CHAPTER 10

# Pipelines and Tankers

Transportation of oil and gas is a key factor affecting the industry. Only rarely are oil or gas fields conveniently located next to consumers. Gas, which requires a huge distribution infrastructure, is particularly affected. Only recently have such solutions as Liquefied Natural Gas (LNG) and Compressed Natural Gas (CNG) tankers allowed many countries to export their natural gas. Qatar, Nigeria and Trinidad, for example, produce far more natural gas than their domestic market requires. The best solution for these countries is to convert their gas to LNG which can be transported to a variety of markets in the world by ship.

Pipelines are the most common forms of transporting crude oil, natural gas, refined products, derivatives and ethanol. They are highly efficient and this is a major reason that oil and gas is such a popular energy source. In fact, pipelines are so efficient that coal companies have tested their use for transporting coal. The coal is ground up into small particles that are pumped within a liquid slurry from the mines to their principle destination, power generating stations or large industrial complexes.

Pipelines extend from oil and gas producing fields, which in turn receive oil and gas from many wellheads. The delivery point can be refineries, liquefaction facilities, petrochemical plants or ports for tanker shipping. Before transportation can occur, however, a complex network of pipelines and associated infrastructure must be in place. Pipelines range from small-diameter field flow lines and gathering lines to huge transcontinental lines.

Oil companies use complex software to visualise, plan, route and monitor pipelines. While this allows routes to be visualised, any relevant geological and geotechnical features of the route will be subject to local inspections and using a 3D visualisation model developed from aerial photographs and topography data processing. Nowadays, where the use of technological innovation allows capturing, storing and processing a large amount of information, the features visualised on flat paper can be brought to life in 3D forms. Principal considerations range from socio-environmental factors to pipeline design and sizing, data transmission, control systems and leak detection[1].

**Socioenvironmental Factors**

Achieving a balance between transporting crude oil, natural gas and its derivatives and acting in a socially responsible manner is not easy. Although pipelines are recognised as one of the safest forms of hydrocarbon transportation and distribution, they require a high degree of monitoring and management. Such care is not only restricted to the oil company, but also encompasses the community that may be affected by the construction of a pipeline. In cases where this occurs, participation of communities that live near the pipeline is vital. If communities participate fully at the planning stages, recommendations can be made regarding the use of land that surrounds the pipeline. This contributes to maintaining harmonious relationships between operators and host communities and reduces the risk of conflicts developing years later. The aim is to maintain a positive co-existence between the populace, host communities and the pipeline network[2].

**Pipeline Design and Construction**

This involves new-build pipeline projects where designs aim to reduce costs, minimise environmental impact and ensure the safe operation of the pipeline. Often this involves the mapping and registration of any existing buried or submerged pipelines as well as the analysis of any likely structural problems. Pipelines installed in unstable geological areas must undergo geotechnical surveys to determine the risk of soil movement or formation collapse. The interaction between the soil and the pipeline is constantly assessed in order to guarantee the structural integrity of the line. For buried pipeline applications, new technologies are being developed and applied to improve safety and these include 3D visualisation and monitoring systems as well as the evaluation of the soil-pipeline interaction[3].

In order to guarantee the structural integrity of the pipelines installed in these areas, it becomes necessary to survey and map all the unstable areas and study the soil mass movements. Creep movements usually involve extensive areas and present slow speed. In general, they are difficult to detect through visual inspection. Natural subsidence, or compaction of shallow sediments, can cause extreme stress on buried lines that can result in damage or rupture.

**Types of Pipeline**

Oil and gas pipelines are often welded together in the case of steel pipes or specially connected in the case of composite materials. Inner diameters can reach 48 inches and pipelines may stretch for many miles onshore and offshore. Onshore pipelines maybe placed within trenches a few feet below ground or they may be suspended off the ground using steel supports.

Offshore, pipe laying vessels such as barges are required to trench and lay pipelines. Pipelines maybe created on site with pipe joints welded together on the vessel. Alternatively, pipe joints are often welded together on land into a continuous pipeline unit which is then floated out to the site for layout saving time and money.

Figure 1 SCADA

The oil and gas is kept mobile within the pipeline by pumping and compressor stations which are carefully spaced along the pipeline according to mobility requirements.

Multi-product pipelines are used to transport two or more different products in sequence in the same pipeline. Usually in multi-product pipelines, there is no physical separation between the different products. Some mixing of products occurs, creating an interface which is removed from the pipeline at receiving facilities and segregated to prevent contamination. If fluids are to be completely segregated from one another, a device called a 'pig' is inserted in the line between the two liquids. Pigs are pliable plugs that can be pumped through the line for long distances. They can negotiate bends in the line and are retrieved by a 'pig trap' that operates like an air-lock at the destination end.

**Remote Operations and Control Compressor Stations**

Compressor stations along natural oil and gas pipelines are often remotely operated. System and equipment status as well as any alarms are exchanged with a Control and Supervision Centre (CSC) through a Supervisory Control and Data Acquisition (SCADA) system (Figure 1).

Supported by the SCADA software, operators receive immediate detailed information about what is happening in the pipelines. By monitoring the levels of flow, pressure and temperature of the oil and gas and at the sign of any abnormality, the system allows for pumps to be switched on or off and valves to be opened or closed within any segment of the entire pipeline. This helps operators avert leakages, blockages and maintains the safe and productive operation of the pipeline.

Such systems can perform a range of control actions such as starting and stopping compressor units and stations as well as remotely setting pressure and flow control points[4]. In addition, most compressors and line pumps are instrumented with sensors and associated telemetry that monitors their 'health' status around the clock.

This can provide early warning of dangerous operating conditions or impending failures and enable operators to take timely action.

**Storage**

Demand cycles affect the gas industry also. Gas, used primarily for home heating, sees widely fluctuating demand between summer and winter. Building a pipeline large enough to handle wintertime demand would be a waste of money because it would only be used efficiently for a few months each year. A system is needed that could accept a steady stream of natural gas all year long, storing it at the terminal end during the summer months against peak demand during the subsequent winter. Storing the huge volumes of gas in surface tanks was impractical and uneconomic so companies created gas storage fields. These consist of storage wells that access depleted oil or gas reservoirs, or large aquifers. Gas is pumped down into these wells in the summer and then produced into the distribution network in winter. Alternatively, large caverns can be leached into salt domes to form huge subterranean storage chambers.

**Pipeline Systems**

Pipeline rated operating pressures will be dictated by several factors including hydrocarbon type, pipeline length, pipeline integrity and others. Often stations are located along the pipeline and will typically use reciprocating compressors driven by gas engines. To provide efficient outflow of large volumes, pipelines with greater diameters and higher pressure ratings are required. Increasing steel burst strength by specifying different alloys means a greater thickness of pipe may not be required. The benefits include saving steel by weight reduction, thereby reducing the costs of pipe purchasing, pipe construction and assembly[5].

**Remote Data Transmission**

This involves the monitoring of all operating parameters and events of station equipment and systems. Typically this includes::

• Operating data indication of every system and its equipment, such as pressure, temperature, power consumption and flow rates, and

• Fire and leak detection with remote signalling

All data mentioned above has to be available as continuous, real-time information to CSC operators[6].

**SCADA**

This system is made up of two basic sub-systems: the control and supervision centre and the local operation station. The components of the control and supervision centre are described below:

• **Real-time database server:** All the current data is stored on redundant servers which continuously communicate with the local database on the compressor stations to receive process data and send operator commands.

• **Historical database server:** These servers are redundant (hot standby) and receive data from real-time servers, storing process data on hard disk and tape cartridges.

• **Human-machine interface:** This is used by operators to supervise and control the pipeline. From these stations, data can be accessed via real-time servers, historical servers and an advanced functions station.

• **Engineering station:** This station is used for developing and testing purposes.

• **Advanced functions station:** This workstation runs the pipeline simulator. Additionally, there are three software modules for pig tracking, inventory calculation (line-pack) and leak detection.

• **Very Small Aperture Terminal (VSAT) communication system:** This system comprises a personal earth station at the CSC, a hub station at the provider's installations, and a personal earth station at each compressor station.

• **INMARSAT communication system:** This is used for communication with the city gates where natural gas from a pipeline enters the smaller diameter distribution network. This system does not communicate continuously. The operation is periodic (every four hours) and by exception (from the city gates to the CSC).

• **Leased lines:** These lines are used as backup for the VSAT system at the compressor stations.

• **Global Positioning System (GPS):** These systems are used to maintain each compressor station synchronised with the CSC.

The components of the local operation station, which is provided at each compressor station, are described below:

• **Local database and operation station:** This redundant server has the function of continuously gathering data from the programmable controllers, and sending data for the real-time database server at CSC. These stations can be used to operate the compressor station in case of communications problems with the CSC.

• **Programmable Logic Controller (PLC):** The PLC is used for process control and interlocking. There is one PLC for each turbo compressor and one redundant Central Processing Unit (CPU) for utilities such as generator sets, switchgear, fuel gas systems, compressed air systems, etc.

• **VSAT communication system:** As described above for CSC.

• **Leased line:** As described above for CSC.

• **GPS:** This is used for time synchronisation between the compressor station and the CSC.

Operational stations continuously communicate with the CSC servers. From these stations, it is possible to access all the operational and maintenance data from the area of responsibility of each operational division[7].

**Corrosion Management**

By preventing corrosion-related failures, corrosion management technology increases operational reliability standards, reduces environmental damage and extends the lifespan of the pipeline network[8].

**Systems Capable of Detecting Leaks**

Oil companies can detect leaks more efficiently by pin-pointing oil, gas or other derivative leaks in pipelines. Overall, this improves profitability by reducing the loss of hydrocarbon products and any environmental impacts. Leak detection technology is used in oil and gas to minimise product losses with a consequent reduction in the environmental impact as well as the costs. A flow and leak detection simulation system for multipurpose pipelines can be employed by the oil company for this purpose[9].

Fig Pipeline Leak Detection

**Rehabilitation of Pipelines**

The reason for rehabilitating pipelines has been to make best use of existing resources and to minimise the need for new builds by adding transportation capacity. This, however, requires integrity criteria to be met which will span the lifespan of the pipeline network. Hydrostatic test methodologies, certification criteria and commonly available repair techniques are all employed. Oil companies are benefitting through higher pipeline utilisation factors, more flexible and economic pipeline repairs, reduced maintenance costs and enhanced safety. To repair in-service pipelines, welding of in-service pipelines and the use of composite materials are commonly used[10].

**Pigging Technology**

'Pigs' play a vital role in keeping the pipelines operational. Pigs are instrumented battery-powered devices that can be pumped through the pipeline to inspect for corrosion, cracking or buckling both internally and externally. Their usage helps ensure the integrity of the pipeline and keeps the flow of products going. Pigs also help reduce the risks of environmental damage and avoid emergency shut-downs. .

Figure Feeler Pig

Both onshore and offshore pipelines can be inspected using pigs.

**Pipeline Material Technology**

By using advanced materials, operators can reduce costs, increase reliability and extend the life of a pipeline. High strength steel has been developed for use in large pipelines in order to increase operational safety and reduce the costs of building new pipelines. Models for the simulation of pipeline structural behaviour are also used extensively in order to identify defects and their repair needs.

Coiled tubing can also be used as an effective tool for pipeline applications. This includes the transportation of pigs, removing organic deposits and hydrate plugs or sand and placing a patch or liner to repair minor leaks.

**Transfer Systems**

These solutions help ensure optimal production flow and supply to the oil and product markets. Studies and tests for the application of friction reducers are carried out for oil product pipelines and this has shown to be viable in various types of pipelines, especially those with utilisation factors close to capacity. The next challenge is the development of proprietary additives to further enhance transfer; for example, to facilitate the transport of heavy crude from the oilfields of Venezuela to the port terminal on the Caribbean Sea, a solvent is added to the crude to reduce its viscosity. This solvent is subsequently separated and retrieved at the terminal end and pumped back to the source to be re-used.

**Tankers**

Crude oil tankers make up many of the world's largest ships, hence the common term 'supertanker'. Tankers are classed as Ultra Large Crude Carriers or ULCCs (a handful of which are able to carry more than three million barrels [MMbbl] of oil) and Very Large Crude Carriers or VLCCs (which may carry approximately two MMbbl of oil).

Another fleet class exists at the one MMbbl mark and refers to ships that serve smaller ports where larger counterparts cannot berth. berth[11].

Figure ULCC

Refined oil products are carried by far smaller vessels carrying half a MMbbl of oil to storage depots or other facilities. These vessels begin the distribution process of moving oil from the refineries to the tanks in consuming countries, from where the oil cargoes are fed by road, rail, pipeline and coastal tankers and inland tank barges to power stations and depots close to where the products are consumed.

Tankers are advantageous over pipelines as they are can respond to market fluctuations much more quickly. Cargo can be distributed to any destination in the world that has berthing facilities.

Modern tankers are usually built with a lattice construction and double hull to enhance safety. Tankers are often filled using onshore pumps, but are discharged using the tankers' own pumps.

**LNG Tankers**

LNG tankers must be specially designed to meet the needs of LNG transportation*. Special needs are generated by the very low temperatures that must be maintained to keep gas at a pre-determined liquefied state.

Figure LNG Tanker

LNG companies mostly build LNG ships for a specific project, then own and operate them thereafter. Construction costs have dropped from US$280 million in 1995 (for a 138,000-cubic-meter-capacity ship) to US$150 to $160 million in 2004. This is still more than double the cost of a crude oil tanker. Most added costs relate to the construction of insulated tanks[12].

* The process of gas liquefaction is covered in Chapter 13 Gas and Renewables.

LNG shipping costs vary based on the ship's operating and amortisation costs, the size of the cargo, and the distance transported. The costs of building and operating receiving terminals, unloading, storage, and re-gasification facilities vary by site. In the US, new onshore terminals built on existing designs are expected to cost US$400 million or more[13]. The cost of constructing offshore LNG facilities is substantially higher. LNG is transferred from the production facility to the tanker's storage tanks using specially constructed booms and pumps. Specially configured loading pipes are designed to withstand the very low temperatures necessary for liquefaction.

The two main designs are the membrane and spherical tanker type. The former has multiple tanks with linings made from thin nickel steel alloys capable of withstanding extreme temperatures. These tanks are integrated into the hull of the ship.

The spherical design tanker has characteristic circular containment tanks that are structurally supported by beams in the hull of the ship[14].