OIL AND GAS PIPELINES: Yesterday and Today[1]

by Phil Hopkins

Chairman (2006-7),

Pipeline Systems Division (PSD),

International Petroleum Technology Institute,

American Society of Mechanical Engineers (ASME).

Phil Hopkins, Technical Director at Penspen Ltd., UK, and the 2006-7 Chairman of PSD, is well known for his many technical papers and training courses in pipeline engineering. In this article, specially written for ASME, he traces the history of oil and gas pipelines, and highlights the key strategic role of today's pipelines.

[1] Photographs are copyright of Penspen Ltd. UK, and Willbros Group Inc. USA. Text is copyright of Penspen Ltd., 2007.

1. INTRODUCTION

Most people associate 'pipes' with the hot and cold water they see in their houses. Also, most of us will have seen the plastic pipes laid under our streets and roads to locally distribute natural gas. But what many people do not know is that there are hundreds of thousands of kilometres of very large 'pipelines' crossing our nations and oceans delivering ('transmitting') huge quantities of crude oil, oil products, and gas. Most are underground or undersea: out of sight, out of mind!

'Crude'[2] oil is often transported between continents in large tankers, but oil and natural[3] gas is transported ('transmitted') across continents by pipelines. These pipelines are very large diameter (the Russian system has diameters up to 1422mm), and can be over 1000km in length.

Figure 1. Most of today's oil and gas pipelines are welded together and buried underground or laid subsea

'Transmission' pipelines are the main 'arteries' of the oil and gas business; working 24 hours per day, seven days a week, continuously supplying our energy needs. They are critically important to most countries' economies. They have a long history: pipelines have been used to transport liquids and gases for thousand of years: the Chinese used bamboo pipe to transmit natural gas to light their capital, Peking, as early as 400 BC.

The oil and gas are transported in these large transmission pipelines to refineries, power stations, etc., and converted into energy forms such as gasoline for our automobiles, and electricity for our homes. Oil and gas provides most of the world with its energy. The fuels providing the world with its primary energy needs are:

- Oil = 34%
- Coal = 24%
- Gas = 21%

---

[2] We call oil extracted from the ground 'crude' as it has not been processed ('refined') into products such as gasoline or kerosene that we can use.

[3] 'Natural' gas is mainly methane gas, obtained 'naturally' from underground reservoirs, as opposed to 'manufactured' gas which is obtained from burning coal. Manufactured gas was the main gas we used for lighting and heating up to the middle of the 20th century. The latter half of that century saw natural gas emerge as a major energy source.

- Nuclear = 7%
- Hydro = 2%
- ‘Other’ = 12%

Without pipelines we would not be able to satisfy the huge oil and gas needs of our planet. These pipelines are also very safe forms of transporting energy:

- Pipelines are 40 times safer than rail tanks, and 100 times safer than road tanks for transporting energy;
- Oil pipeline spills amount to about 1 gallon per million barrel-miles, according to the USA Association of Oil Pipelines. One barrel, transported one mile (1609m), equals one barrel-mile, and there are 42 gallons (159 litres) in a barrel. In household terms, this is less than one teaspoon of oil spilled per thousand barrel-miles.

Figure 2. Pipelines are essential for transporting our oil and gas

These high pressure, large capacity pipelines carry hazardous products, and consequently, they are designed, constructed and operated using recognised standards that all have a focus on safety. Additionally, these pipelines have to satisfy safety regulations in most countries. These high standards and regulations ensure safe and secure pipelines.

This short paper will now look at pipelines, including their development and the pipelines in use today.

2. PIPELINES OF YESTERDAY

Many of the pipelines we use today to transport our oil and gas were built many years ago, and it is to the credit of those early pipeline engineers that they continue to deliver safe and secure energy supplies today.

But we need to go back much farther in history to trace the origins of pipelines. For thousands of years, pipelines have been constructed in various parts of the world to convey water for drinking, and irrigation for agriculture. These pipes included baked clay and hollow bamboo: the ancient Chinese used bamboo pipes to transport water.

There are references to the Egyptians using copper pipe to transport water in 3000BC, the Cretians used earthenware pipe for water in 2000BC to 1500BC, and the Greeks used earthenware, lead, bronze and stone pipes from 1600BC to 300BC. In that era, 'blacksmiths' connected the metal pipes together by simply hammering the red hot ends together.

Ancient civilisations such as the Persians and Romans all used pipes of some type; for example, metal pipe was used as far back as 500 BC when the Romans used lead pipes to distribute water in highly developed towns.

The first recorded use of a pipe to transport a hydrocarbon was in China: about 2,500 years ago, the Chinese used bamboo pipe to transmit natural gas from shallow wells: they could burn it under pans to boil seawater to separate the salt, and make the water drinkable. Later records indicate that the Chinese used bamboo pipe, wrapped in wax, to light their capital, Peking, as early as 400 BC.

Today's oil and gas pipeline industry has its origins in the oil business. Up to the 19th century, oil was only obtained from natural seepages to the earth's surface. In the 19th century, oil was discovered underground by persons drilling for water, but it was considered a nuisance! However, entrepreneurs soon realised that this 'land oil' could be used as a lubricant and luminant. Oil had been drilled in Baku, Azerbaijan in 1848, and Poland in 1854, but the first major exploitation and commercialisation using pipelines started 150 years ago in the USA, by a certain 'Colonel' Drake.

In 1859, Edwin Drake drilled two oil wells, near a surface oil seepage, in Titusville, Pennsylvania, USA. The wells had a combined value of $US40,000. They produced 2,000 barrels[4] (bbl) of 'crude' oil, but this smelly, muddy crude was not popular until 1860, when simple 'refineries' were in operation to process the oil. These refineries boiled the crude: naptha, then kerosene boiled off, leaving heavy oil and tar. The kerosene alone was a perfect and cheap replacement for the whale oil then in use for lighting, and allowed the oil to be sold for $20/barrel. In these early days, gasoline and other products made during refining were simply thrown away because people had no use for them, but in 1892, the "horseless carriage" solved this problem, since it required gasoline.

In the early 1860s, the oil was transported in wooden barrels on rivers by horse-drawn barges. This was dangerous: weather, and labour disputes, often disrupted flow. The railway relieved this, but the oil was now controlled by the rail bosses and their workers… the 'teamsters'. Pipelines were an obvious solution to this transport problem, and the early oil workers were familiar with pipes: cast iron and wrought iron pipes of various diameters were in use around the producing wells from the start of the industry.

In 1865 a 6in (152mm) diameter gravity (no pumps) oil line was built in Pennsylvania, USA, transporting 7000 barrels/day. It was completed by the Pennsylvania Tubing and Transportation Company along Pithole Creek from the Pithole oilfield to the mouth of the creek where it flows into the Allegheny River.

[4] A 'barrel' contains 42 US gallons, or 159 litres.

Other areas in the world were developing pipeline systems and realising huge transportation savings: in 1878, in Baku, Azerbaijan, the Nobel brothers built a 3in (76mm) diameter, 10km oil pipeline that reduced transportation costs by 95%, and paid for itself in a year! The pipe was imported from the USA because of its low cost and high quality, but it is interesting to note that pipelines in Baku around this time was also opposed by companies and workers with interests in cooperages, etc..

'Long' pipelines started to be built at the turn of the 20th century; for example:

- in 1906 a 472mile (755km), 8in (203mm) diameter pipeline was built from Oklahoma to Texas;
- similar length, small diameter (8in to 12in (203 to 305mm)) lines were built in Baku at the same time;
- in 1912, a 170 mile (272km), 16in (406mm) diameter manufactured gas pipeline was built in 86 days in Bow Island, Canada, to make it one of the longest pipelines in North America.

By the end of the 1920s major refineries were capable of processing 80,000 to 125,000 barrels of oil a day, to feed huge increases in demand (for example, from 1910 to 1920 the number of cars and trucks on American roads grew from fewer than 500,000 to more than 9 million). During the 1920s, driven by this growth of the automobile industry, the total USA pipeline mileage grew to over 115,000 miles (184,000km).

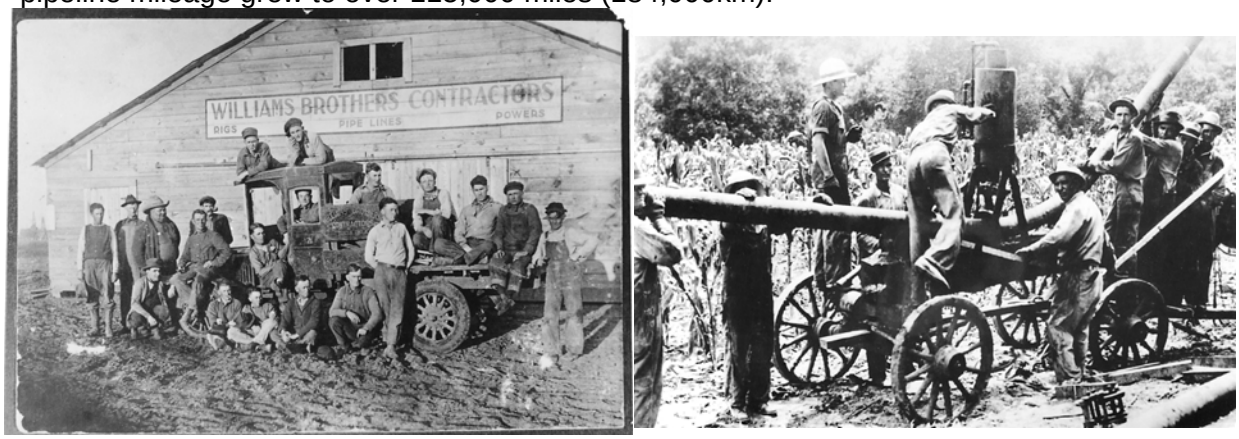

Figure 3. Increased demand for fuel for automobiles encouraged more pipelines to be built in the early 1900s.

The next big change in pipeline engineering was the building of long distance, large diameter pipelines: these were pioneered in the USA in the 1940s due to the energy demands of the Second World War. During the 1950s and 1960s, thousands of miles of natural gas pipelines were constructed throughout the United States as the demand for this type of energy increased.

The Second World War also forced innovation in pipeline technology: in 1944, 'Pluto', the 'Pipeline Under The Ocean' was commenced. This project was to construct undersea oil pipelines under the English Channel between England and France, to provide vital fuel from Britain to Allied forces in France. These small diameter (~75mm), cable pipelines eventually totalled 500 miles (800km), and delivered 1,000,000 gallons (~4,000,000 litres) of fuel per day across the channel: an amazing feat.

Figure 4. Long distance pipelines started to be built in the mid-1900s

As the world emerged from the Second World War it was able to build high pressure, long distance, oil and gas pipelines.

3. PIPELINES TODAY

The oil and gas business is big, and it is going to become bigger. Consider these facts:

- the US Energy Information Administration's World Energy Outlook has predicted fossil fuels will remain the primary sources of energy, meeting more than 90% of the increase in future energy demand;
- global oil demand will rise by about 1.6% per year, from 75 millions of barrels of oil per day (mb/d) in 2000, to 120 mb/d in 2030;
- demand for natural gas will rise more strongly than for any other fossil fuel: primary gas consumption will double between now and 2030.

This expanding, secure industry is also highly profitable: Exxon Mobil, the world's largest oil company, announced (January, 2006) profits of $US36 billion, the largest ever by a listed company. In February 2006, Shell announced a record profit for a British company: $US23 billion. These profits are expected to continue in the foreseeable future, as the price of a barrel of oil continues on record highs of over $US60/barrel.

To support this growth in energy demand, pipeline infrastructure has grown by a factor of 100 in approximately 50 years. It has been estimated that world pipeline expansion could be up to 7% per year over the next 15 years. This means over 8000km/annum of pipeline being built in the USA alone, at a cost of $US8 billion/annum.

Figure 5. New, large diameter pipelines are expanding

Internationally, 32,000km of new pipelines are constructed each year: this is a $US28billion business, and 50% of these new builds are expected in North and South America. Additionally, 8,000km of offshore pipelines are being built per year: this is a $5billion business with 60% in North West Europe, Asia Pacific, and the Gulf of Mexico.

The total length of high pressure transmission pipelines around the world has been estimated at 3,500,000km. The 'split' is:

- ~64% carry natural gas;
- ~19% carry petroleum products;
- ~17% carry crude oil.

Figure 6. New pipelines are being built around the world to meet increased demand for oil and gas

These systems can be huge; for example, if you laid the Canadian pipeline system, end to end, it would extend 17 times around the world! In the USA, the vast pipeline oil and gas pipeline system consist of:

- Onshore Gas Transmission 295,000 miles (472,000km);
- Offshore Gas Transmission 6,000 miles (10,000km);
- Onshore Gas Gathering 21,000 miles (34,000km);
- Offshore Gas Gathering 6,000 miles (10,000km);
- Liquid Transmission Lines 157,000 miles (251,000km).

This list ignores the 1,000,000 miles (1,600,000km) of low pressure gas distribution pipelines in the USA, and pipelines carrying water, sewerage, slurries, etc..

We now have many types of pipelines in the world. The types of oil and gas pipelines can be summarised as:

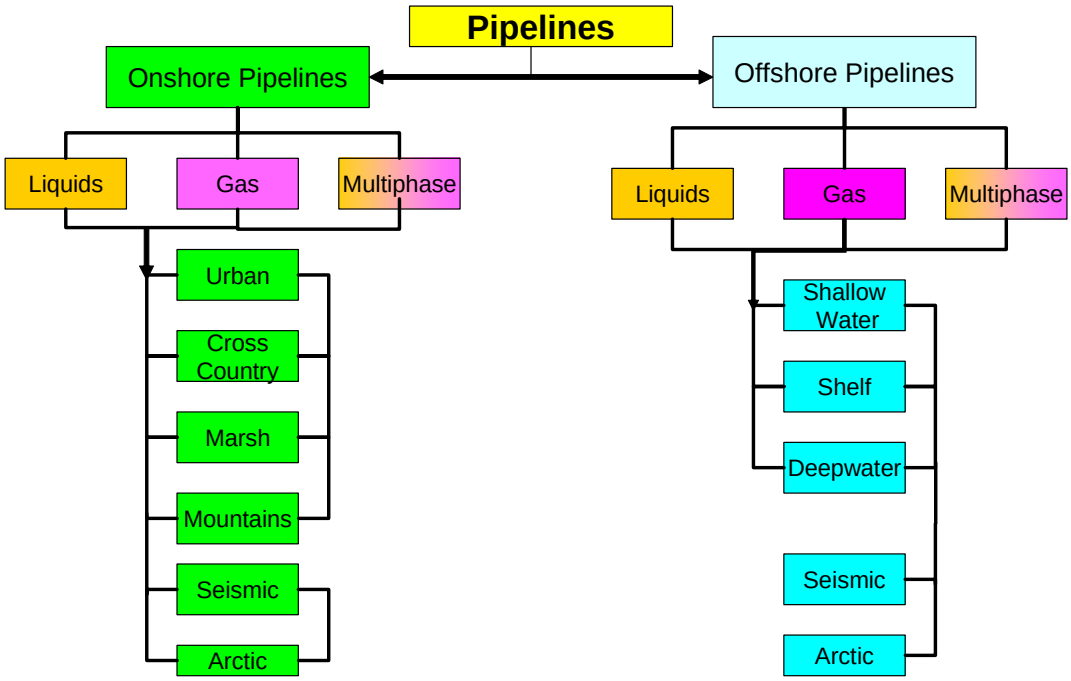

Figure 7. Types of hydrocarbon pipelines

These pipelines are made from high quality steel ('line pipe' steel), constructed using well-established methods, and operated using procedures developed over many decades.

Figure 8. There are now 100,000s km of pipelines transporting energy around the world.

4. WHY WE ALL SHOULD BE INTERESTED IN PIPELINES

We rely on pipelines to deliver our energy needs, but everyone is a stakeholder in oil and gas transportation:

- pipeline operators (transporters) want a safe, reliable supply, and a reasonable profit;
- the general public (consumers) want cheap gasoline, natural gas, etc., delivered reliably and safely, with minimal environmental damage;
- shippers (producers) want cheap, reliable supplies and transportation, and a reasonable profit;
- regulators want a fair and competitive market;
- government groups want safe, environmentally-friendly, delivery;
- advocacy groups (focussing on environmental, cultural, etc., aspects) have focussed interests;
- etc..

These stakeholders have differing, and often competing, demands between themselves (e.g. pipeline companies want high transportation charges, whereas shippers want low transportation charges), and within themselves (the customer wants a cheap product, but delivered safely and reliably). These stakeholders are complemented by the media, who will look to report on any profitable industry.

Figure 9. Pipelines are critical transportation infrastructures

Pipeline systems are now critical transportation infrastructures in most nations (in the USA gas pipelines are designated 'critical infrastructure' by the Department of Homeland Security, as they deliver about two thirds of America's energy needs), and essential to both standards of living, and economies.

The future for pipelines is both bright and challenging. They will continue to carry the bulk of our primary energy sources, but engineers will need to ensure they perform both safely and securely, as the systems continue to age. Indeed, the biggest challenge facing the pipeline engineer today and tomorrow is safety, and both the pipeline industry and its engineers will be judged on the industry's safety standards.