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CHAPTER FOUR:

TRANSPORTING OIL AND GAS

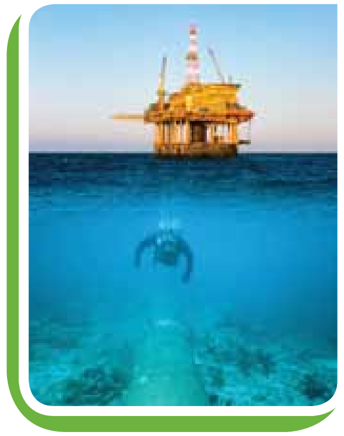
What's in a Barrel of Oil?

Early producers shipped their oil to market in earthenware vessels aboard slow-moving barges. Since then, the need to move increasingly large quantities of petroleum* has brought about some big changes in the industry. As containers evolved, the 42-gallon oil barrel became the current U.S. standard for measurement, though it is no longer used for shipping. The unit originated in the 1860s, when there was no standard measure for oil. Producers simply used whisky and molasses barrels or whatever was handy until customers demanded something more uniform. The most common size cask — 42 gallons — became the agreed-upon standard. As U.S. oil companies became active in other countries, many of them also adopted that standard as well. For much of international trade, however, the common unit is the metric ton, which is approximately 7 U.S. barrels.

Beyond the Barrel

When barrels proved too leaky and expensive, producers began looking for other shipping methods. The first U.S. oil pipeline was constructed in 1865. It ran just five miles through western Pennsylvania, but it revolutionized the transportation of petroleum. The maiden voyage of the first oil tanker 15 years later was another significant advance because oil could now be pumped directly into the ship's hull without the containers' extra cost and bulk. Today, nearly 200,000 miles of petroleum pipelines crisscross the United States, moving two-thirds of the nation's crude oil and refined products. It is the world's largest energy pipeline network — 10 times larger than Europe's. Modern oil tankers include enormous supertankers, which can carry 2 million barrels of crude oil. That's enough oil to meet 10 percent of U.S. energy needs for one day, or produce enough gasoline to drive a car 31,000 times around the Earth.

Pipelines



A diver inspects an underwater pipeline.

Once the offshore facility has separated the oil and gas, it sends them to refineries and processing plants on land. Most offshore oil and gas production is transported by pipelines to onshore facilities. The technique for laying pipelines under water had its beginnings in England during World War II. Steel tubes were welded together and coiled around floating drums. One end of the pipe was fixed to a terminal point and as the floating drums were towed across the English Channel, the pipe was pulled off the drum. The pipeline connected fuel supply depots in England with distribution points in Europe to support the Allied invasion of Europe.

* The terms "petroleum," "hydrocarbons" and "oil and gas" are often used interchangeably throughout this text. For definitions and distinctions, refer to the glossary at the end of this chapter.

EXCAVATOR DIGS A TRENCH FOR LAYING A PIPELINE.

Pipeline designs vary depending on what they are transporting – crude oil, natural gas or refined products – and their function. The world's longest underwater pipeline is the Langeled project, which was completed in 2007 to transport natural gas some 750 miles from Norway to England. Water depths of over a half mile, extremely uneven terrain and freezing temperatures make the Langeled something of a modern wonder. But as more than a third of the worldwide growth in drilling is expected to come from offshore, technological advances in pipeline construction and safety are accelerating, making them the safest, most efficient and economical transportation mode available.

Oil vs. Gas

Crude oil is generally piped from the offshore production site to an onshore terminal with large storage tanks and then sent to refineries in pipelines over land. Natural gas is transported to gas plants for processing. Once components such as butane and propane are recovered, they are sent to other plants for further processing or directly to the market. Almost all overland natural gas transportation is by pipeline. Transporting it by truck, train, or barge would increase safety risks and be more costly.

Designing Safe Pipelines

Pipeline design must take into consideration a number of issues including the volume of oil or gas to be transported, the soil strength and stability of the seafloor, environmental conditions such as water depth, temperatures, marine life and other activities in the area such as shipping and industrial operations. Companies are responsible for the safety and reliability of their pipeline systems and they are rigorously audited and inspected by a host of agencies.

The Pipe

The diameter must be large enough to allow the maximum volume to pass with the minimal resistance for optimal efficiency. The velocity must also be kept high enough to keep the pipe free of corrosion or debris that can plug the pipe. The pipes are usually made of high-quality carbon steel that is produced to specific standards, tested and quality checked from its raw steel state to the finished product. Generally, the pipes or joints are manufactured in approximately 40-foot lengths. Pipes transporting certain types of fluids must contain special corrosion resistant alloys. Heavier (thicker) oil may need to be heated to keep it flowing easily. Depending on the distance the fluid needs to travel, the pipeline may need to be insulated or equipped with additional pumps or heating stations to keep the product flowing.

The Route

Pipeline routes are selected to allow safe operation over the life of the pipeline. Surveys are conducted to gather data on the seafloor terrain, soil properties and environmental events such as currents and ice movements. The data is then used to select routes with the most stable conditions to ensure the lines will be safe.

Seafloor Conditions

In most environments, offshore pipelines can lie on the seafloor, protected by the water covering them. Even during hurricanes, pipelines see limited effects from the massive waves on the surface, though they must still be designed to withstand strong subsurface currents and tidal surges. In some areas, pipelines must be buried to protect them from near-shore wave forces, ship anchors and commercial fishing activities. In the Arctic, burial may be required in some areas because of ice and environmental conditions and surveys of the ocean bottom are conducted to identify those areas.

Other Pipeline Route Considerations

Sometimes these site surveys have uncovered some surprises — like shipwrecks and archeological sites. Spanish Galleons, World War II ships and other artifacts have been found while ocean bottoms were being surveyed for pipeline routes. These finds are brought to local historical societies for investigation and the pipelines are then routed around any sensitive areas.

Pipeline Installation

Once manufactured, the pipe is coated to protect it from corrosion and may have special insulation applied before it is shipped to the installation site. Pipelines can be installed by a number of methods depending on the site conditions. Barges and other types of vessels are often used to construct and lay the pipelines. “Lay barges” are equipped like small factories to weld the pipes together and then lower them to the seabed one pipe or joint at a time as the vessel slowly moves ahead. It is critical that each weld be inspected using X-ray and/or ultrasonic techniques to ensure a proper weld and the integrity of the pipeline system. For burying the pipelines, specialized equipment is used to dig a trench and then cover the pipeline. The trenching methods vary depending on how deeply it must be dug, the water depth and strength of the seafloor soils. The trench may be dug before the line is laid down and/or the trench can be dug around a pipeline sitting on the seabed. The seafloor may be plowed, jetted with pressurized water or trenched with a machine that resembles a large-slow-speed chainsaw.

The final phase of pipeline installation is to conduct a hydrostatic test, a check on system integrity while under pressure. Water is pumped into the pipeline and then pressurized to a minimum 1.25 times its design pressure for an extended period of time. Once this final testing has determined that the system is sound, the water is removed and the pipeline is set for operation.

PIPELINES IN ARCTIC CONDITIONS

PIPELINE ROUTES

Surveying potential pipeline routes in the Arctic means looking for ice gouges and strudel scours. Ice gouging can occur when ice ridges are pushed toward shore and their ice keels contact the seafloor. The gouges indicate where pipelines must be buried to protect them from the ice keels. Strudel scours are formed during the spring melt, when fresh water from local stream and river breakups flow over the sea ice. This water finds seal breathing holes or cracks in the ice where it can drain into the water below. These drains can create whirlpool actions that scour the seafloor and could expose pipelines. The surveys are performed over several years to determine the frequency and depth of the gouges and scours as conditions change annually.

PIPELINE INSTALLATION

In the Arctic, pipelines are often installed from equipment situated on the surrounding ice during winter construction. Extended reach backhoes are used to dig trenches in the seafloor where the pipeline is to be buried. This method works for shallower waters near the shore. In deeper water, vessels are used to weld and install the pipelines or, in some rare occasions, the pipelines are constructed on land, moved into the water and towed to location.

TRANS-ALASKA PIPELINE SYSTEM

The Trans-Alaska Pipeline System (TAPS) transports all North Slope oil production from current fields, like Prudhoe Bay and Kuparuk, to the southern port of Valdez. From there, the oil is shipped by tankers to refineries on the U.S. West Coast. Construction on the 800-mile long, 48-inch diameter pipeline was started in 1975 and completed in 1977. It was considered an engineering and construction marvel, passing through extreme climates and environmentally sensitive areas.

Designed to transport up to 2.1 million barrels of crude oil daily, TAPS carried only about 700,000 barrels a day in 2008 due to production declines. There are opportunities to develop new onshore and offshore fields on the North Slope that could slow or even reverse that decline. Oil production from future developments may connect to TAPS to take advantage of the existing infrastructure.

Pipeline Operations

Pipeline systems are typically operated remotely from centralized control centers. These centers use state-of-the-art control and communications systems to monitor and control every aspect of the pipeline system, including starting and stopping pumps, opening and closing valves and monitoring temperatures, pressures and flow rates. Computers are also used to help monitor the systems and detect any early signs of abnormal conditions or events. If an irregularity is detected, support personnel are alerted to take appropriate action.

Pigging the Line

Pipelines are maintained and inspected using a “pig,” a tool that can be inserted in one end of the pipeline and pushed by the fluid to the other end. The most basic pigs are used to clean the inside of

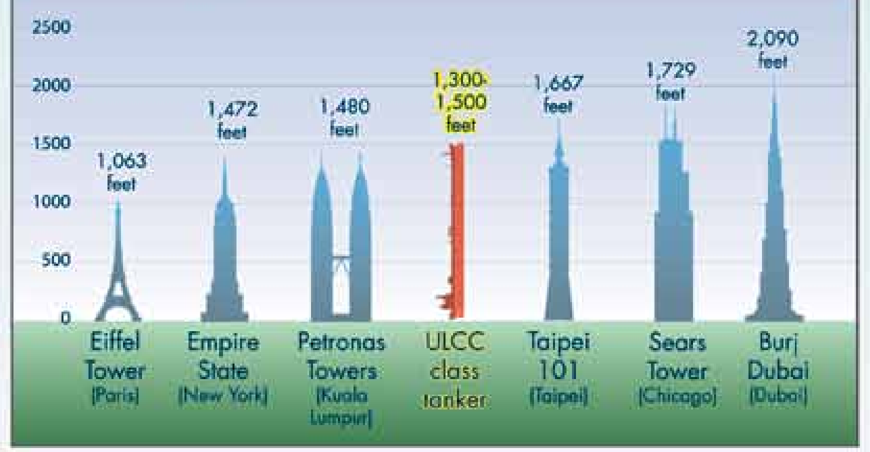
PIPELINE TECHNOLOGY AND OPERATIONS

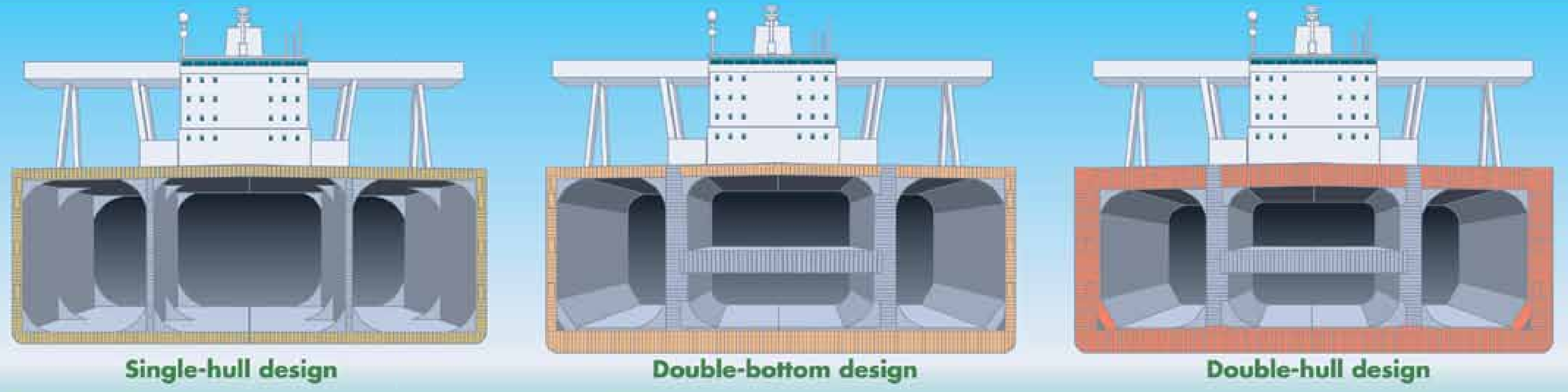
Objects are not shown to scale.

TANKER TECHNOLOGY

Tanker categories

Size comparison with well-known landmarks





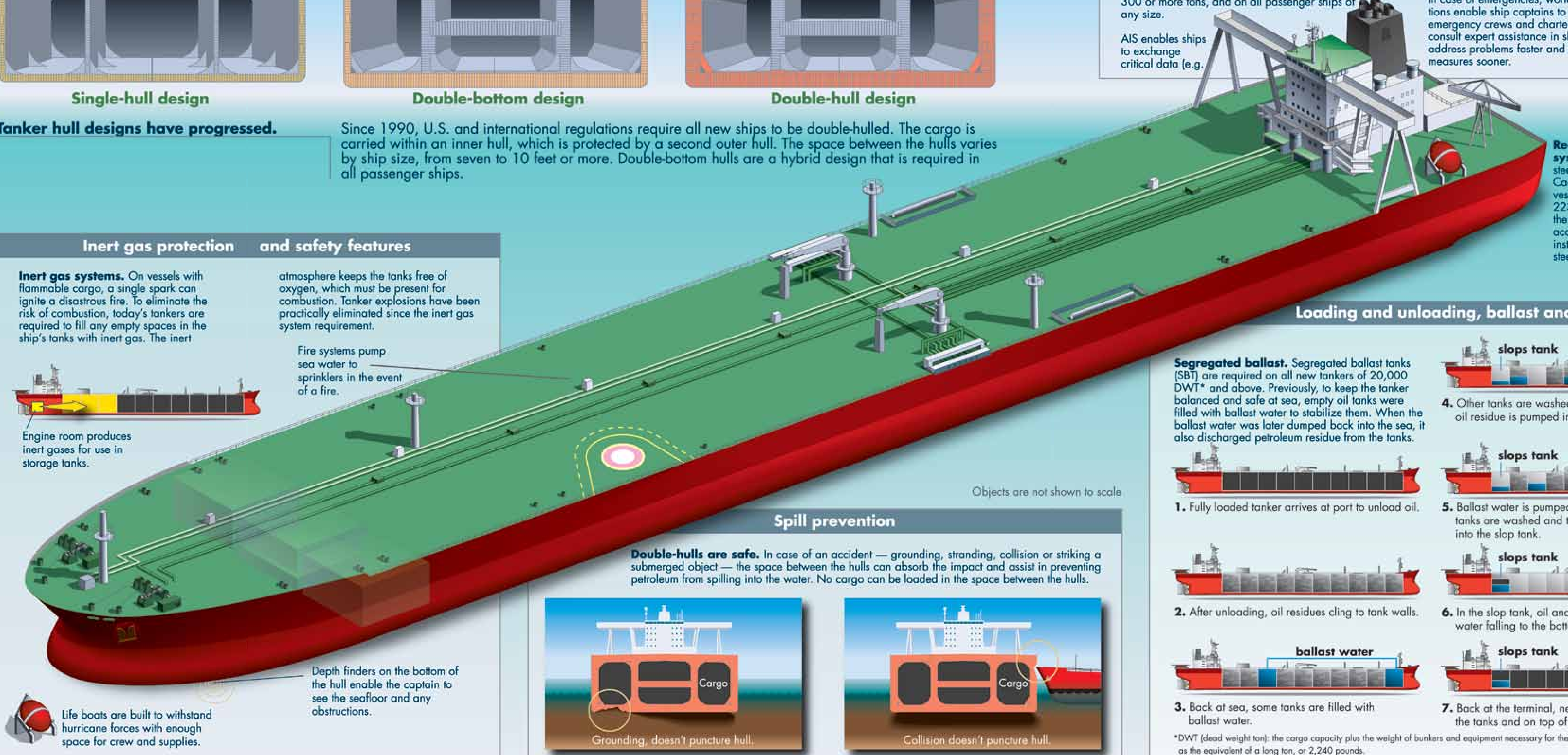
Tanker hull designs have progressed. Since 1990, U.S. and international regulations require all new ships to be double-hulled. The cargo is carried within an inner hull, which is protected by a second outer hull. The space between the hulls varies by ship size, from seven to 10 feet or more. Double-bottom hulls are a hybrid design that is required in all passenger ships.

Communications systems

Modern tanker communication systems rely on satellites, GPS and sophisticated electronics to maintain safety during maneuvers and navigation on the oceans and within coastal shipping lanes. For example, the Automatic Identification System (AIS) is now required on all vessels sailing international waters with gross tonnage (GT) of 300 or more tons, and on all passenger ships of any size.

AIS enables ships to exchange critical data (e.g. identification, position, course and speed) with other nearby ships, as well as with control stations at harbors and ports. This constant stream of information allows on-board crews and maritime authorities to monitor shipping lanes and coordinate vessel movements.

In case of emergencies, worldwide satellite communications enable ship captains to contact authorities, emergency crews and charters at any time. Able to consult expert assistance in short notice, crews can address problems faster and take preventative measures sooner.



Redundant steering systems. In 1978, the single steering system of the Amoco Cadiz failed, causing the vessel to run aground and spill 223,000 tons of crude oil off the coast of France. The accident led to the mandatory installation of back-up steering systems.

Inert gas protection and safety features

Inert gas systems. On vessels with flammable cargo, a single spark can ignite a disastrous fire. To eliminate the risk of combustion, today's tankers are required to fill any empty spaces in the ship's tanks with inert gas. The inert atmosphere keeps the tanks free of oxygen, which must be present for combustion. Tanker explosions have been practically eliminated since the inert gas system requirement.

Engine room produces inert gases for use in storage tanks.

Fire systems pump sea water to sprinklers in the event of a fire.

Depth finders on the bottom of the hull enable the captain to see the seafloor and any obstructions.

Life boats are built to withstand hurricane forces with enough space for crew and supplies.

Objects are not shown to scale

Spill prevention

Double-hulls are safe. In case of an accident — grounding, stranding, collision or striking a submerged object — the space between the hulls can absorb the impact and assist in preventing petroleum from spilling into the water. No cargo can be loaded in the space between the hulls.

Cargo

Grounding, doesn't puncture hull.

Cargo

Collision doesn't puncture hull.

Loading and unloading, ballast and cleaning

Segregated ballast. Segregated ballast tanks (SBT) are required on all new tankers of 20,000 DWT* and above. Previously, to keep the tanker balanced and safe at sea, empty oil tanks were filled with ballast water to stabilize them. When the ballast water was later dumped back into the sea, it also discharged petroleum residue from the tanks.

ballast water

slops tank

slops tank

slops tank

clean tanks

slops tank

full tanks

1. Fully loaded tanker arrives at port to unload oil.
2. After unloading, oil residues cling to tank walls.
3. Back at sea, some tanks are filled with ballast water.
4. Other tanks are washed. Wash water containing oil residue is pumped into a slop tank.
5. Ballast water is pumped into clean tanks; ballast tanks are washed and the wash water pumped into the slop tank.
6. In the slop tank, oil and water separates, with water falling to the bottom.
7. Back at the terminal, new oil cargo is loaded into the tanks and on top of the oil left in the slop tank.

*DWT (dead weight ton): the cargo capacity plus the weight of bunkers and equipment necessary for the ship's propulsion; also measured as the equivalent of a long ton, or 2,240 pounds.

the pipes; highly-complex "smart pigs" can inspect the condition and thickness of the pipeline.

Leak Detection

All pipelines are monitored with some kind of leak detection system. The most common method uses computers and software to assist the pipeline operator. One type, called "mass balance," measures the amount of oil going in the pipeline and the amount coming out. Another method called "real-time transient modeling" compares actual measured data with computer models. In both these methods, if the results are outside normal operating limits, an alarm alerts the operator to take appropriate action. New methods are also being developed that use equipment or sensors to supplement computer systems.

Tankers

Offshore pipelines are more expensive and difficult to build than onshore pipelines, and if the oil and gas field is small, it may be uneconomical to use them. In some areas, long distances or unstable seafloor conditions may make it impractical or impossible to lay pipelines. Instead, tankers can be used to transport the oil to shore. If liquefied using special processing equipment, natural gas can also be shipped in tankers from one port to another. Special regasification facilities at the receiving port then return the liquid to its gas form for cross-country shipment by pipeline.

FPSOs

Floating production storage and offloading (FPSOs) units are usually used in combination with tankers. Like other types of production platforms, FPSOs separate the oil, gas and water, and store the oil until tankers transport it to refineries. Gas from FPSOs is usually reinjected into the reservoir to produce later, or it is transported via pipeline to the shore for further processing and sales.

Tanker Capacities

New sources and rising demand for oil and gas during the last half of the 20th century meant shipping larger quantities for longer hauls. To make long-distance transportation more cost effective, producers also wanted to use the largest carriers the ports could manage. Ultimately, tanker manufacturers developed supertankers, or "very large crude carriers (VLCCs)," that measure up to four football fields in length.

Innovations have made larger tankers more fuel efficient than smaller vessels. Though it requires more energy to power a larger ship, it takes less power to deliver each barrel of oil at the same speed. For example, 16,000 horsepower are needed to drive a 420,000-barrel ship, but 42,500 horsepower can propel a 1,820,000-barrel tanker. That's more than four times the cargo moved with only 2.5 times the power requirement.

Oil tankers are divided into six major categories based on how much they can carry. Cargo capacity is measured in dead weight tons (DWT) a unit that equals 2,240 pounds. Ultra-large crude carriers (ULCCs) and VLCCs are the largest vessels and can carry 200,000 DWT or more for long hauls. The mid-size Suezmax and Aframax tankers ship cargos of 120,000 to 200,000 DWT and travel both long and medium distances. The smallest vessels are Handysize and Panamax tankers, typically used for short hauls with cargos of 10,000 to 80,000 DWT.

Transport Safety

Safety measures have seen significant advances, including safe tank venting, sophisticated engine room control systems and satellite navigation. One of the most important changes is the double-hull design, a spill prevention measure that became mandatory in the early 1990s following the Exxon Valdez oil spill. All single-hulled tankers will be phased out worldwide by 2015.

Glossary

Barrel – 42 U.S. gallons.

Crude Oil – The basic raw material pumped from the earth. There are many different grades of crude, each containing various vapors, liquids and solids. This crude is changed at a refinery into products.

Hydrocarbons – organic chemical compounds of hydrogen and carbon atoms forming the basis of all petroleum products. They may exist as gases, liquids or solids. An example of each is methane, hexane and asphalt. For this document the terms "hydrocarbons," "petroleum" and "oil and gas" are interchangeable.

Mass balance – A leak detection method that measures the amount of oil going in the pipeline and the amount coming out and then compares that to a rate generated by computer modeling. If the actual rate differs from the computer modeling rate, an alarm alerts the operator to take appropriate action.

Petroleum – a substance occurring naturally in the earth in solid, liquid, or gaseous state and composed mainly of mixtures of chemical compounds of carbon and hydrogen, with or without other nonmetallic elements such as sulfur, oxygen and nitrogen. In some cases, especially in the measurement of oil and gas, petroleum refers only to oil — a liquid hydrocarbon — and does not include natural gas or gas liquids such as propane and butane. For this document the terms "hydrocarbons," "petroleum" and "oil and gas" are interchangeable.

Pig Traps – This device, also know as scaper traps or launchers or receivers, is where pigs are inserted or removed from the system. After its insertion and after normal flow of oil and gas is restored, fluids carry the pig through the pipeline.

Pipeline System – All parts of the physical facilities through which oil is transported, including line pipe, valves, pumping units, metering stations and tanks.

Strudel Scour – The formation on the seafloor caused during the spring melt, when rivers overflow existing ice. Cracks and seal breathing holes allow the water to flow through the ice, causing a circular draining action that can scour the seafloor and create unsafe conditions for pipelines.

Smart Pig – An electronic internal inspection device placed inside the pipeline to provide data about the condition of the pipeline, such as measuring dents or locating corrosion.

Trunk Line – A main pipeline.

ULCC (Tanker) – ultra-large capacity carrier.

VLCC (Tanker) – very large capacity carrier

Sources

- ABS (www.eagle.org)
- Association of Oil Pipelines
- Energy Information Agency (US Department of Energy)
- General Maritime Corporation
- Natural Gas Supply Association
- Occupational Safety & Health Administration
- Pacific L.A. Marine Terminal LLC (www.pacificenergypier400.com)
- Schlumberger Oilfield Services
- Society of Petroleum Engineers
- State of Alaska Dept. of Natural Resources Division of Oil and Gas
- The Learning Space (http://openlearn.open.ac.uk)
- The National Ocean Industries Association
- United States Maritime Administration

Shell in Alaska

TO FIND AND DEVELOP COMMERCIAL HYDROCARBON RESOURCES IN THE CHUKCHI AND BEAUFORT OUTER CONTINENTAL SHELF. TO SUPPORT COMMUNITIES WHERE WE OPERATE IN BENEFITING FROM ANY POTENTIAL OFFSHORE ACTIVITIES ECONOMICALLY AND SOCIALLY. TO RESPECT THE WAY OF LIFE OF THE RESIDENTS OF ALASKA.