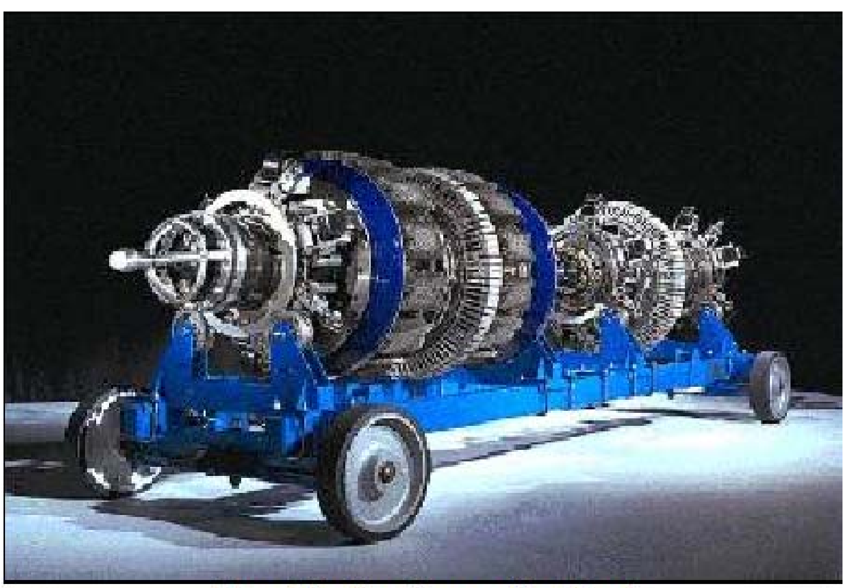
Once the pipe is in place, trenches are dug alongside the laid out pipe. These trenches are typically 5 to 6 feet deep, as the regulations require the pipe to be at least 30 inches below the surface. In certain areas, however, including road crossings and bodies of water, the pipe is buried even deeper. Once the trenches are dug, the pipe is assembled and contoured. This includes welding the sections of pipe together into one continuous pipeline, and bending it slightly, if needed, to fit the contour of the pipelines path. Coating is applied to the ends of the pipes (the coating applied at a coating mill typically leaves the ends of the pipe clean, so as not to interfere with welding), and the entire coating of the pipe is inspected to ensure that it is free from defects.

Once the pipe is welded, bent, and coated, it can be lowered into the previously dug trenches. This is done with specialized tracked construction equipment acting in tandem to lift the pipe relatively uniformly and lower it into the trench. Once lowered into the ground, the trench is filled in carefully, to ensure that the pipe and its coating do not incur damage. The last step in pipeline construction is the hydrostatic test. This consists of running water, at pressures higher than will be needed for natural gas transportation, through the entire length of the pipe. This serves as a test to ensure that the pipeline is strong enough, and absent of any leaks of fissures, before natural gas is pumped through the pipeline.

Laying pipe across streams or rivers can be accomplished in one of two ways. Open cut crossing involves the digging of trenches on the floor of the river to house the pipe. When this is done, the pipe itself is usually fitted with a concrete casing, which both ensures that the pipe stays on the bottom of the river, and add an extra protective coating to prevent any natural gas leaks into the water. Alternately, a form of directional drilling may be employed, in which a sort of 'tunnel' is drilled under the river through which the pipe may be passed. The same techniques are used for road crossings - either an open trench is dug up across the road and replaced once the pipe is installed, or a tunnel may be drilled underneath the road.

Once the pipeline has been installed, and covered up, extensive efforts are taken to restore the pipeline's pathway to its original state, or to mitigate for any environmental or other impacts that may have occurred during the construction process. This often includes replacing topsoil, fences, irrigation canals, and anything else that may have been removed or upset during the construction process.

2.1.4 Pipeline Inspection and Safety:-



Pig - Pipeline Inspection Tool
Source: Duke Energy Gas Transmission Canada

In order to ensure the efficient and safe operation of the extensive network of natural gas pipelines, pipeline companies routinely inspect their pipelines for corrosion and defects. This is done through the use of sophisticated pieces of equipment known as pigs. Pigs are intelligent robotic devices that are propelled down pipelines to evaluate the interior of the pipe. Pigs can test pipe thickness, and roundness, check for signs of corrosion, detect minute leaks, and any other defect along the interior of the pipeline that may either impede the flow of gas, or pose a potential safety risk for the operation of the pipeline. Sending a pig down a pipeline is fittingly known as 'pigging' the pipeline.

In addition to inspection with pigs, there are a number of safety precautions and procedures in place to minimize the risk of accidents. In fact, the transportation of natural gas is one of the safest ways of transporting energy, mostly due to the fact that the infrastructure is fixed, and buried underground. According to the Department of Transportation (DOT), pipelines are the safest method of transporting petroleum and natural gas. While there are in excess of 100 deaths per year associated with electric transmission lines, according to the DOT's Office of Pipeline Safety in 2001, there were 2 deaths associated with transmission pipelines, and 5 deaths associated with distribution systems. To learn more about pipeline safety, visit the DOT's Office of Pipeline Safety here.

A few of the safety precautions associated with natural gas pipelines include:
Aerial Patrols - Planes are used to ensure no construction activities are taking place too close to the route of the pipeline, particularly in residential areas. Unauthorized construction and digging is the primary threat to pipeline safety, according to INGAA

Leak Detection - Natural gas detecting equipment is periodically used by pipeline personnel on the surface to check for leaks. This is especially important in areas where the natural gas is not odorized.

Pipeline Markers - Signs on the surface above natural gas pipelines indicate the presence of underground pipelines to the public, to reduce the chance of any interference with the pipeline.

Gas Sampling - Routine sampling of the natural gas in pipelines ensures its quality, and may also indicate corrosion of the interior of the pipeline, or the influx of contaminants.

Preventative Maintenance - This involves the testing of valves and the removal of surface impediments to pipeline inspection.

Emergency Response - Pipeline companies have extensive emergency response teams that train for the possibility of a wide range of potential accidents and emergencies.

The One Call Program - All of the states have instituted what is known as a 'one call' program, which provides excavators, construction crews, and anyone interested in digging into the ground around a pipeline with a single phone number that may be called when any excavation activity is planned. This call alerts the pipeline company, which may flag the area, or even send representatives to monitor the digging.

These are but a few of the efforts undertaken by the pipeline industry to ensure the safety of the public and the environment, and to protect the integrity of their pipelines

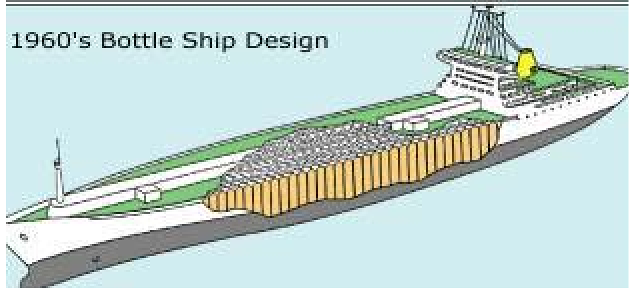
2.2 CNG: A Competitive Technology to LNG for the Transport of Natural Gas:-

Existing means of transporting natural gas consist primarily of pipelines and LNG. Pipelines account for 75%, with LNG making for the rest. Pipelines are the obvious means for the onshore transport of natural gas. But for offshore transport, as the water depth and distance between sources and users increase, pipelines become economically unattractive. LNG provides then an appropriate way of delivering natural gas from offshore. However, because of the large upfront investment, LNG requires large reserves of natural gas near the facilities to support a LNG project and get acceptable returns capital investment
Compressed natural gas (CNG) technology provides an effective way for shorter-distance transport of the gas. The technology is aimed at monetizing offshore reserves, which cannot be produced because of unavailability of pipeline or because the LNG option is very costly. Technically the technology is easy to deploy with less requirements for facilities and infrastructure.

2.2.1 Compressed Natural Gas:-

Compressed Natural Gas (CNG) as a mode of transport of natural gas is now pursued with renewed interests. Earlier attempts in the 1960s to commercialize the technology were made with technical difficulties and along with the requirement of heavy investments made the commercial application of the technology unfeasible.

Ocean Transport Pressure System 1968



- ✓ CNG at 80 bar and -600C
- ✓ Approved by USCG
- ✓ Prototype built and tested in New Jersey, but not found to be commercial

2.2.2 Saga / Moss Rosenberg CNG Design 1976:-

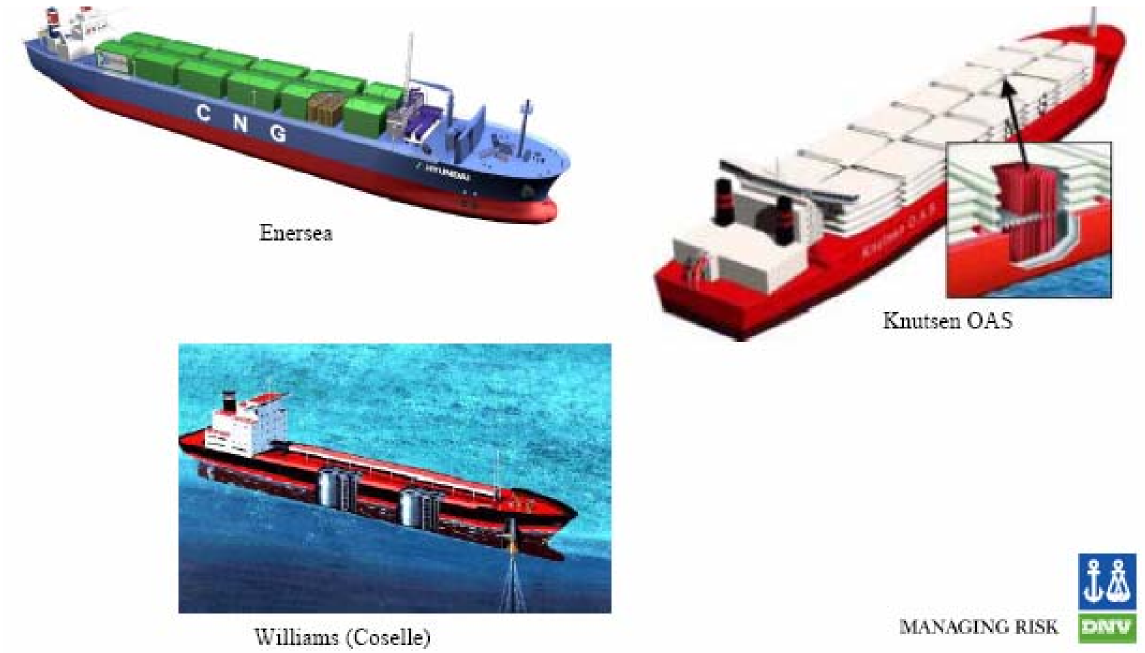
• CNG carrier capable of carrying a mixture of gas and oil at 100 bar• Idea conceived by Saga Petroleum in 1976
• Concept drawings developed by Saga and Moss Rosenberg yard of Norway
•Loading directly from sub-sea wells using well pressure for loading and water for discharging the cargo.
•18,000 m3in 280 bottles

2.2.3 Modern CNG Carrier Concepts :-

With present developments in materials and their applications and CNG's promising outlook in handling and marketing associated gas and the exploitation of stranded reserves, have renewed the interest in commercializing the technology. One of the proponents of the CNG technology in the early 1990s was Cran & Stennings Technology Inc. that proposed a wellknown concept, "Coselletm". The idea seeks to reduce the manufacturing cost of the gas containment system. Spooling small diameter (6 inch) coiled tubing into large carrousels achieves the purpose. The gas is pressured up to 3000 psi at ambient temperatures. Similar methodology is used by others namely Trans Ocean Gas, a Canadian enterprise, and Knutsen O.A.S Shipping of Norway with varying characteristics of the containment system7. Another approach to CNG is espoused Enersea Transport LLC, They developed the "VOTRANStm" concept in which the natural gas is compressed and cooled to lower temperatures6. This reduces the volume of the compressed gas compared to just compressing it at ambient temperatures. At the lower temperatures of 0 to –40oF the process works at lower pressures than at ambient temperatures.

Many concepts are proposed for transportation of CNG but most of them are based on transportation in pipeline/pressure vessels

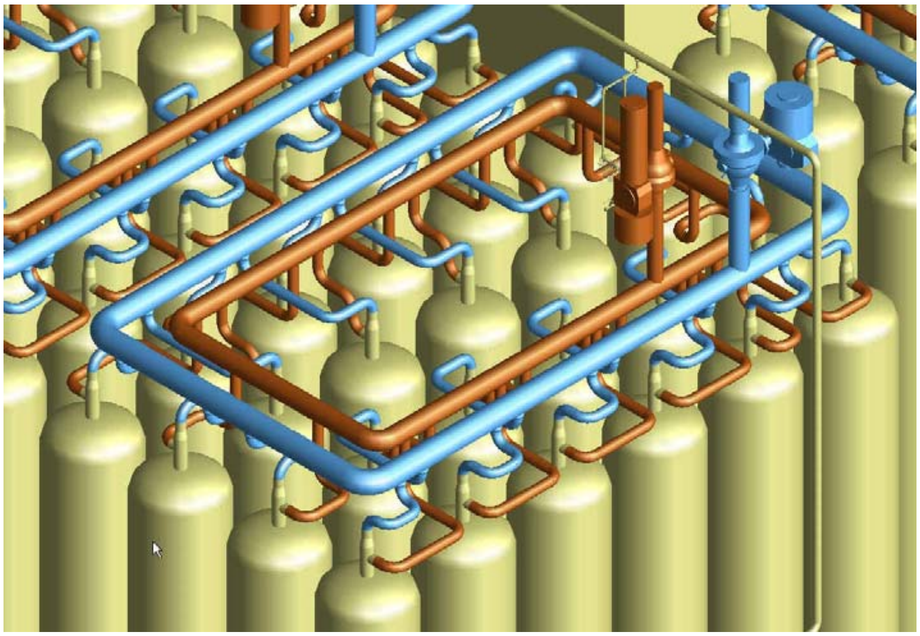
- EnerSea(steel, vertical pipes, 130 bar, -29°C)
- Coselle(Williams) (steel, coiled, 275 bar, ambient)
- Knutsen (steel, vertical pipes, 250 bar, ambient)
- CETech: (Statoil, Teekay, Höegh) steel, horizontal pipes, 200-250 bar, ambient)
- TransCanada(wrapped steel liner)
- Trans Ocean Gas (composite)



2.2.4 The CNG Transport Technology:-

The technology is relatively simple. Natural gas, originally at certain temperature and pressure is compressed to higher pressures and chilled to lower temperatures. Specially designed ships, which have a containment system made of stacked horizontal or vertical pipes, transport the cold compressed gas. The technology can be divided into three parts namely, compression, refrigeration and transportation. Transportation includes the loading, the voyage using the CNG carriers and unloading

CNG Cargo Containment System



2.2.5 CNG vs. LNG

In comparing CNG with LNG the same transporting ship real-volumetric capacity is used. However, in making the comparison it is worth remembering the disparity in the actual standard volume of the gas transported. For the same ship volume, LNG transports 2.1 Bcf of natural gas compared to a maximum volume of 1.2 Bcf transported as CNG.

Keeping aside the difference in standard volumes, a proper comparison between the two technologies warrants a review of the requirements and the respective costs involved for both. For any LNG project to be economically viable a throughput of 0.5 to 1 Bcf/d of natural gas is required. Typically a LNG plant of 3 MMtpa needs a gas at rate of 400-450 MMscf/d5. This translates into gas reserves of 5 to 8 Tcf for a project life of 20 years, depending on the amount of condensates in the gas5. CNG projects, on the other hand, do not require such amount of reserves for the same throughput12. Fields with modest reserves and ga s rates can support CNG projects10 For LNG projects, the liquefaction plant is the most capital intensive. They make for almost 50% of the total investment for a LNG project13. Taking an industry estimate of production cost of $200/ton of LNG per annum, a project handling 500 MMscf/d (3.8 million tonnes of LNG per annum) requires an investment of 750 million. A CNG plant with loading facilities including compressors, pipelines and buoys costs $30 to 40 million8 The lower investment along with simplicity of the operations helps, in effect, in faster planning and commissioning of a CNG project. For CNG the shipping of the compressed gas is the most capital intensive. The ships cost approximately $230 million8 while for LNG the ships cost approximately $160 million15. Offloading of the LNG requires special facilities namely a regasification terminal. Regasification facilities cost $500-550 million depending upon terminal capacity13. CNG offloading facilities consisting of separators , scrubbers and heaters cost from $16 to 20 million8. Overall for CNG the total investment can range from $1-2 billion mainly depending upon the number of ships required. For LNG the investment can range from $1.5 to 2.5 billion depending on the market needs and number of ships required.

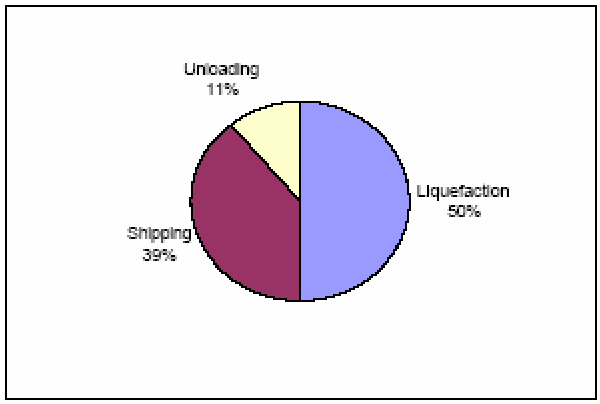


Figure 2- Cost components for a LNG project

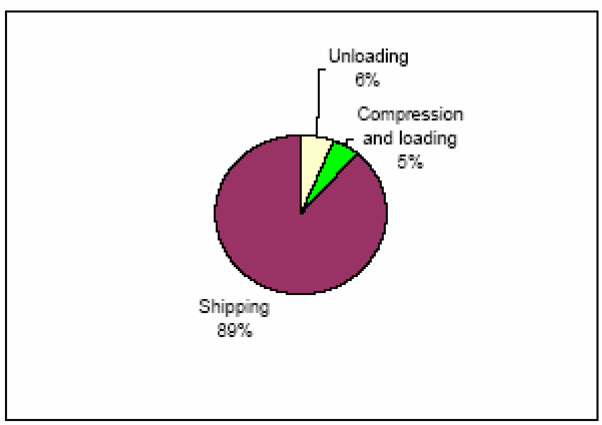


Figure 3- Cost components for a CNG project

From Figures 2 and 3, one of the main attractions of CNG is that the bulk of the investment is in movable assets, while for LNG a very large of the investment is in fixed assets. The investment breakdown lowers the CNG investment risks, by providing a way to recover most of the investment and allow its deployment in other projects or applications. The next step is to estimate and compare the unit

price of gas delivered as CNG or LNG. For LNG the typical chain value per MMBTU of gas is15: Exploration and Production: $0.5- 1.0/MMBTU, Liquefaction: $0.8-1.2/MMBTU, Regasification and Storage: $0.3-0.5/MMBTU. Shipping of LNG is a function of distance of transport and the discount factors. Assuming the ships for transporting LNG are newly built the unit cost of shipping range from $0.4-1.5/MMBTU for distances from 500 to 5000 miles16. Thus, the total cost of producing and transporting LNG can range from $2 to $4.2
per MMBTU for the distances considered. For CNG, keeping the same unit cost for exploration and production, the chain value per MMBTU is: Exploration and Production: $0.5- 1.0/MMBTU, Processing and Transportation: $0.88-3.82/MMBTU for distances from 500 miles to 5000 miles. This translates into a unit cost of $1.38 to $4.82 per MMBTU. Taking a gas price of $0.75/MMBTU for both CNG and LNG and liquefaction cost of $1.0/MMBTU with regasification cost of $0.4/MMBTU, the unit price of LNG delivered is shown in Table 5.

Distance	Transport cost17	Unit cost
miles	$/MMBTU	$/MMBTU
500	0.4	2.55
1000	0.5	2.65
1500	0.6	2.75
2000	0.7	2.85
2500	0.8	2.95
3500	1.1	3.25
5000	1.5	3.65

Table 5- Estimated unit cost of transporting the

2.2.6 Advantages of CNG over LNG:-

- Requirement of lower throughput of gas for a project
- Involvement of lower capital
- Ease of deployment … faster implementation of a project
- Ability to access stranded reserves and monetize them
- Majority of the investment is in the shipping, making the assets movable and reducing the risk involved

2.2.7 Disadvantages:-

Inability to transport large volumes of gas such LNG
Disparity in the volume transport hinders commercial possibility of CNG

2.3 Transportation By LNG Carriers:-

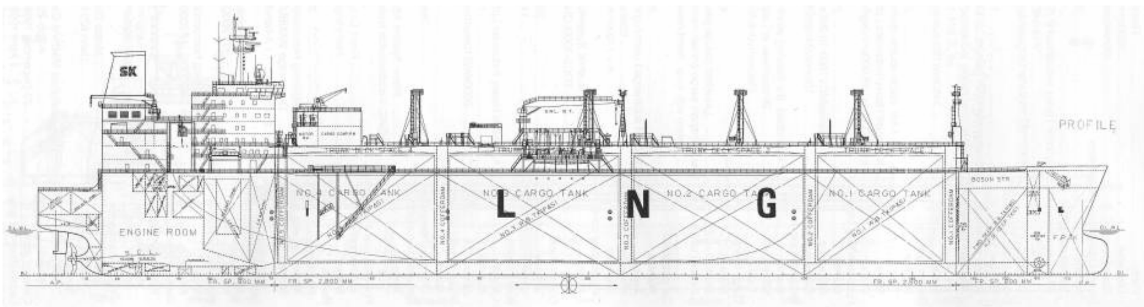
LNG carriers have been used to transport liquified natural gas overseas on a commercial basis since the late 1960s. Nowadays, a fleet of about 130 vessels transports 5% of the world annual gas consumption from producer to consumer. Over the years, there have been many improvements in the designs, but the main propulsion system is still the same. In all other sectors of commercial shipping, the steam turbine has been replaced by much more efficient diesels, but LNG carriers stick with steam turbines. The main reason is for this is the steam turbine propulsion system's unique capability to running on two cheap fuels simultaneously: Heavy Fuel Oil and Boil-off Gas. This feature, combined with a very high reliability, ensured the survival of the steam turbine in spite of its very low thermal efficiency until now.

In 2002, Chantiers de l'Atlantique in France recieved the first order from Gaz de France for a 74,000 cubic meter diesel-electric driven LNG carrier. Diesel manufacturer Wärtsilä in Finland will deliver the dual-fuel diesel gensets. The choise to select diesels instead of the conventional steam turbine indicated that there are owners and/or charterers in the LNG shipping community who are willing to try new technology, which increases thermal efficiency of the propulsion plant. A few LNG carrier operators have indicated they are interested in a more fuel efficient vessel, but charterers so far have been unwilling to consider engaging anything other than steam turbine driven LNG carriers.

Due to the small size of the LNC carrier ordered at Chantiers de l'Atlantique, its power requirements are too low to lend itself for gas turbine drive. However, larger vessels, such as "K Freezia", with propulsion power requirements between 24 and 30 MW, are ideally suited for the use of aero-derivative gas turbines. It is these vessel that will be used in this review of alternative propulsion plants for LNG carriers.

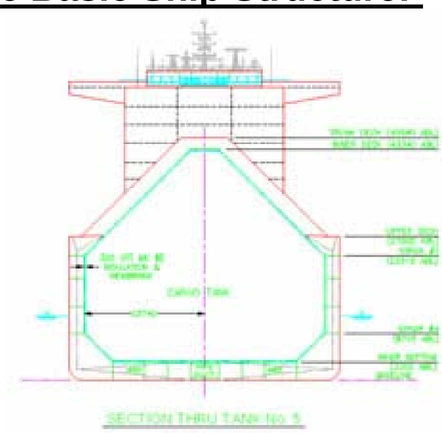
2.3.1 Conventional LNG Carrier

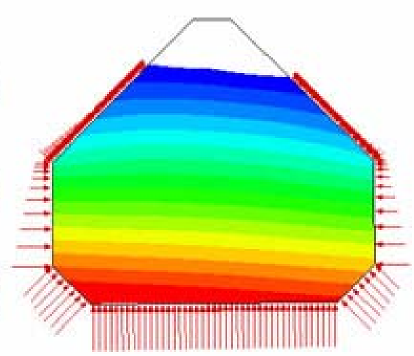
Name / Owner	SK Summit / SK Shipping Co., Korea
Builder / Delivery	Daewoo HI, Korea / 1999
Dimensions	277 x 43.4 x 11.3 m (L x B x D)
Cargo capacity (100%)	138,000 cubic meter
Speed	20.3 kn
Fuel consumption	2,400 kg/h HFO + 3,950 kg/h BOG
Propulsion machinery	1 Kawasaki UA-400 steam turbine, 29,830 kW



SK Summit represents the current standard in LNG carriers, 138,000 cubic meter cargo capacity and a cruising speed of around 19 knots. As of November 2002, there are approximately 60 vessels rather similar to SK Summit on order, with about 25 options. SK Summit is therefore a great example to be used as a benchmark when determining the relative merits of alternative LNG carriers propulsion systems. Prices for these vessels hover between USD. 165M and 170M. Total project cost per vessel can reach USD. 200M as a result of financing, delivery, project management, insurances, bank guarantees, etc.

2.3.2 The Basic Ship Structure:-





All LNG ships are double hulled and rely on insulation to keep LNG liquid at -260°F (-162.2°C). The cargo is carried at atmospheric pressure in specially insulated tanks, referred to as the cargo containment system, inside the inner hull.