Transportation of oil and natural gas

Transportation of oil and natural gas

Oil is often produced in remote locations away from where it will be consumed; therefore, transportation networks have been built to transport the crude oil to refineries where it is processed and to ship the refined products to where they will be consumed (like a gas station). Storage facilities are used to balance supply and demand of oil and refined products.

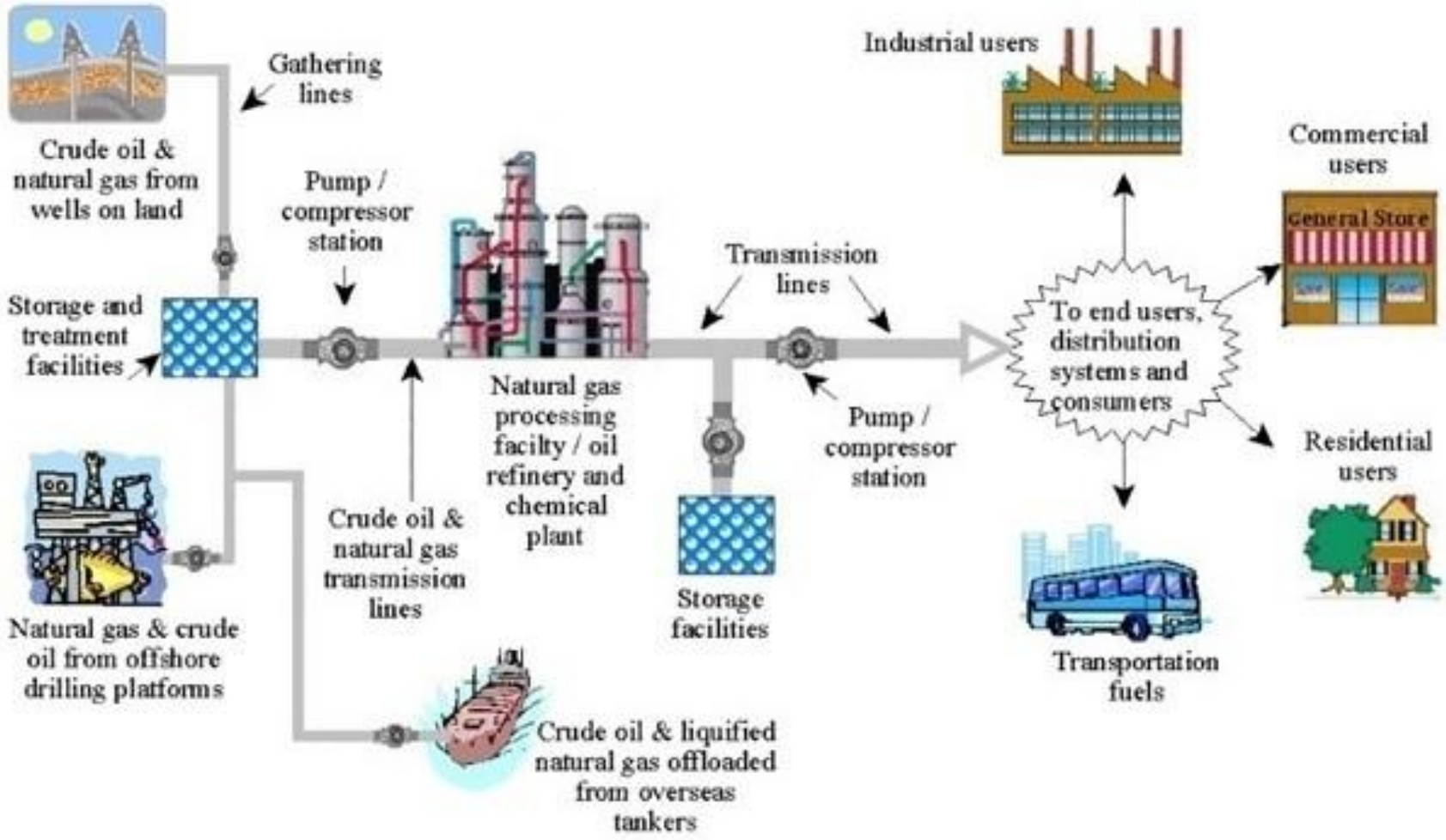
Oil is normally transported by one of four options:

- **Pipeline –** the most commonly used form of oil transportation is through oil pipelines. Pipelines are typically used to move crude oil from the wellhead to gathering and processing facilities and from there to refineries and tanker loading facilities. Pipelines **require significantly less energy** to operate than trucks or rail and have a lower carbon footprint.
- **Rail –** Oil shipment by train has become a growing phenomenon as new oil reserves are identified across the globe. The relatively **small capital** costs and **construction period** make rail transport an ideal alternative to pipelines for long distance shipping. However **speed, carbon emissions and accidents** are some significant drawbacks to rail transport.
- **Truck –** while the most limited oil transportation method in terms of storage capacity, trucks have the greatest **flexibility in potential destinations**. Trucks are often the last step in the transport process, delivering oil and refined petroleum products to their intended storage destinations.
- **Ship –** where oil **transport over land is not suitable**, oil can be transported by ship. A typical 30,000-barrel tank barge can carry the equivalent of 45 rail tank cars at about **one-third the cost**. Compared to a pipeline, barges are cheaper by 20-35%, depending on the route. Tank barges traditionally carry petrochemicals and natural gas feedstocks to chemical plants. The drawbacks are typically **speed and environmental concerns**.

Types of Pipelines

Within the energy sector, there are two major types of pipelines, **liquids pipelines** and natural **gas pipelines**. Liquid pipelines transport crude oil or natural gas in liquid form to refineries where they undergo distillation and other production processes. Some liquids pipelines are also used to transport distilled petroleum products such as gasoline to distribution centers. Natural gas pipelines are used solely for the transport of natural gas to processing plants and are used for distribution. Natural gas is also often delivered directly to homes through pipelines. In addition to these two main types of pipelines, there are also other sub-categories of pipelines:

Gathering Lines: These lines are 10-30 centimeters in diameter, and work to transport natural gas, crude oil, and natural gas liquids short distances. They exist mainly to gather products from wells and move them for processing.
Feeder Lines: Feeder lines move crude oil, natural gas, and natural gas liquids from storage tanks and processing facilities to transmission pipelines.
Transmission Pipelines: These can range from 10 centimeters in diameter to over a meter. They carry natural gas, natural gas liquids, crude oil, and refined products (depending on whether they are liquids or natural gas pipelines). These transport petroleum products long distances, including over international boundaries.
Distribution Pipelines: These range in diameter from 1-15 centimeters and are used to distribute natural gas to homes and businesses.
Carbon dioxide (CO_2) lines allow CO_2 to be used to enhance oil recovery.



Gathering pipelines
Short length
Small diameter
Variable pressure

Transportation Pipelines
Long length
Large diameter
High pressure

Distribution Pipelines
Medium length
Small diameter
Low pressure

Pipeline operation

- **For liquid pipelines** that transport crude oil and liquefied petroleum products, small diameter gathering lines collect the product from where it is extracted. After moving to a gathering facility, it moves to feeder pipelines with relatively large diameters which transports product to refineries. Transmission lines are used when oil and liquids have to travel long distances. To push the liquid through the pipe, powerful pumps are used and move oil at around walking speed. Liquids pipelines are very versatile and can transport a variety of grades or varieties of crude oil and crude oil products.

- The process is similar for **natural gas pipelines**—extracted natural gas is transported for processing in gathering and feeder lines, then moves into large transmission pipelines (generally composed of steel pipe). Gas is able to flow as it moves from areas of high pressure to low pressure. This pressure difference is obtained through the use of compressors that increase the pressure of the gas, pushing it along. Once the gas reaches a distribution plant, companies reduce the pressure of the gas and distribute it through small distribution pipelines.

Environmental Concerns

There are environmental concerns with the construction and operation of pipelines that vary depending on how and where the pipelines are being built. Some of the concerns include:

Reduction of air quality as a result of dust production during construction and emissions due to the combustion of fossil fuels used for construction equipment.
Increased noise pollution as a result of construction and pumping stations.
Soil erosion and contamination from construction and any leaks.
Loss of plant life as a result of construction, surface disturbances, and changes in water flows.
Water resource disturbances in terms of quantity and quality as a result of erosion, herbicides, and leaks.

Pipelines have been constructed extensively for many years and thus there are numerous steps taken to minimize any environmental effects. The environmental impacts cannot be avoided entirely, only reduced. Although these issues are all concerning, most people are concerned with a **rupture in a pipeline and a spill**. A spill of petroleum products can cause **significant environmental damage and pose a risk to human health—as they can burn, contain toxic chemicals, and pollute groundwater.** However, pipeline ruptures are not extremely common, but they do occur. Older pipelines are much more vulnerable to rupture as a result of corrosion.

Leak Detection

Leakages can have different causes, including **excessive deformations caused by earthquakes, landslides or collisions with ship anchors, corrosion, wear, material flaws or even intentional damage**. Other causes include but not limited to;

- Fatigue cracks are one cause, these occur as the result of material fatigue and are often found on longitudinal welds.
- The tensile strength can cause stress tears which can reduce the effectiveness of Cathodic corrosion protection systems, resulting in corrosion on the pipeline.
- Cracks can also be caused by **hydrogen indexing**. In this case, atomic hydrogen diffuses into the metal grid of the pipe wall, forming molecular hydrogen. This can lead to the pipe material becoming brittle and prone to early failure.
- Material **manufacturing errors** can also cause leaks, e.g. when cavities are rolled into the material during production of the pipe.
- Leaks can also occur when an **external force** acts from the outside;

The cost of failure to detect the leaks results in;

- Loss of life and property
- The direct cost of loss products and lie downtime
- Environmental clean-up costs
- Possible fines and legal suits

Pipeline leak detection systems

Pipeline leak detection systems can be categorized into two major types;

- Continuous
- Non-continuous systems.

Non-Continuous	Continuous	
	External systems	**Internal systems**
• Inspection by helicopter	• Fibre optic cable	• Pressure point analysis
• Smart pigging	• Acoustic systems	• Mass/Volume balance method
• Tracking dogs	• Sensor hoses	• Statistical systems
	• Video monitoring	• RTTM-based systems
		• E-RTTM

Pigging

Pipeline pigs (pipeline scrapers) are a type of tool utilized in the pipeline industry to complete certain tasks including **pipeline cleaning and inspection**. Pigs are commonly used for:

Hydrostatic Testing – The pig allows the line to be filled with water or hydrostatic testing medium without entrapping air. The pig is inserted at the front with water being pumped behind the pig, keeping the pipe full of water. The pig forces air out of the pipeline at the front.

Pipeline Cleanup – Pipeline scraping/cleaning is done regularly to remove scale, wax buildup, and other types of debris from the inner wall of a pipeline to keep up a high pipeline flow efficiency. Natural gas pipeline pigs are used to remove trapped liquid accumulation and generally serve to keep the pipeline free of any liquid. Entrained liquid causes higher rates of erosion in a natural gas pipeline and should therefore be minimized.

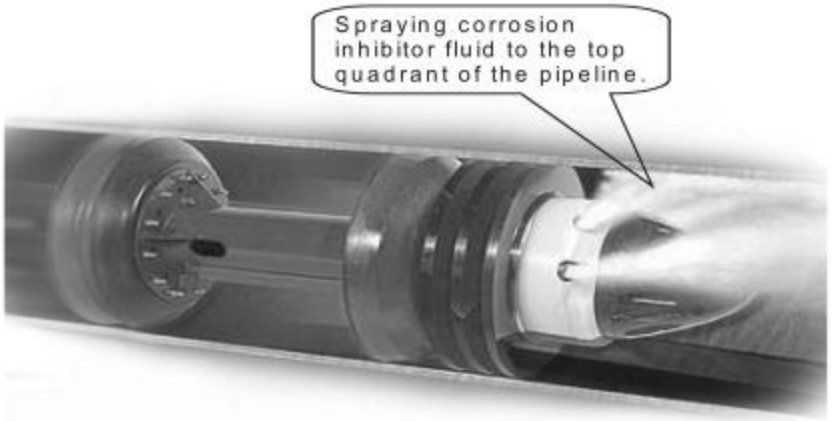
Batch Transportation – Pigs are used to separate batches of different products inside of a pipeline. This is required in the case of a multi-product pipeline transporting more than one type of hydrocarbon in batches.

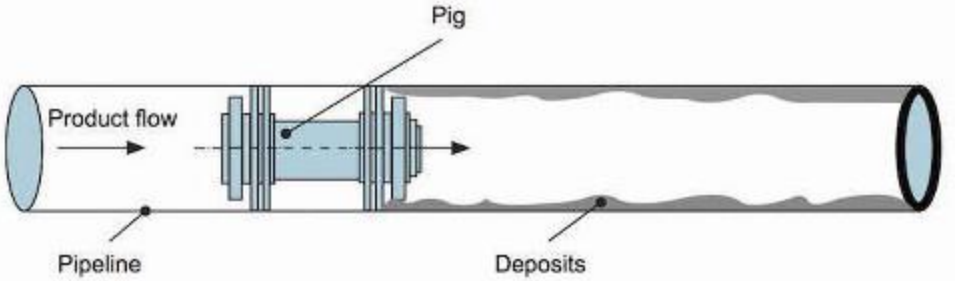
Prevention of Solid Accumulation and Corrosion – This is for crude oil lines to keep water and solids from accumulating in low spots and creating corrosion cells. This becomes particularly relevant for low-velocity lines.

Internal Pipe Coatings – Pigs are used to apply certain internal coatings like epoxy-based coatings.

Inspection – One of the most frequent uses of pigs is as an inspection tool. Sizing or gauging pigs are often run after the completion of a new pipeline to determine if there are any internal obstructions, bends, or buckles in the pipeline. Pigs can be fitted with cameras for internal viewing of the pipeline.

Intelligent Pigs – Smart/Intelligent pigs use magnetic and ultrasonic systems to locate internal and external irregularities; whether those are pittings, dents, buckles, corrosion pitting, or any other abnormality.


Spraying corrosion inhibitor fluid to the top quadrant of the pipeline.


Pig
Product flow
Pipeline
Deposits

Types of Pigs

Pigs can be divided into the following types:

Foam Pipeline Pigs – these pigs are used to remove debris and water from pipelines. Foam pigs can furthermore be broken down into the following:

- ***Bare Foam and Coated Foam Pigs –*** Used for general cleaning, batching and proving of pipelines. These types of pigs have generally used post-construction due to their flexibility.
- ***Brush Pigs –*** These pigs are fitted with brushes that remove material and debris from pipelines. These materials typically include corrosion deposits.
- ***Foam Disc Pigs –*** These pigs are used for the removal of liquids from a pipeline.

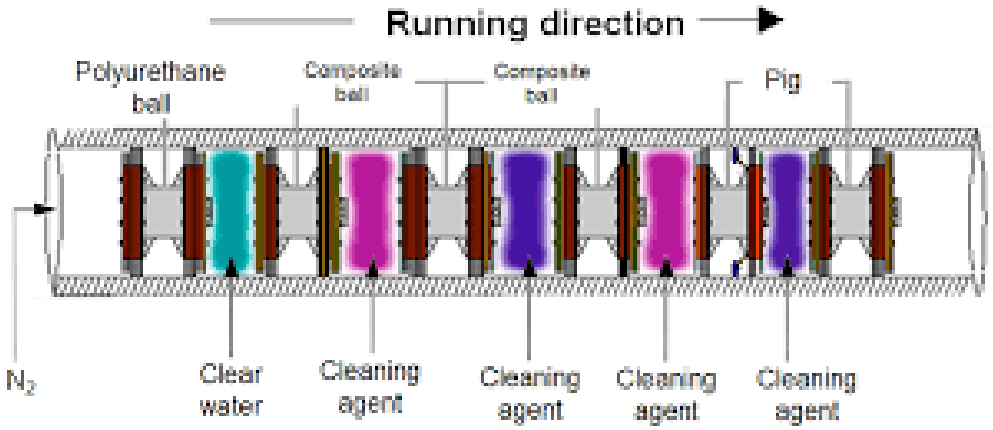
Mandrel Pigs – Pigs that are designed with a metal body. These pigs are customizable with the possibility of alternating various types of discs, cups, scrapers, brushes or gauging plates. Cups and discs are added where a tighter seal is required and are very effective with the removal of liquids and black powder.

Urethane Pigs – A more flexible type of pig used for wax removal or liquid displacement and is constructed as a single piece of equipment. Polyurethane is a wear-resistant formulation of urethane pigs.

Pig Trains

Pig trains are another form of pigging and are used for many pipeline operations and maintenance procedures. A pigging train consists of a train of pigs **sent in a sequence to achieve a certain cleaning service.** An example of this entails the use of four pigs in a train used to clean saltwater from a line:

1. The first pig pushes a slug of clean water to eliminate/push out the saltwater
2. The second pig is pushing another batch of clean water
3. The third pig is pushing a glycol solution slug (the glycol is dehydrating the line)
4. The last pig is propelled by nitrogen and is pushing another slug of glycol



Intelligent/Smart Pigs

Intelligent or smart pigs are internal inspection devices (in-line inspection, ILI) used extensively for inspecting pipelines that are in service. The intelligent pig is a sophisticated form of measuring device that travels through the pipeline in the same manner as a normal cleaning pig while **measuring and recording irregularities in the pipe wall that may represent corrosion, gouges, and other typical pipeline deformations, know as pipe anomalies.**

Intelligent pigs can be broken down into four main types discussed in further detail below. These include the following:

- Magnetic Flux Leakage Pigs
- Ultrasonic Testing Pigs
- Shear Wave Ultrasonic Pigs
- Geometry Pigs

Multiproduct pipelines

- Multiple hydrocarbon products such as diesel, kerosene, and gasoline, are often transported in a single pipeline as this is usually more cost-effective compared to using separate pipelines for each product.
- Batching can furthermore be utilized in cases where fuels are received from more than one source and are transported to more than one destination or have multiple intermediate take-off points.

Types of Batching

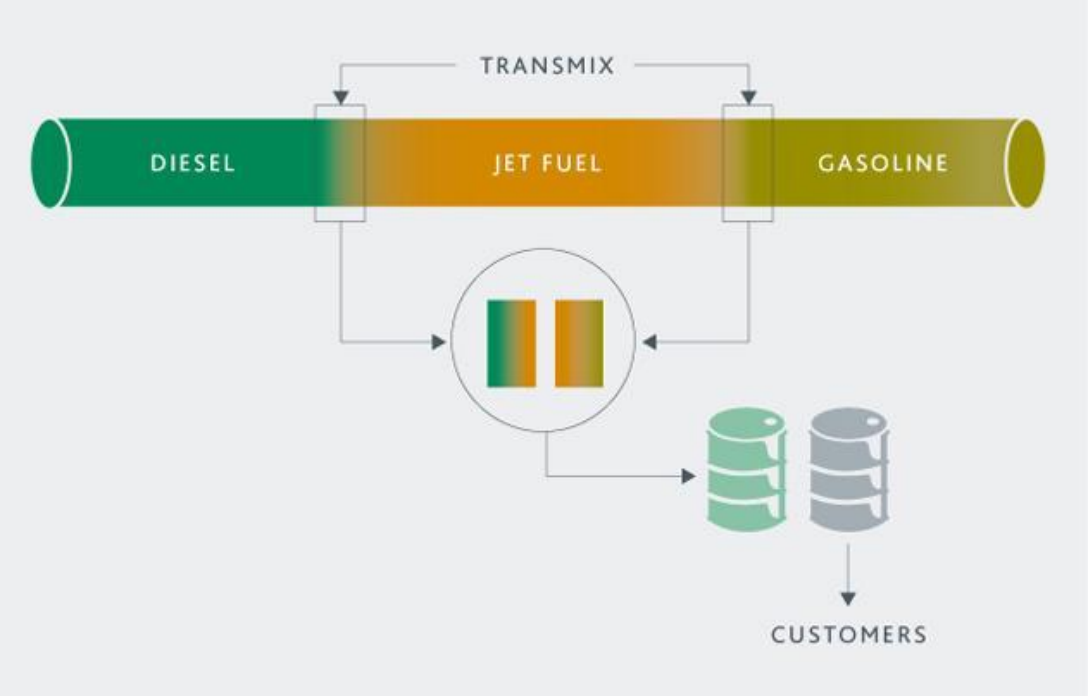
- Batching procedures are typically executed employing the following types of batching as mentioned earlier in this section:
  - Batching with Interfacing
  - Batching with the Use of Pigs
- The different hydrocarbons can be separated with or without the use of physical separations, meaning **with or without the use of pigs** (or liquid plugs). In the absence of pigs, an interface forms between two adjacent products (batches), resulting in mixing, and ultimately contamination of the adjacent products. The length of this **interface needs to be kept to a minimum** to reduce the amount of contaminated product.

Interface Batching

- Interface batching includes interfacing between batches and therefore a repetitive sequence of diesel fuel is typically utilized. **The diesel fuel has the highest density but is also less sensitive to minor contamination of other hydrocarbons**.
- The sequence followed is therefore to transport a batch of diesel between each other type of hydrocarbon.
- The interfacing tanks are used to store the portion of the fuel that is mixed and is then usually either mixed back into a diesel tank in selected quantities or sent back to a refinery.
- The interface detection is done by measuring the density of the incoming fuel and switching between the respective diesel, other hydrocarbons, and interface tanks.

Interface Processing

- Formed interfaces must be removed to avoid degradation beyond the maximum allowable contamination of the products.
- After the interfaces have been removed, they must be **reprocessed (e.g. through distillation)** to deliver saleable products.
- It is, however, more economically appealing to **blend the interface into one of the adjacent products**, by adding it to one of the products' tanks.
- In this case, it is important to ensure the product specifications are still met, otherwise the product will be downgraded.



Factors to Consider for Interface Batching

Different hydrocarbon products are consecutively transported in batches in a pipeline. To reduce contamination between two adjacent products, the **length of the interface** and various factors have to be considered. These factors include:

- **Velocity –** interface volume growth decreases with increased flow rate.
- **Density Difference –** smaller density difference results in the shorter interface.
- **Viscosity –** smaller difference in viscosity results in smaller interface volume.
- **Pipe Diameter**

An increase in batch size does not affect the amount of interface product but can reduce the amount of reprocessing or refining required, thereby reducing the associated costs. Contrarily, **the order in which batches are transported has a significant effect on the amount of refining that is required.** It is important to keep the following in mind:

- Immiscible products shouldn't be placed adjacently
- Products with notable differences in viscosity shouldn't be placed next to each other

Interfaces are developed at early stages in transportation. Therefore, after an interface has been established, products moving through pump stations further along the pipeline do not significantly change the amount of contamination.

Blending

Blending is the process of mixing intermediate hydrocarbon products and additives to produce a final, marketable product that adheres to required specifications and environmental standards. It is more profitable to maximize the blending of the higher value product, up to the specification limits are met. The three most common methods of blending are:

In-line Blending – turbulence ensures extensive mixing when proportionate amounts of each component are added directly to the mainstream in a pipeline.

Batch Blending – additives are added during or/and before blending. Additives such as anti-oxidants or octane enhancers can provide certain properties, not inherent in the hydrocarbons.

Onboard Blending – products can be prepared to specification without the use of onshore facilities.

Online blending (and in-line), ensuring enhanced accuracy, has become more common due to technological advancements, computerization, and the accessibility of certain equipment. **Many different software packages that optimize the blending process and production of profitable products are available.**

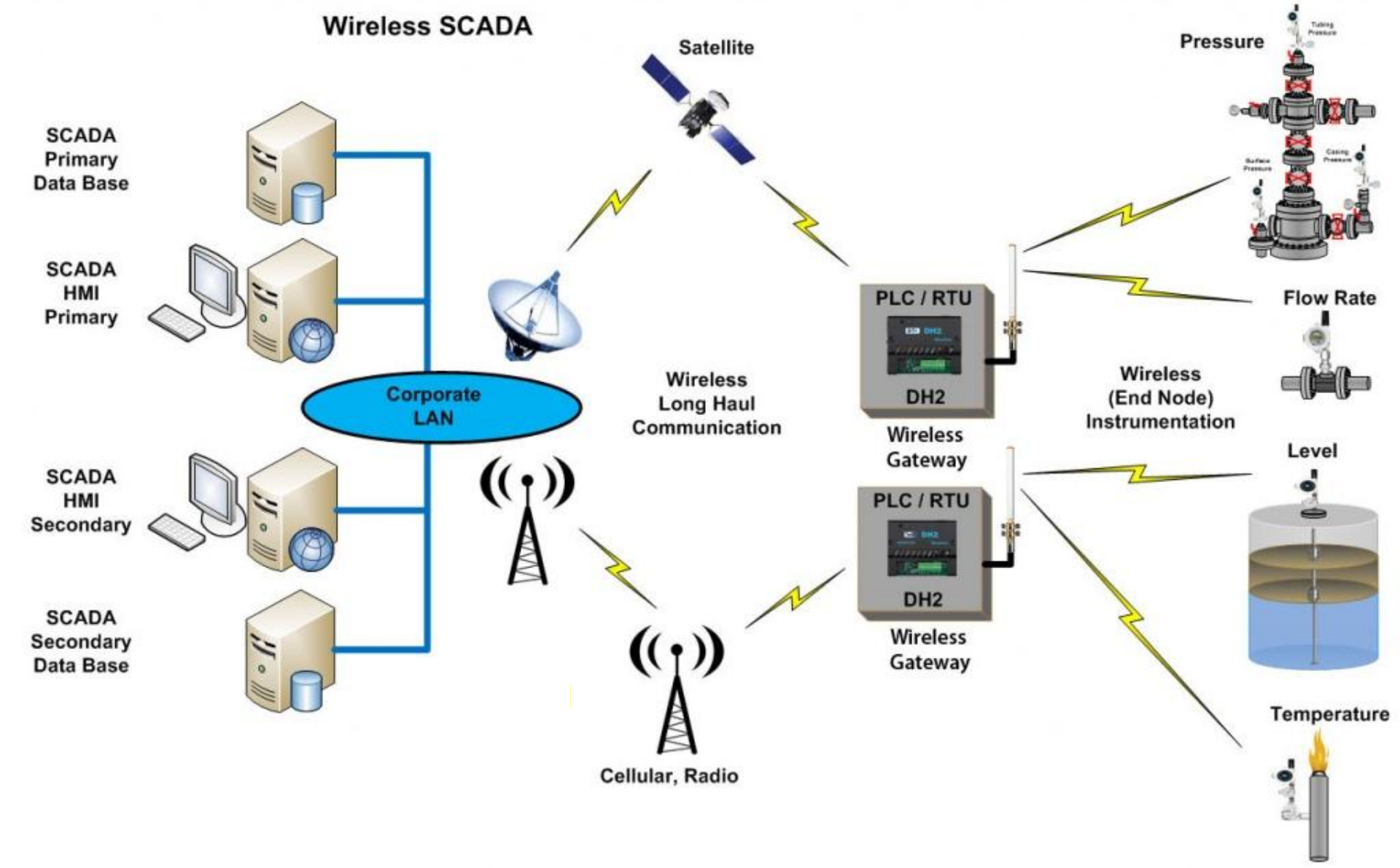
Pipe line automation

- Modern refinery operations are generally **fully automated** and **remotely** performed.
- From centrally located **control rooms**, operators direct the product flow.
- From there, they start & stop pumps, open & close valves, fill & empty tanks.
- Supervisory control & data acquisition systems, known as **SCADA**, are used.
- SCADA is a computer-based system for gathering and analyzing real-time data to monitor and control equipment that deals with critical and time-sensitive materials or events.
- SCADA continuously monitors:
  - pump pressures
  - flow rates
  - batch locations
  - tank levels

Wireless SCADA

- Many organizations are now adopting the latest wireless communication technologies to replace certain sections of their hardwired SCADA system infrastructures with wireless equipment for improving reliability and cost. Wireless technologies cost-effectively provide remote and localized control and transfer of live and historical data to the industries home centralized location operation.

- Implementing a wireless infrastructure is particularly beneficial to new production sites or facilities since installing wireless equipment can drastically reduce installation cost and time, reduce permit costs, and eliminate trenching and running conduit, while minimizing wire failure due to degradation and other environmental factors. Again, utilizing wireless technology reduces initial cost by completely removing the need for long distance direct burial analog (4-20 mA) cabling. In addition, I/O analog to digital converter modules typically used in hardwire control instrumentation loops utilized by PLCs or RTUs are also eliminated.


Wireless SCADA
Satellite
Pressure
SCADA
Primary
Data Base
SCADA
HMI
Primary
Corporate
LAN
Wireless
Long Haul
Communication
PLC / RTU
DH2
Wireless
Gateway
Flow Rate
Wireless
(End Node)
Instrumentation
Level
SCADA
HMI
Secondary
PLC / RTU
DH2
Wireless
Gateway
SCADA
Secondary
Data Base
Temperature
Cellular, Radio

Thanks