# PIPELINE OPERATIONS

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## Content





## Summary

The basic function of a pipeline is to move a product (liquid hydrocarbon or natural gas) efficientlty and safely from a receipt location to a delivery point as required by a shipper, customer or the pipeline owner as the case may be. This leads to a set of general functions normally performed by a pipeline and can be described as customer support, operation

The following is an overview of Pipeline systems Operation as Practiced by the industry. It is extracted from the book “Pipeline Operation & Maintenance _ A Practical Approach “M.Mohitpour, T. Van Hardeveld & J.Szabo, ASME Press, New York ( with permission”)

It is designed to provide an overview of pipeline systems operation for transmission of liquids and gases by providing descriptive and illustrative know-how, tasks and techniques that generally face pipeline professionals making design decision through to operation of pipeline facilities. It covers specifically aspects of pipeline transporting range of products specifications from receipt to delivery locations including customer service/contract management to pipeline planning and controls,

## 1. Pipeline Operation

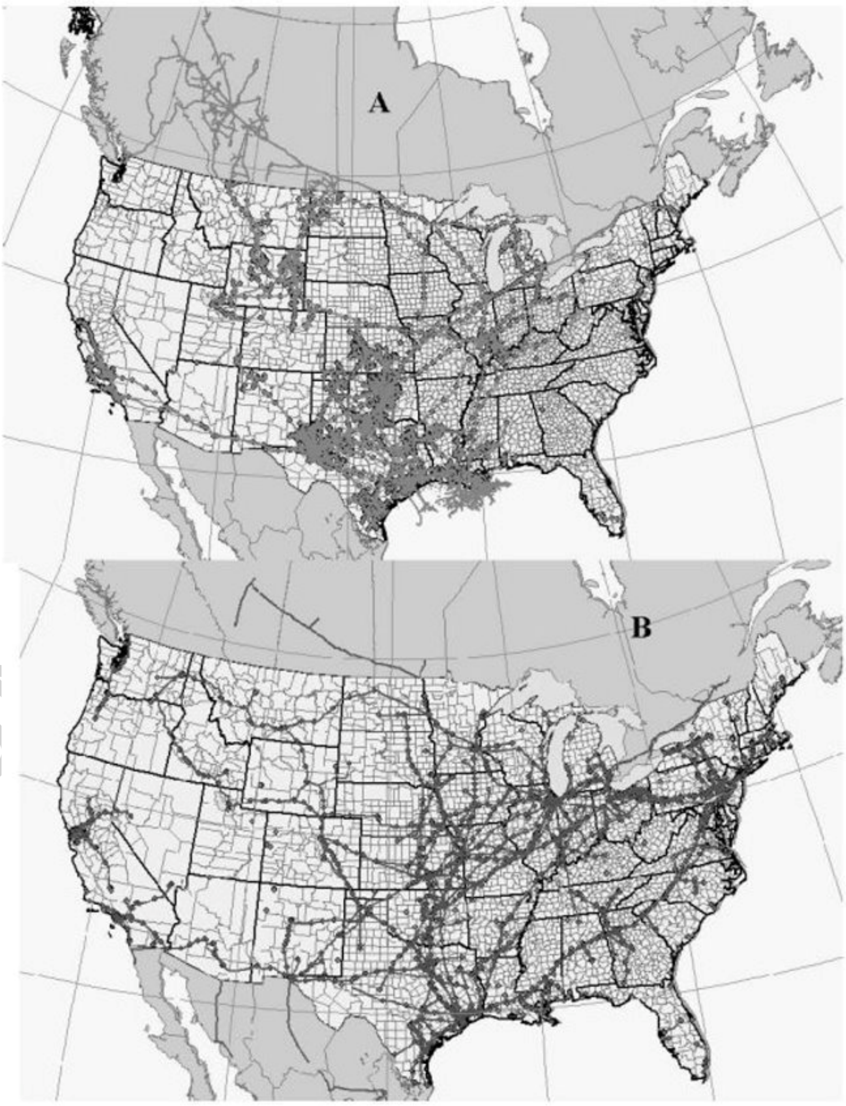


Figure 1. North American Crude Oil (A) and Refined/Batched (B) Products Pipelines and Facilities ( Image Courtesy of MapSearch and PennWell Publishing Corp, Tulsa, OK.)

This generally consists of pipeline systems operation and control [including supervisory control and data acquisition (SCADA) and leak detection] as well as field operation and maintenance, and is generally applicable across the pipeline industry whether transporting gas or liquids.

However, operational planning and management of liquid pipelines differ from those of gas pipelines depending on the number of liquid products that are simultaneously transported from different suppliers/shippers, storage facilities available and delivery locations or customers. Typical of North American oil and refined products (including batched) pipeline systems are those that stretch between Canada (Alberta) and through the USA (Figure1)

Multi batched products pipelines usually transport many (between 75-120) different commodity products including crude (light, medium and heavy), condensate, refined petroleum products (motor gasoline, diesel fuels, aviation fuels), synthetic oil and natural gas liquids (NGL) (propane, butane and condensate mixtures) from different shipping sources with line fill capacities of several million barrels.

An example of this is the KMP Product Pipelines (Morgan, 2002) covering more than 16000 km of pipeline transporting over 2 million barrels per day of gasoline, jet fuel and diesel fuel, as well as natural gas liquids. This system includes associated storage terminals and transmix processing facilities. It has 12 liquids terminals with a storage capacity of 35.6 million barrels.

Another example is the Colonial Pipeline systems which carries about 20% of petroleum product shipped on pipelines in the U.S. Colonial systems moves 2.2 million barrels (> 90 million gallons) refined petroleum products through about 10,000 km of pipelines from 30 refineries in the Gulf Coast to markets in the Southeast, Mid-Atlantic and Northeast. It operates in 13 US states and indirectly serves the Mid-West and New England by delivering products to other pipelines and barges.(Jacobs, 2002, AOPL, 2004)

Prior to the 1970s pipelines typically moved from 10 – 20 products. In the mid-1970s pipelines began to transport low lead and unleaded gasolines that were segregated to avoid contamination. Products were tested as they moved through the pipeline system to minimize degradation.

Leaded gasolines were mostly eliminated in the 1980s, but by this time the vapor pressure of gasolines began to be regulated requiring segregation of pipeline batches based on regional or local, as well as summer and winter, vapor pressure requirements, (API-AOPL, 2001).

Typical large refined petroleum pipelines operators transport from 30 – 50 products regularly moving on each system over a cycle. A cycle is the period of time from pumping of a certain grade until all other grades are pumped and the initial grade is pumped again beginning the new cycle. However, pipelines have been carrying as many as a total of 100 – 120 product grades for which they may occasionally provide transportation services for specialized fluids.

In general government regulation drive the majority of segregated batches, followed by customer specifications, and individual state or city requirements. The number and mix of products and specifications shifts by the regions as serviced by the pipeline operators (EIA,2001).

One pipeline operator in the Midwest USA carries 43 grades of product on a typical 10-day cycle (34 grades of gasoline, 5 grades of fuel oil, and 4 grades of jet fuel).

Although the pipeline usually has 43 grades of product in the pipeline at one time, it actually carries a total of 85 fungible and segregated products for 60 different shippers.

Typically pipeline operators batch the products in sizes of 5,000-6500 $m^3$ (32,000-40000 bbl), or larger, for each individual product. All commodities are usually segregated, eg.: regular gasoline, mid-grade gasoline, premium gasoline, jet fuel, aviation fuel and diesels for different refineries.

All batches combined in "slug/batch train" with each "box car" = one individual batch. Batch slug/train can be about 65,000 –100,000$m^3$ in size (400,000 – 600,000 bbl).

Liquid product viscosity ranges that are transported through a batched system may include those shown in Table 1:

| ***Viscosity (mm $^2$/s)*** | ***Density (kg/m$^3$)*** | ***Classification*** |
|---|---|---|
| *100–350* | *904–940* | *Heavy crude* |
| *20–99* | *876–903* | *Medium crude* |
| *2–19* | *800–875* | *Light crude* |
| *0.4 – 1* | *600–799* | *Products and condensate* |
| *to 0.3* | *to 599* | *NGL* |

Table 1. Range of Product Viscosities Transported Through a Batched Pipeline.

From the above, the complexity of operational management of a liquid pipeline transporting different liquid petroleum products can be realized.

In liquid pipelines, inventories and deliveries are managed through a system of tankage/storage facilities and pipeline/pumping to the withdrawal, transport and delivery of dedicated products to customers without mixing of similar or dissimilar products from different shippers.

However, while a gas pipeline network (Figure.2) can be very complicated and can have many more supplies (producers) than a liquid pipeline network, gas mixing is normally allowed within acceptable gas specification limits.

Typical gas compositions transported are shown in Table 2 and allowables are given in Table.3.

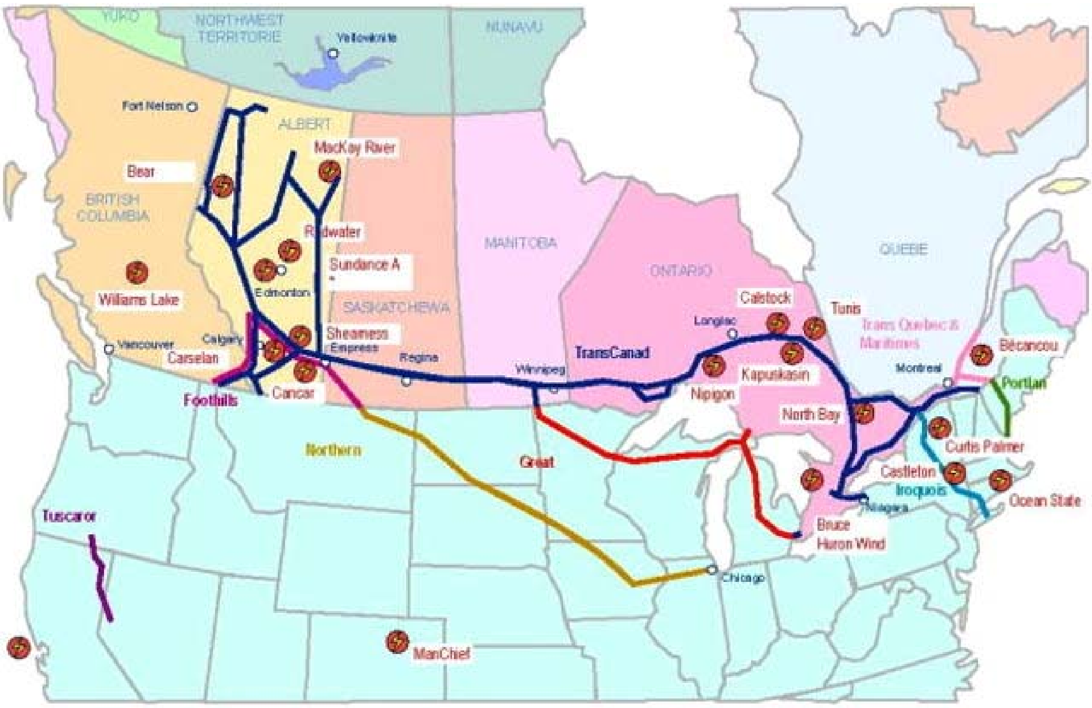


Figure.2. Gas Pipeline Transmission Network Canada–USA (Schematic Courtesy of TransCanada PipeLines Limited)

| Component | Light gas | Heavy gas |
|---|---|---|
| $CO_2$ | 0.0388 | 5.01995 |
| $C_1$ | 98.0276 | 78.4436 |
| $C_2$ | 0.2523 | 10.3178 |
| $C_3$ | 0.0542 | 3.86919 |
| $IC_4$ | 0.0171 | 0.609872 |
| $NC_4$ | 0.0088 | 0.729847 |
| $IC_5$ | 0.0060 | 0.169964 |
| $NC_5$ | 0.0022 | 0.119975 |
| $C_6$ | 0.0046 | 0.0599874 |
| $C_7$+ | 0.0144 | 0.0299937 |
| Nitrogen | 1.5687 | 0.61987 |
| Hydrogen | 0.0053 | 0.0099979 |
| Total | 100.000 | 100.000 |

Table 2. Typical Gas Supplies to Pipeline Network (14.7 psia and 60 $^{o}$F)

| **Component** | **Limit** |
|---|---|
| Water content | < 65 mg/m$^3$ |
| Dew point | <-10 $^o$C |
| Temperature | <49 $^o$C |
| Gross heating value (GVH) | > 36 MJ/m$^3$ |
| $H_2S$ | < 23 mg/m$^3$ |
| $S_2$ | < 112 mg/m$^3$ |
| $CO_2$ | < 2% by volume, 0.02 ppm |
| $O_2$ | < 4% by volume, 0.04 ppm |

Table 3 Typical Natural Gas Pipeline Specification

Gas pipeline operation is generally managed by balancing the supplies and deliveries within the contractual arrangements while ensuring that line-pack within a gas network is maximized.

The function is thus to estimate gas supply/demand for ascertaining the ownership of the gas flowing into and out of the gas pipeline system at any time and declaring an estimated balance each day.

Gas mixing from different shippers are allowed and are not an operational management concern as long as each gas quality received meets the industry standard of quality specifications. In liquid lines on the other hand, line-pack is not a consideration from delivery points of view. It is the dedicated product delivery that dictates operational management concerns.

An example of supply of natural gas from two different locations in a gas pipeline network can be those provided in Table 2: Resulting gas delivery at some 120 km away after mixing is shown in Table.4.

| Date | GHV BTU/MSCF | SG | C1 | Ic4 | nC4 | C2 | C3 | iC5 | nC5 | C6 + | N2 | CO2 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Day 1 | 1101.286 | 0.688 | 82.6042 | 0.5120 | 0.5597 | 8.1043 | 3.1574 | 0.1089 | 0.0688 | 0.0225 | 0.7695 | 4.0722 |
| Day 2 | 1099.375 | 0.687 | 82.7882 | 0.5011 | 0.5478 | 8.0231 | 3.1101 | 0.1050 | 0.0661 | 0.0209 | 0.7771 | 4.0399 |
| Day 3 | 1101.021 | 0.689 | 82.4945 | 0.5062 | 0.5549 | 8.1800 | 3.1640 | 0.1057 | 0.0664 | 0.0205 | 0.7589 | 4.1268 |
| Day 4 | 1102.154 | 0.690 | 82.3063 | 0.5101 | 0.5613 | 8.2762 | 3.1940 | 0.1075 | 0.0675 | 0.0212 | 0.7467 | 4.1849 |
| Average | 1100.959 | 0.688 | 82.5483 | 0.5074 | 0.5559 | 8.1459 | 3.1564 | 0.1068 | 0.0672 | 0.0213 | 0.7630 | 4.1059 |

Table.4. Gas Delivery Property (14.7 psia and 60$^{o}$F)

In a gas pipeline system, depending on the industry served (industrial, power generation, commercial or residential), delivery volumes can be time-/seasonal-dependent depending on the number of customers served and storage availability. An example is provided in Figure.3

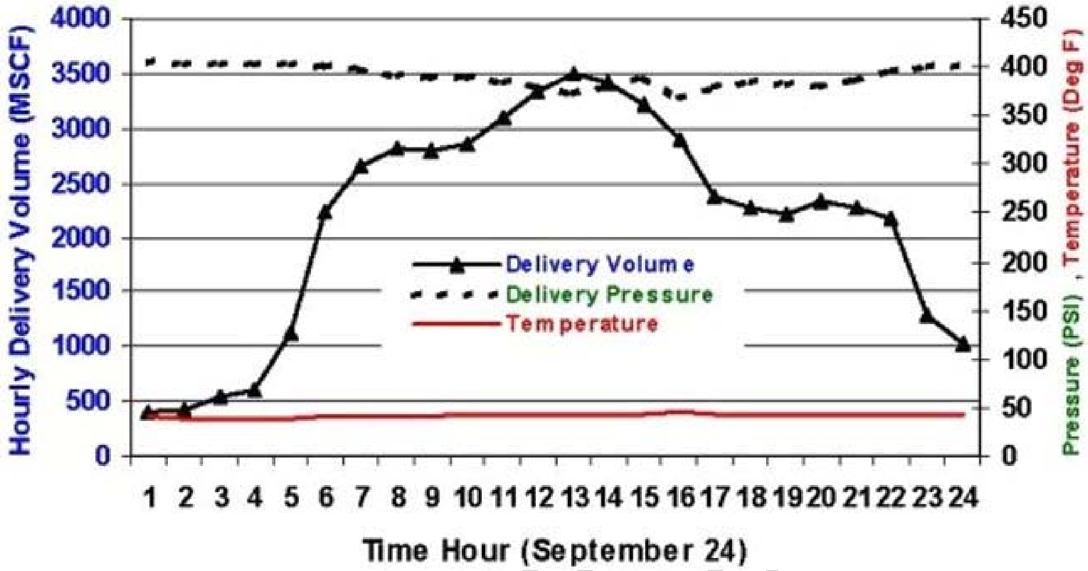


Figure.3. Typical Delivery Characteristics in a Gas Pipeline System

Therefore operational planning needs to be achieved by balancing supplies and deliveries by optimizing line-pack compression fuel requirements.

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**Biographical Sketches**

**Dr Mo Mohitpour**, Ph.D., P. Eng., F. I. Mech. Eng., Fellow EIC, Fellow ASME., P.E (US), C. Eng. (UK) is a Canadian Professional Engineer with thirty one years of direct experience in engineering, construction, inspection and management of pipeline systems and associated facilities for oil, gas, condensate, batched products, specialty fluids (hydrogen and carbon monoxide, bitumen etc) transmission, storage, tankage and distribution. Dr. Mohitpour has also published two technical books and 31 technical papers including several articles on hydrogen pipelining and speciality fluids transportation.

He is President of Tempsys Pipeline Solutions Inc a principal consultant to the pipeline industry. He has worked in the pipeline Industry since 1975 including TransCanada Pipelines/NOVA Corporation, Enbridge Technology Inc., Canuck Group of Companies, Bechtel GB and Fluor, and has provided pipeline instructional training worldwide since 1988. Since year 2000,Tempsys has provided services to TransCanada, Enbridge (for BP/Ocensa, Canadian Energy Services/Oman Gas Company, Indian Oil Corporation, Ecogas/Comania Operados Associados- Columbia, TransPerto/Petrobras, Brazil)), OGP Technical Services/Petronas (Malayisa), TransGas de Occidente (Columbia), Willbros West Africa (Chad/Cameroon)and Alliance/Fredrikson & Byron USA.

He is a Fellow member of Inst. Mech. Eng. (UK), Engineering Institute of Canada (EIC), and American Society of Mechanical Engineers (USA), PE in Texas (USA) and P.Eng in Alberta and British Columbia (Canada), C.Eng (UK). He hold a Ph.D. from Imperial College of Science and Technology and Medicine, London, England, 1972 and a B.Sc., Honours, University of Surrey, England,1968 both in Mechanical Engineering.

He is author of the ASME best seller "Pipeline Design & Construction - A Practical Approach" ASME Publication, released Oct. 2000, 2nd edition Oct 2003, and has published 36 Technical Papers. His second book "Pipeline Operation & Maintenance - A Practical Approach" was released by ASME in December 2004.

**Mr. Andrew Jenkins,** As Vice-President, Major Projects, Andy Jenkins is responsible for bid support, permitting, implementation and operations support of major energy infrastructure projects. This includes major pipeline additions, LNG, Storage and northern development projects.

Mr. Jenkins has more than 30 years of experience in the oil and gas industry. After graduating from the University of Western Ontario with a Bachelor of Engineering Services in 1975, he joined TransCanada in 1976 as a Geotechnical Engineer and has held a variety of senior positions since joining the company.

Mr. Jenkins worked for five years on the Polar Gas Project, prior to relocating to Nova Scotia to work on the Sable Gas Project, responsible for the offshore pipeline component.

During the late 80's and early 90's, he was responsible for TransCanada's pipeline expansion on its mainline system, some $6 billion of facilities over 5 years.

In 1993, he moved to Sunshine Pipelines to take a role of Vice-President Engineering and Construction and later returned to TransCanada in 1996 to assume a role in the International Business Unit. Throughout his career, he has managed a variety of large, complex projects, some in challenging international locations, such as Mexico, Venezuela and Colombia.