เอกสารประกอบการสอนรายวิชา 534203 อุตสาหกรรมปิโตรเลียม (Petroleum Industry)

โดย

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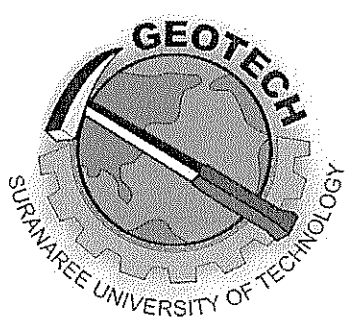
สาขาวิชาเทคโนโลยีธรณี

สำนักวิชาวิศวกรรมศาสตร์

มหาวิทยาลัยเทคโนโลยีสุรนารี



534203 Petroleum Industry
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Dr. Bantita Terakulsatit

Chapter 1

Introduction

Prerequisite: None

Basic technique of petroleum exploration, drilling & production wells including methodology of production process, production efficiency distillation, transportation and marketing of crude oil and natural gas

Course Contents

1. **Introduction**
2. **Petroleum geology**
   - Basic concepts
   - Petroleum system
   - Reservoir fluids
   - Reservoir pressure
3. **Petroleum exploration**
   - Surface geographic studies
   - Data collection
   - Geophysical surveys
   - Reservoir development tools

Course Contents

4. **Drilling operation (9 hrs)**
   - Development of drilling for oil
   - Drilling contracts
   - Rotary drilling systems
   - Routine drilling operations
   - Development of offshore drilling
   - Mobile offshore drilling units
   - Offshore drilling plate forms
   - Directional drilling
   - Fishing
   - Air and gas drilling

Mid Term Exam

Course Contents

5. Petroleum Production

Early production methods
Well completion
Well testing
Reservoir stimulation
Reservoir drive mechanisms
Artificial lift
Improved recovery techniques
Surface handing of well fluids
Measuring and testing oil and gas
Well servicing and testing oil and gas
Offshore and arctic production

Course Contents

6. Transportation

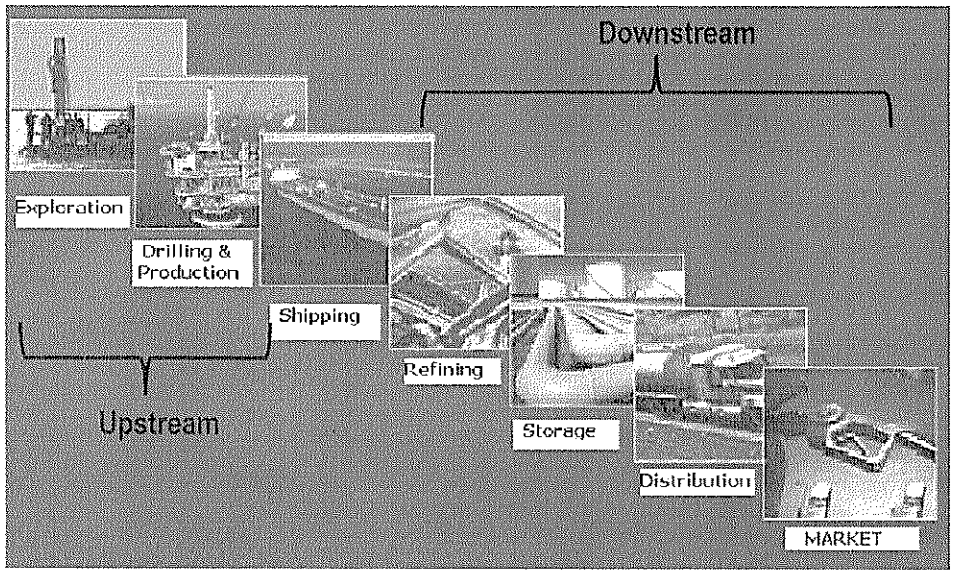
- Onshore
- Offshore
- Pipeline
  - Production pipeline
  - Natural gas pipeline
  - Pipeline construction

7. Petroleum Refinery

8. Petroleum Marketing

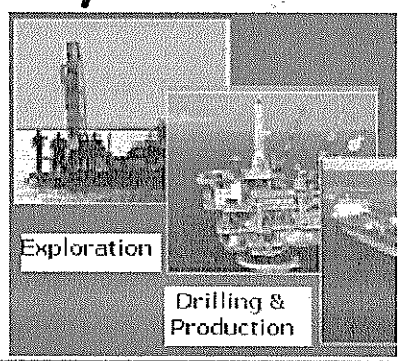
Final Exam

Petroleum Industry Functions

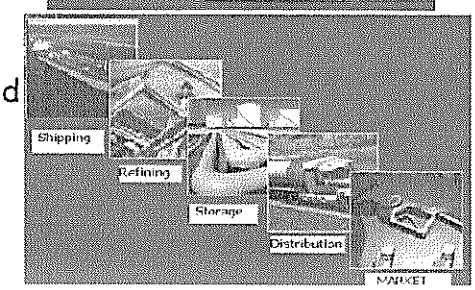


Petroleum Industry Functions

1. **Upstream**
   - Exploration
   - Development Drilling and Production

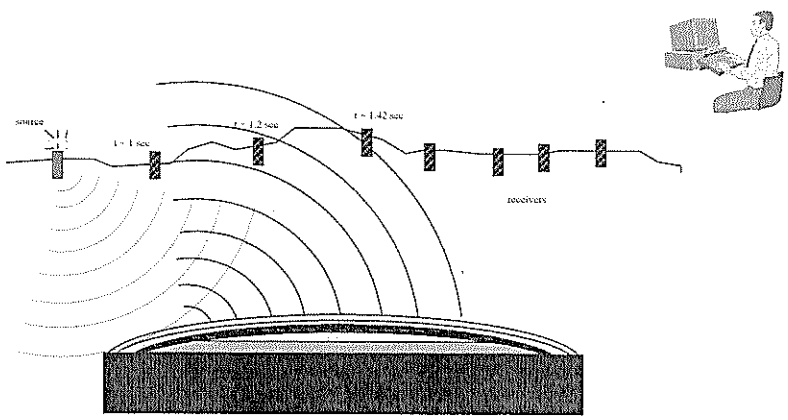


2. **Downstream**
   - Crude Oil Transportation and Storage
   - Refining and Petrochemical
   - Product Distribution and Marketing

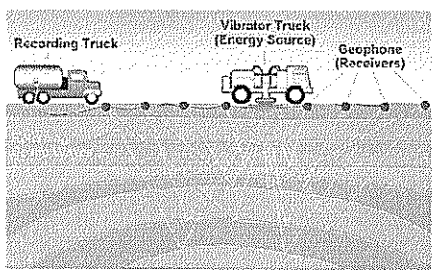


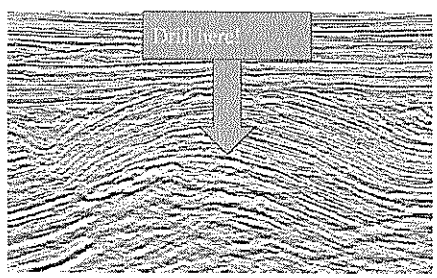
How do we find the oil reservoirs?

- Geophysicists find reservoirs by bouncing sound waves off them, and timing how long it takes for the sound to come back
- Computers process the data to construct pictures of what the earth looks like underground.



Seismic Surveys

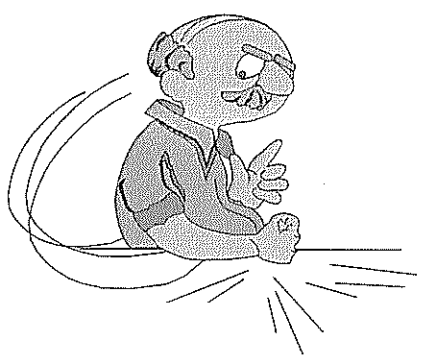




- Seismic surveys are used to locate likely rock structures underground in which oil and gas might be found
- Shock waves are fired into the ground. These bounce off layers of rock and reveal any structural domes that might contain oil

What do we do after we find a reservoir?

We Drill Into It ! ! !

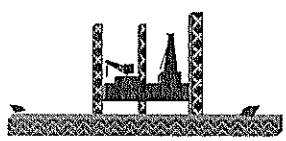


What do we drill with ?

A Drilling Rig !

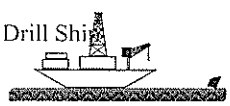
Here are a few different types of drilling rigs available:

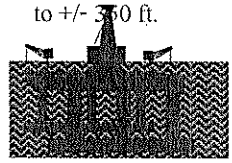
For drilling on land.



Jackup Rig
For drilling in water depths from 15 ft to +/- 350 ft.

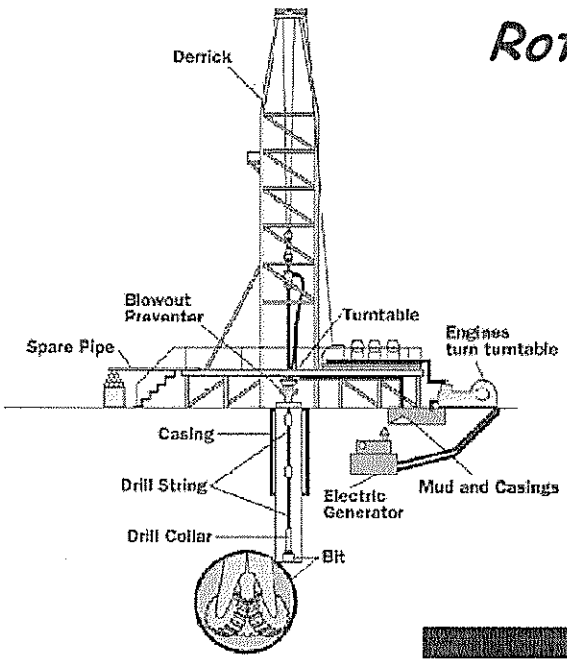
For drilling in water depths from 8 to 30 ft.





Semi-Submersible Rig

Drill ships and semi-submersible rigs are for drilling in water depths from 100 to 5000+ ft.

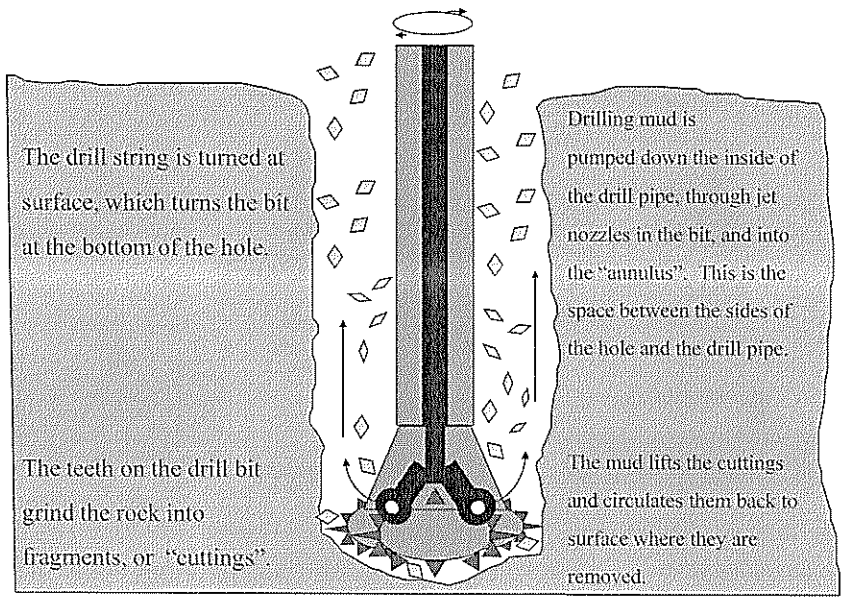


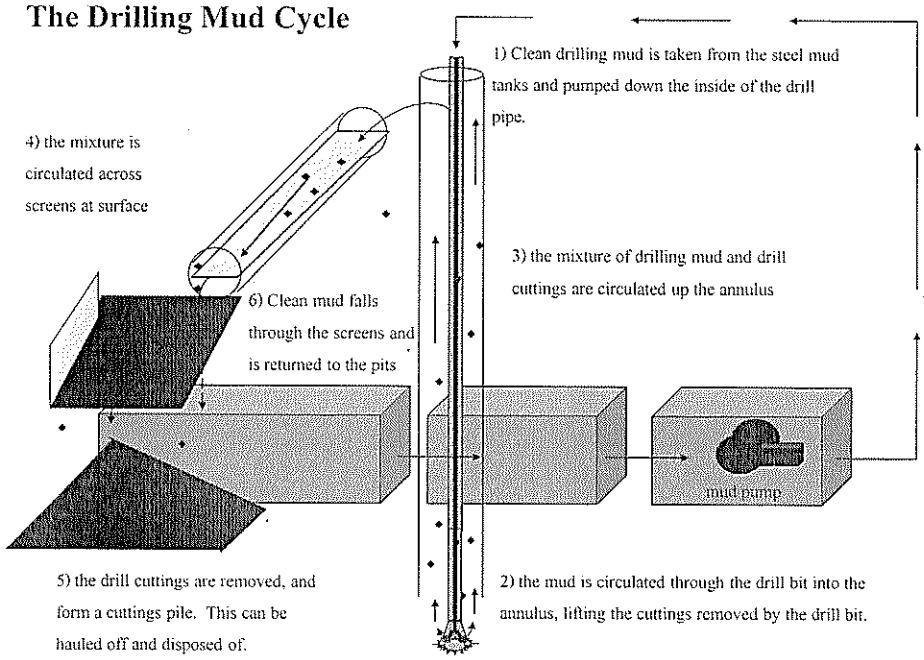
Anatomy of an oil rig

Rotation Drilling Systems

1. Power System
2. Hoisting System
3. Rotating System
4. Circulation (mud) Sys.
5. Well control system
6. Well monitoring system

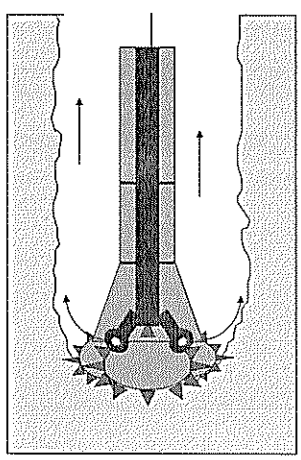
Here's a picture of the drill bit drilling the rock.



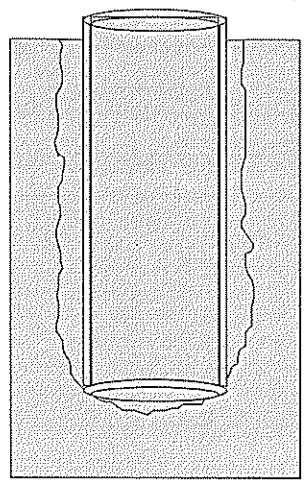


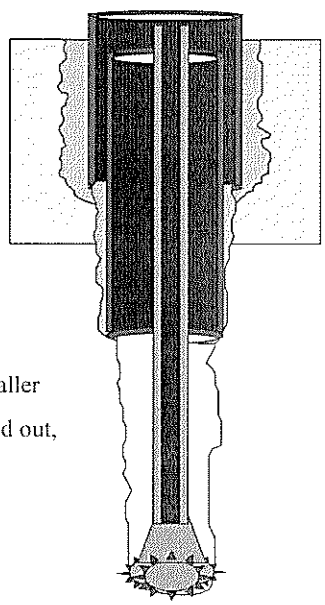
Here's a sequence showing how holes are drilled,

First, a large drill bit is used to drill a short interval of hole.

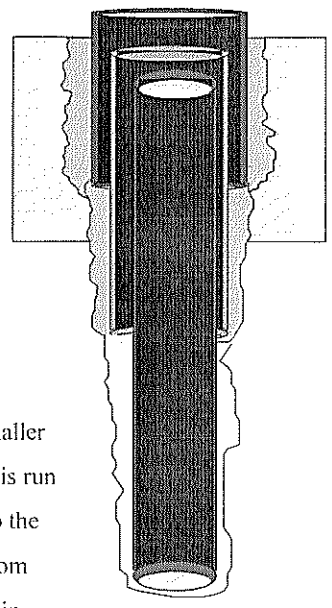


Then, steel casing is run and cemented on the outside to keep the hole from collapsing.



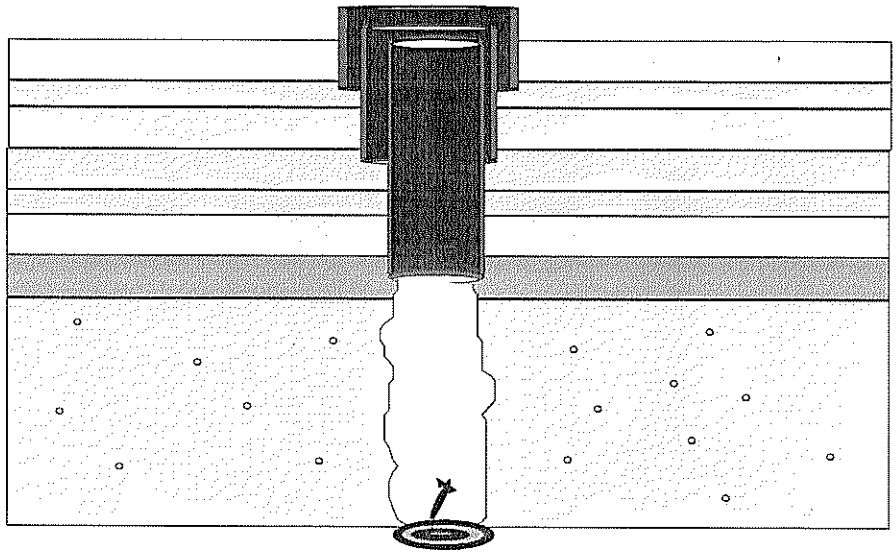


Again, a smaller hole is drilled out,



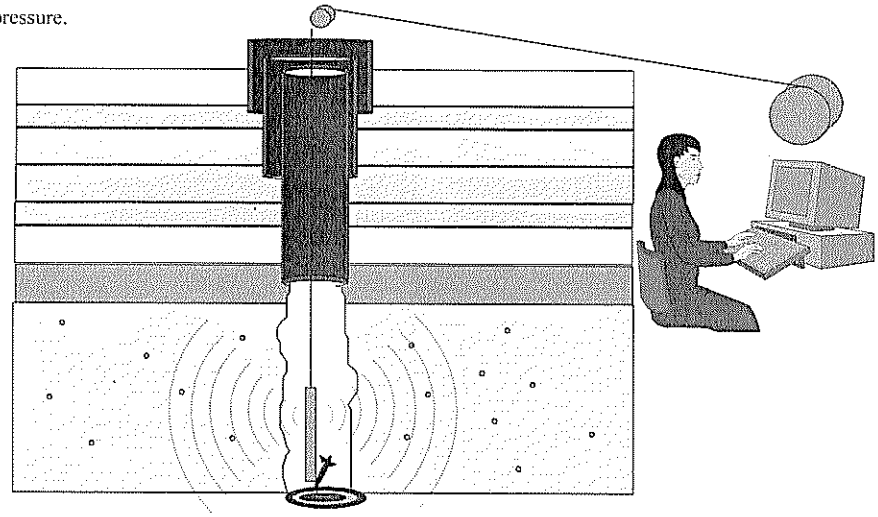
and smaller casing is run to keep the hole from falling in.

In this way, the hole is drilled in stages, until the target reservoir rock is penetrated. At this point, the geologists must figure out if there is oil or gas in it.

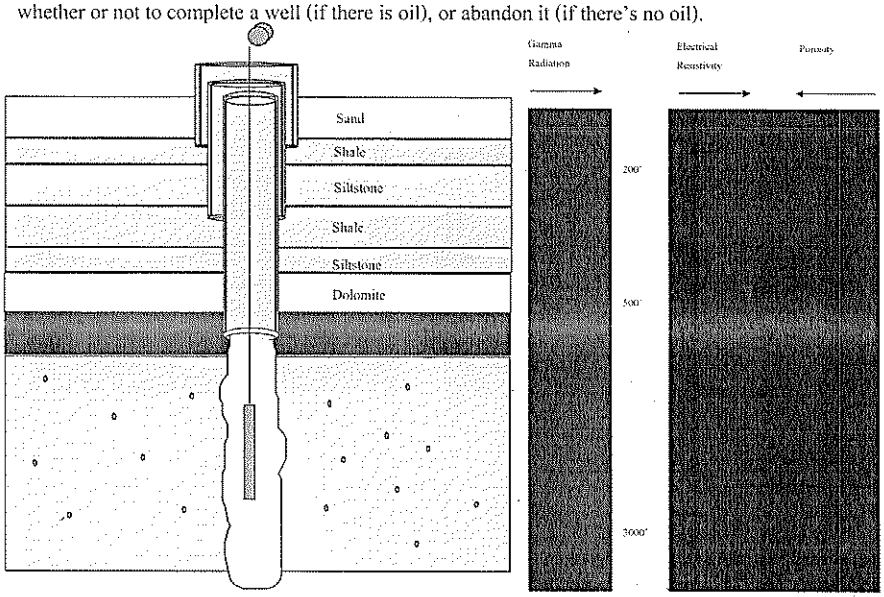


How do Geologists tell if the reservoir has oil or gas?

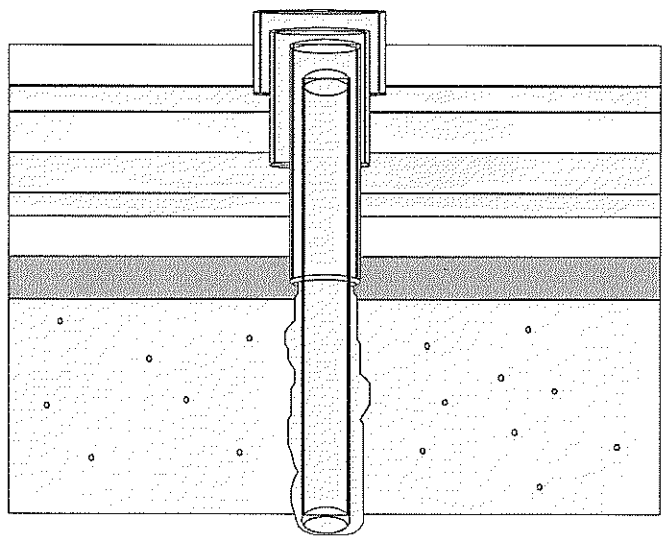
They do this by running logs across the zone. Logs are tools run on electric cable ("wireline") which record the physical properties in the rock such as resistivity, porosity, density, radioactivity, and pore pressure.



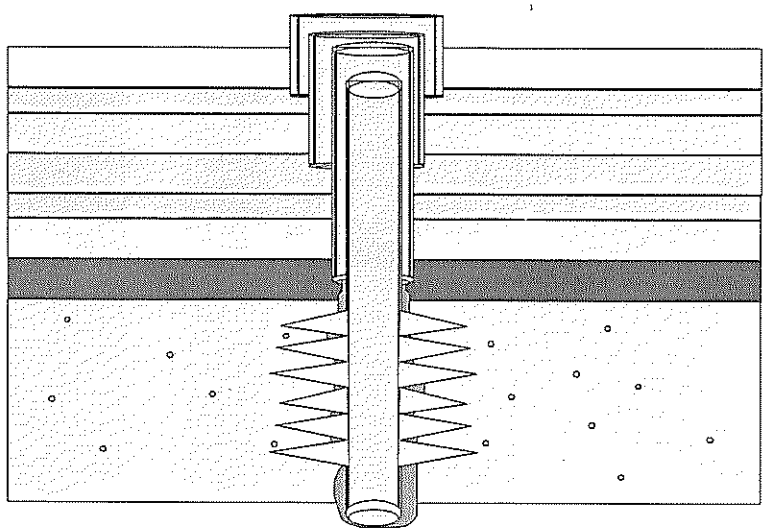
Here's an example of what a log looks like. Geologists look at logs to decide whether or not to complete a well (if there is oil), or abandon it (if there's no oil).



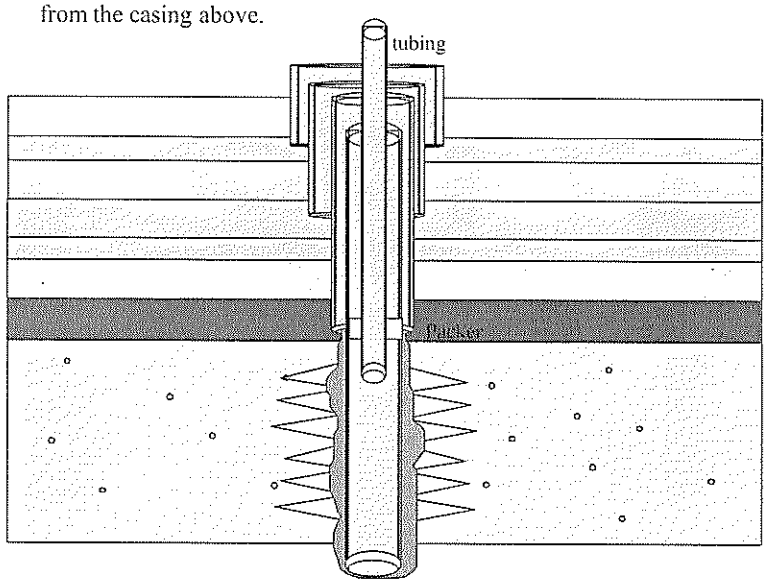
If the well looks good on the logs, we run a final string of casing across the production zone, and cement it in place.



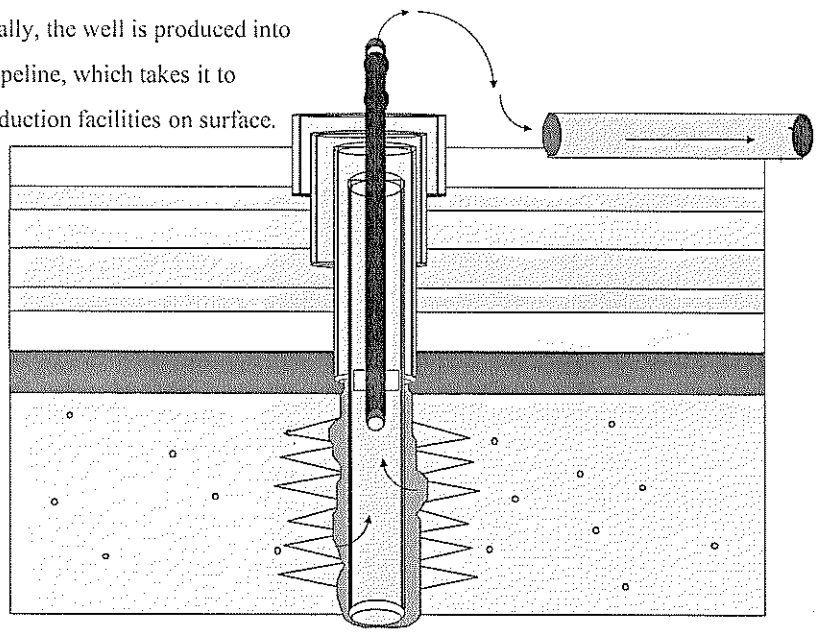
Then, we run perforating guns in the hole and perforate (shoot holes) in the casing across the productive zone.



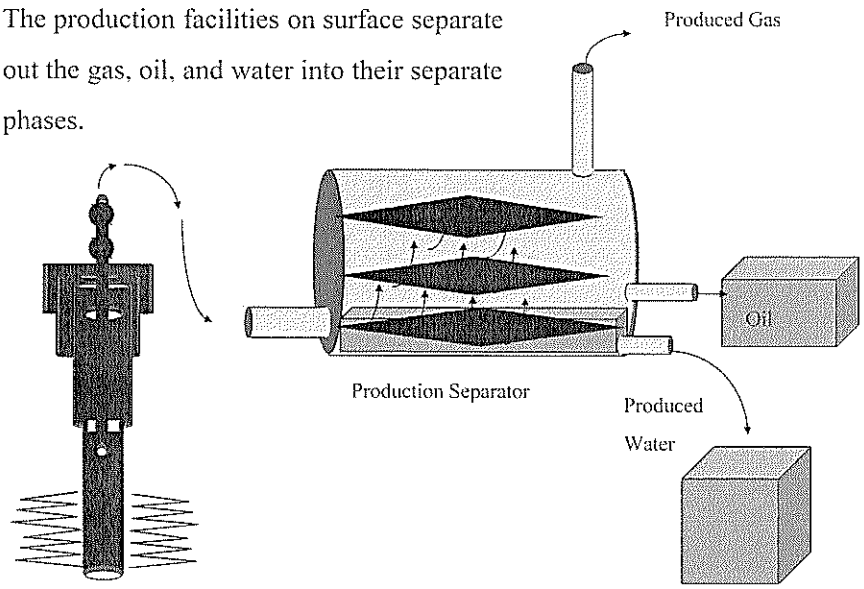
Production tubing is run, with a packer to isolate the produced zone from the casing above.



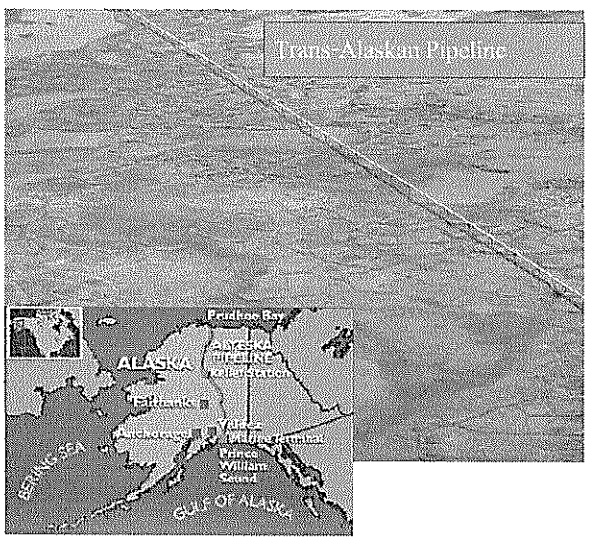
Finally, the well is produced into a pipeline, which takes it to production facilities on surface.



The production facilities on surface separate out the gas, oil, and water into their separate phases.



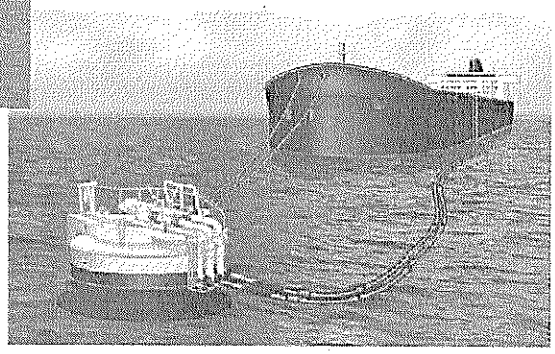
Transportation



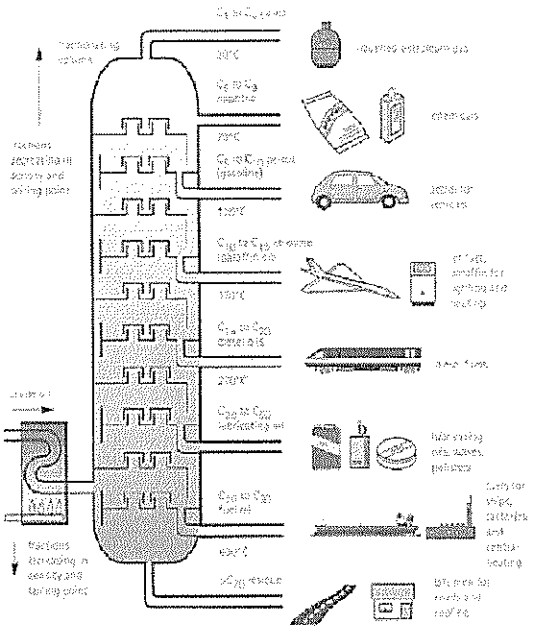
- Once extracted oil and gas must be sent to a refinery for processing
- Pipelines transport most of the world's oil from well to refinery
- Massive Oil Tankers also play an important role in distribution

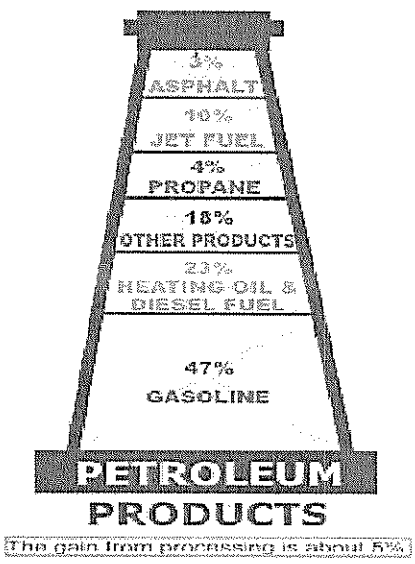
Floating Storage and Offloading Unit (FSO)

- Knock Nevis at Persian Gulf

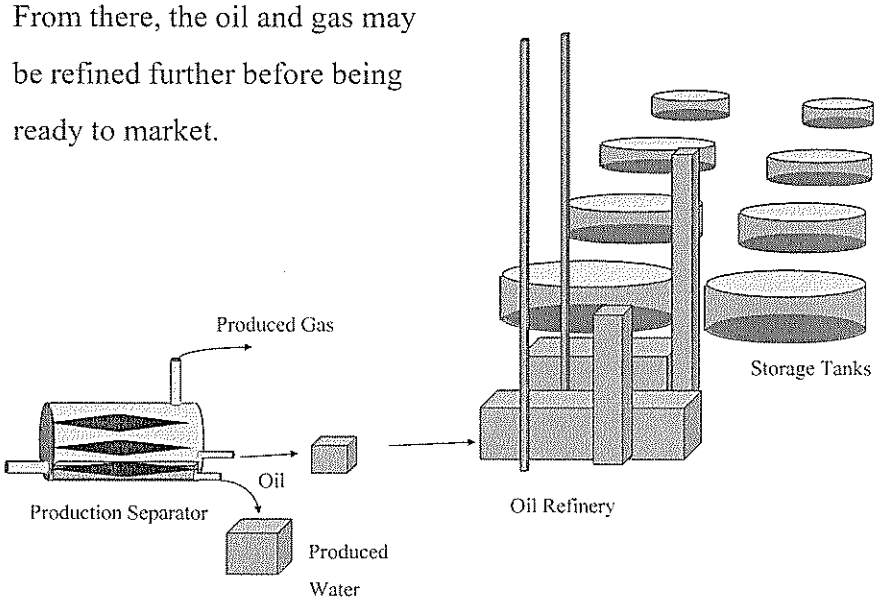


Refinery



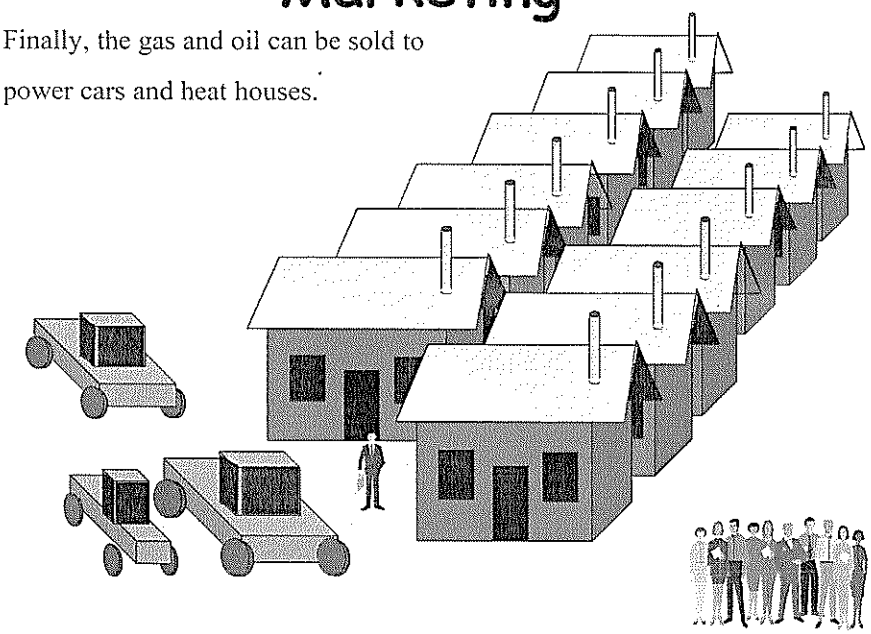


From there, the oil and gas may be refined further before being ready to market.

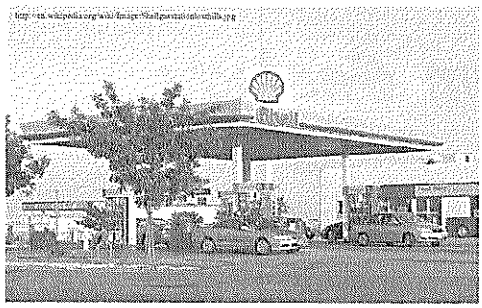


Marketing

Finally, the gas and oil can be sold to power cars and heat houses.



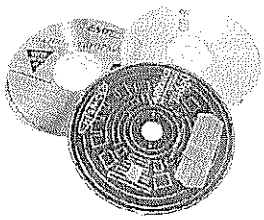
Marketing: Fuel source



- Demand is ever increasing, especially due to growth of Chinese economy

- 84% of crude oil is refined into fuel, principally for cars and planes

Marketing: Other uses



CDs and DVDs

Plastic

Fertilizers and Pesticides

Food additives

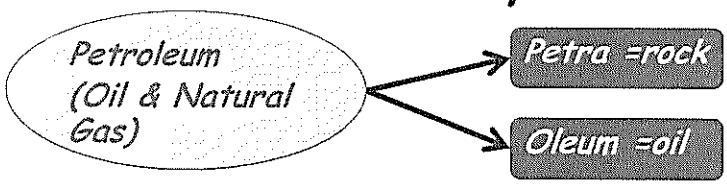
- The remaining 16% of crude oil is used for a range of purposes shown above as well as synthetic fibres, dyes and detergents

Chapter 2
Petroleum Geology

Course Contents

- Basic concepts
- Petroleum system
- Reservoir fluids
- Reservoir pressure

What is petroleum?



Rock oil or crude oil is a naturally occurring, flammable liquid consisting of a complex mixture of hydrocarbons of various molecular weights, and other organic compounds, that are found in geologic formations beneath the earth's surface.

- *Hydrocarbons* composition (mostly H, C (>75%), minor of S, N, O)

1. Gas
   - Natural Gas
   - Condensate
2. Liquids
   - Oil, Crude oil
3. Solids
   - Coal
   - Kerogen- Insoluble in organic solvents
   - Bitumen-Soluble
   - Plastic
     - Asphalt, Tar

Classification of Hydrocarbon

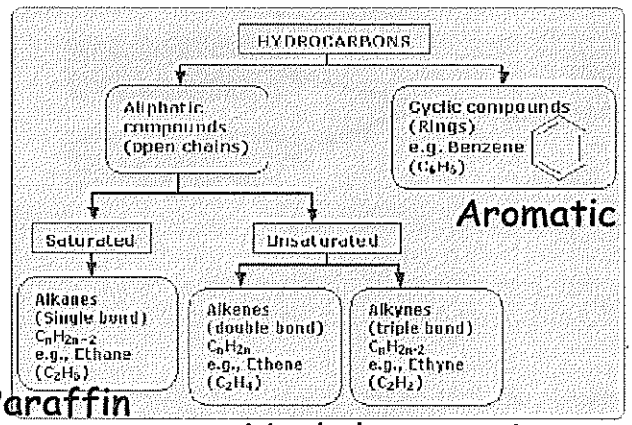
There are 3 series of hydrocarbon

1) Paraffin or methane series: $[C_n H_{2n+2}]$: Alkanes

2) Naphthene or cycloparaffin series: $[C_n H_{2n}]$ Alkenes & $[C_n H_{2n-2}]$ Alkynes

3) Aromatic or Benzene series; Mostly found in general crude oil $[C_n H_n]$

Classification of Hydrocarbon

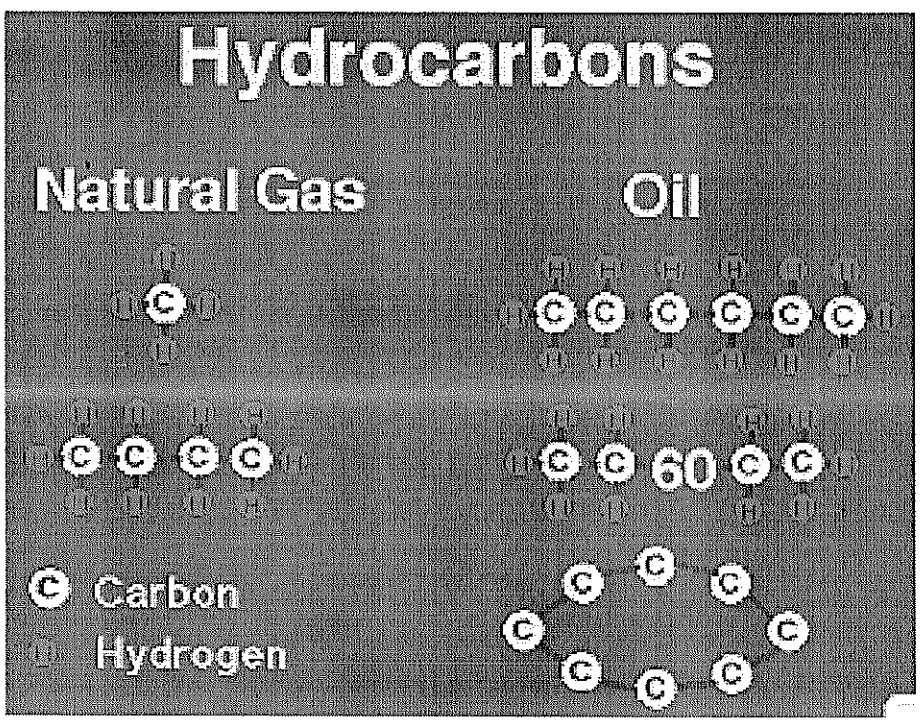


Aromatic series

Paraffin (Methane series)

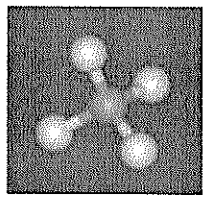
Naphthene series

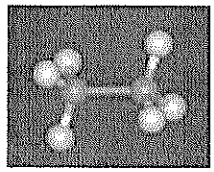
	Alkanes	Alkenes	Alkynes
General formula	C_nH_{2n+2}	C_nH_{2n}	C_nH_{2n-2}
Naming	All the members end with 'ane'	All the members end with 'ene'	All the members end with 'yne'

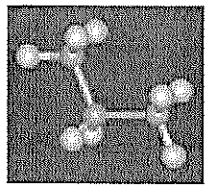


Natural Gas

- Paraffins (Alkanes)
- Saturated Chains


Methane


Ethane


Propane

Properties of Oil

	Vol%	API	Density g/cm3	Viscosity millipoise
Gasoline (C5-C10)	27%	60	0.74	6
Kerosene (C11-C13)	13%	50	0.79	20
Diesel (C14-C18)	12%	45	0.79	100
Heavy Gas Oil (C19-C25)	10%			
Lubicating Oil (C26-C40)	20%	30	0.85	500
Residual (>C40)	18%	10	1	10^5

- **Light Oil**: Used for gasoline, benzene, and aviation fuel.
- **Medium Oil**: Used for kerosene, diesel fuel, jet fuel, and power plants
- **Heavy Oil**: Used for fuel oil for ships and power plants

Origin Of Petroleum Theory

There are Two theory:

1. Inorganic (Igneous and metamorphic rocks)
2. Organic matter (sedimentary rock)

1. The Inorganic Theory

- Material left over from the formation of the solar system or was formed into petroleum later within the depths of the earth.
- The petroleum generated from an igneous and metamorphic rocks

Origin Of Petroleum Theory

2. The Organic Theory

- Oil and gas formed from remains of plants and animals
- Organisms that lived in rivers and seas subsequently died and became trapped in seafloor
- They were unable to decay normally because of a lack of oxygen or had a quick burial
- Sediment deposited over organic matter trapped it in the seafloor
- Increasing pressure from continued sedimentary deposits, high heat, chemical reactions and other forces transformed organic matter into oil and gas

Which Theory does most accept?

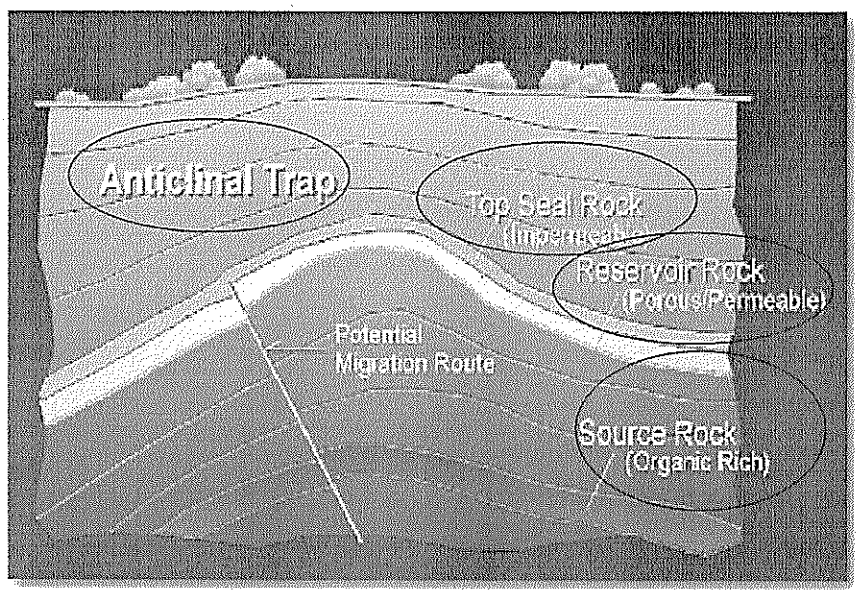
Most exploration today is based on the **Organic Theory.**

- 99.9% of oil in sedimentary basins (not in igneous or metamorphic rocks)
- 99% in rocks younger than 400 million yrs
- Bituminous shales can be heated up to produce oil
- Analogous to coal (which contains plant fossils)
- Crude oil contains many biomarkers
- $^{13}C/^{12}C$ is typical of biological activity (enriched in ^{12}C)

Concept of Petroleum Origin

- ✓ **Source Rocks** (any carbon bearing element such as plants or marine plankton)
  - ➢ **Burial or Accumulation** of organic matter (The generation of petroleum from a source rock is controlled by *temperature*)
  - ➢ **Maturation** (Oil Kitchen: enough heat and pressure)
  - ➢ **Migration** (movement of the hydrocarbon from deep in the subsurface to shallow)
- ✓ **Reservoir Rocks** (a porous sedimentary rock in which the liquid or gas hydrocarbon can be held)
- ✓ **Trap and Seal Rocks** (something preventing the hydrocarbon from leaking out)

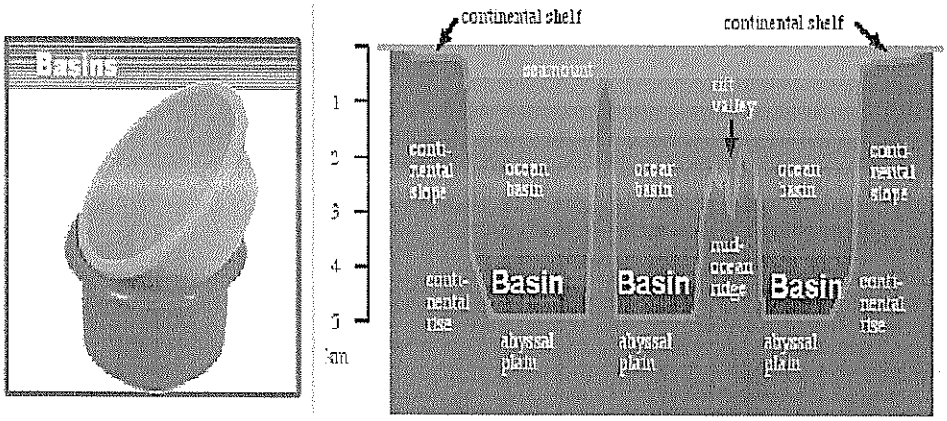
Concept of Petroleum Origin



Petroleum—Where is it found?

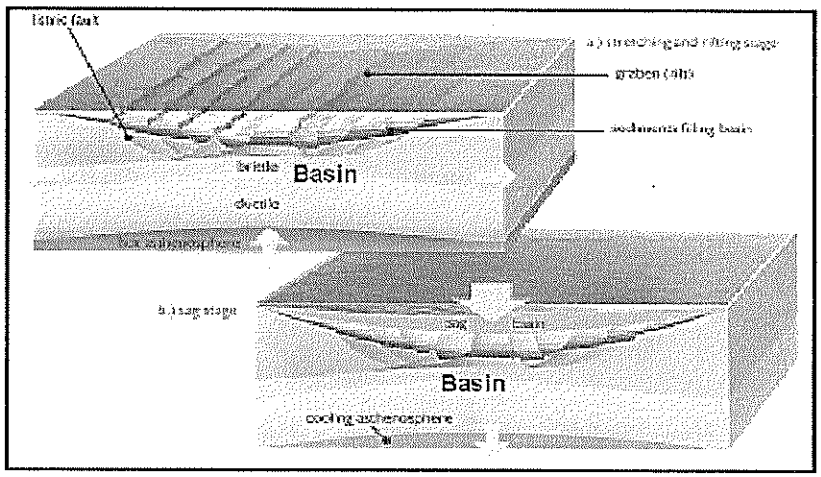
Basins are containers for sediment

Earth's basins contain sedimentary rocks, air, or water



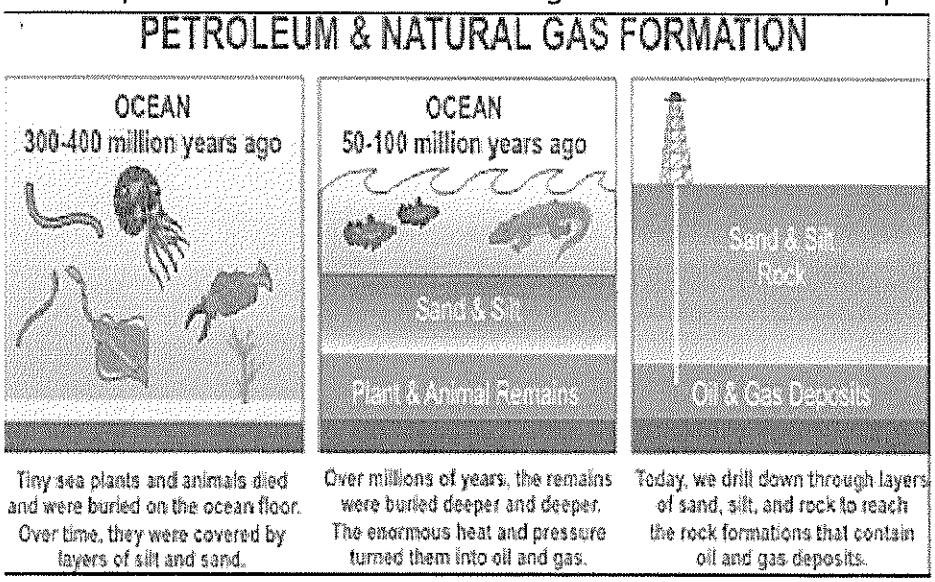
Basins: Forces that shape the earth's crust

Basins form in response to subsidence of the crust and grow due "loading" of sediment deposited in them

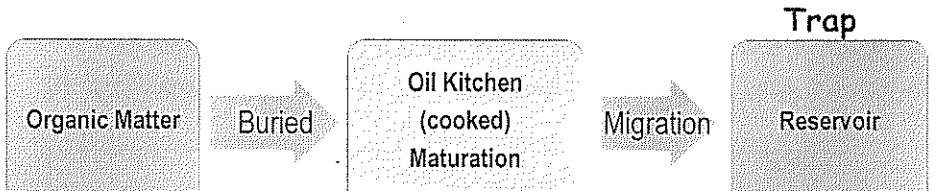


Origin of Petroleum

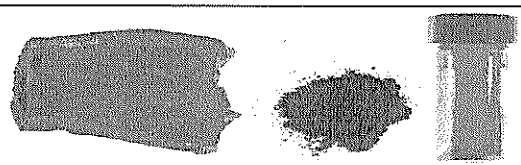
Development of the oil and natural gas shown in three steps



Petroleum Generation and Accumulation

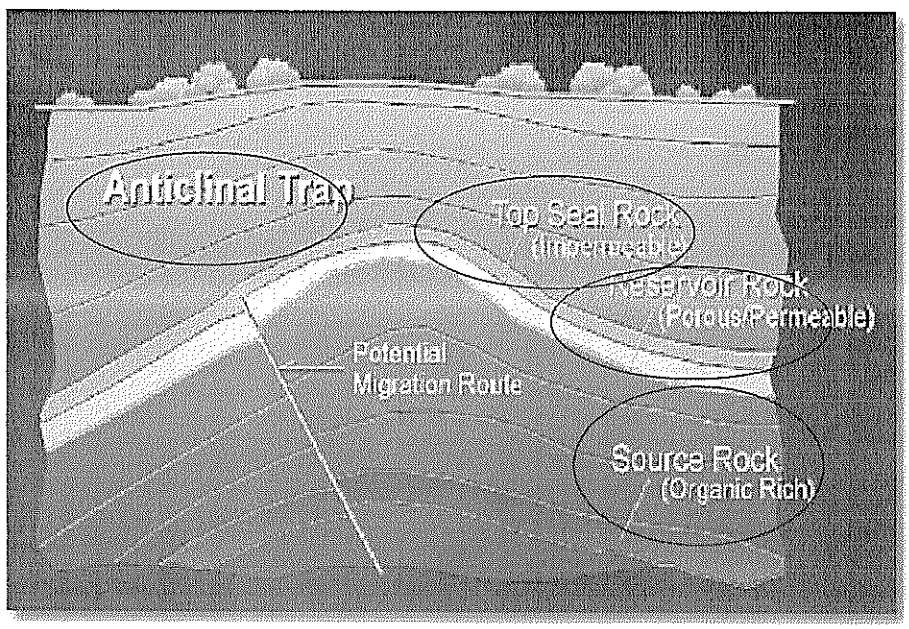


Source Rocks	Oil Kitchen	Migration	Reservoir Rocks
Shale	Time	Compaction	Sandstone
Carbonate	Temperature	Buoyancy	Carbonates



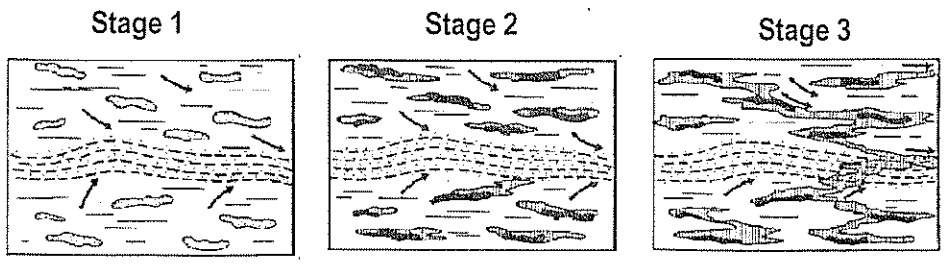
Organic-rich Source Rock ⇨ Thermally Matured Organic Matter ⇨ Oil

Concept of Petroleum Origin



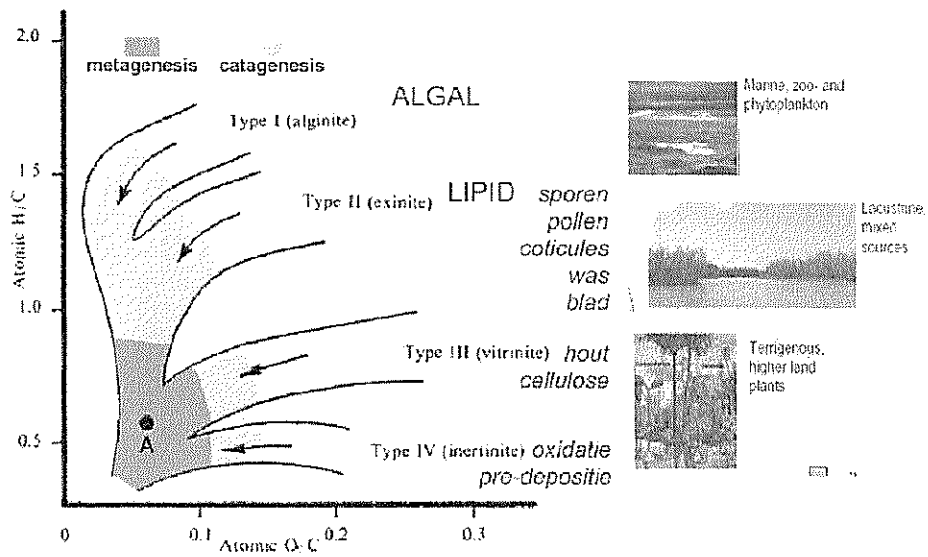
Kerogen

Kerogen: Complex organic molecules that are produced by modification of organic matter preserved in sediments. When heated, this solid waxy organic substance can produce coal macerals, oil and gas.



Kerogen Transformation

Kerogen Type



Van Krevelen diagrams are a graphical-statistical method that cross-plots the O/C and H/C ratios of

Kerogen vs. Petroleum Types

Kerogen Type	H/C ratio	O/C ratio	Origin material	Petroleum products
Type I	1.7-0.3	0.1-0.02	Algae in lacustrine and/or lagoonal environments,	Light, high quality oil and some natural gas
Type II	1.4-0.3	0.2-0.02	Mixture of plant debris and marine microorganisms	Main source of crude oil and some natural gas
Type III	1.0-0.3	0.4-0.02	Land plants in coaly sediments	Mainly natural gas with very little oil
Type IV	0.45-0.3	0.3-0.02	Oxidized and charred wood	No petroleum

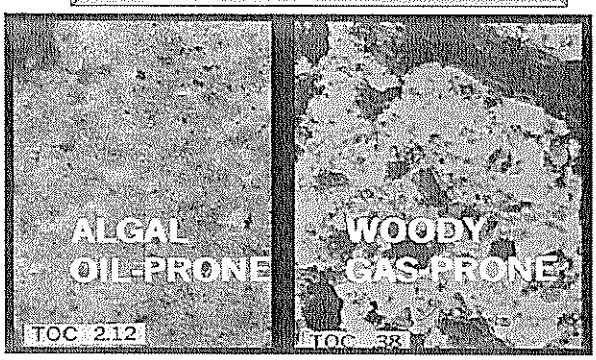
Types of Petroleum

Oil and gas are formed by the thermal cracking of organic compounds buried in fine-grained rocks

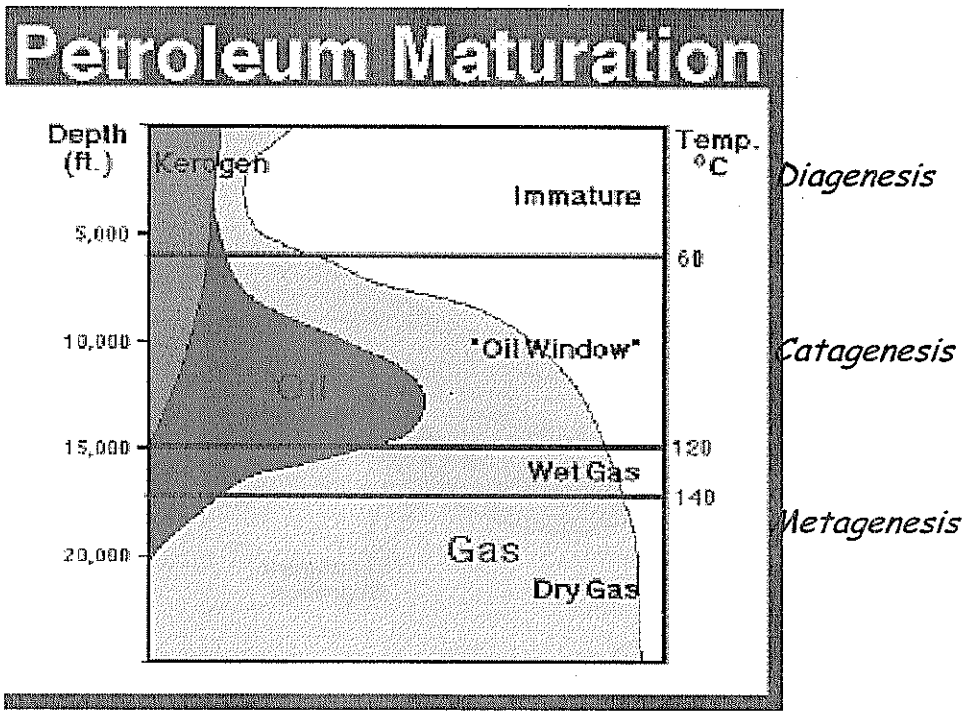
Algae = Hydrogen rich = Oil-prone

Wood = Hydrogen poor = Gas-prone

TOC 2.12 WT.%



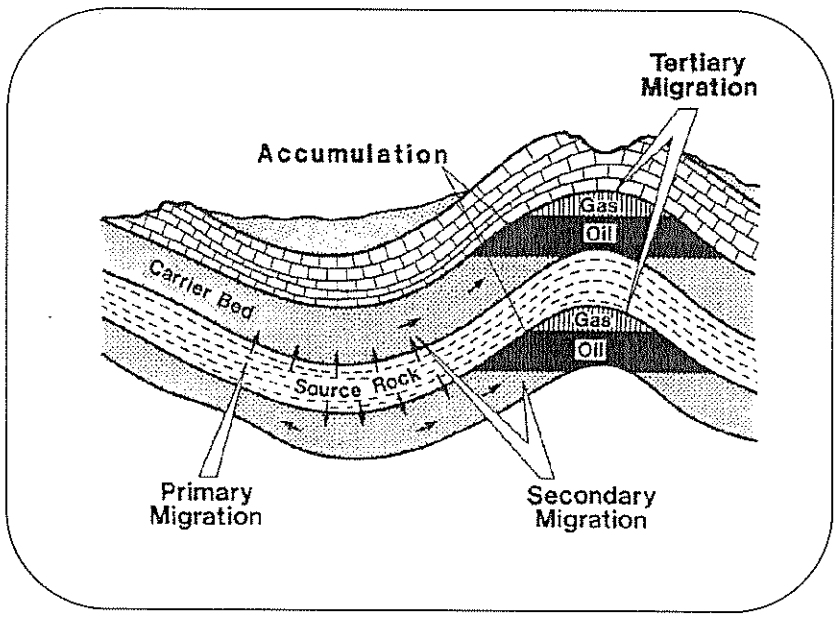
TOC .38 WT.%



Three Stages of Genesis:

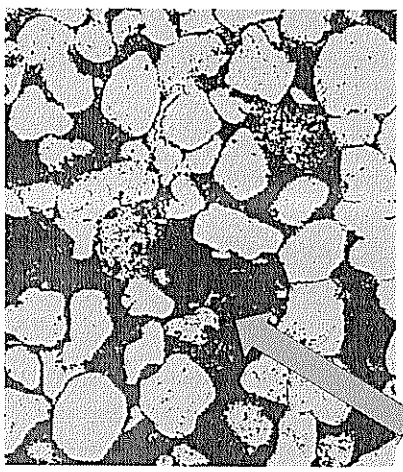
1. *Diagenesis*. Biogenic decomposition produces *biogenic methane*. At slightly higher temperatures and pressures the organic matter is converted to *kerogen* - an amorphous material of carbon, hydrogen, and oxygen. (< 60°C , few hundred feet depth; "heavy" oil)
2. *Catagenesis*. At higher temperatures and pressures kerogen is altered and the majority of *crude oil* is formed. During this phase and the next, the larger molecules break down into simpler molecules (a process called *cracking*). (60-140°C, > 5000 ft – kerogen and "light" petroleum)
3. *Metagenesis*. In the final stage of alteration (at higher temperatures and pressures) of kerogen and **crude oil**, *natural gas* (**mostly** *methane* is formed.(>140°C gas , depth >15000 ft)

Petroleum Migration



Reservoir Rock

Petroleum deposits are called reservoirs which are permeability and porosity of rock.

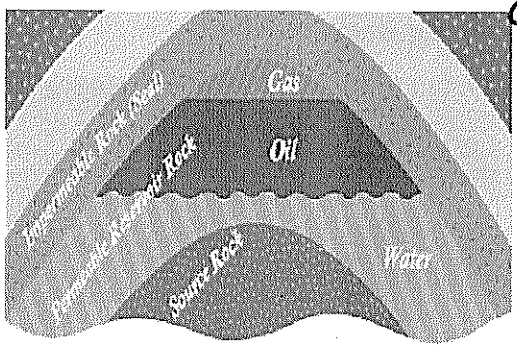


- The permeable (porosity& permeability) strata in an oil trap is known as the Reservoir Rock

- Reservoir rocks have lots of interconnected holes called pores. These absorb the oil and gas like a sponge

As oil migrates it fills up the pores (oil-filled pores shown in black)

Requirements for Reservoir Rocks



- ✓ High Porosity (>10%)
- ✓ High Permeability
- ✓ Great thickness (>10 ft.)
- ✓ Good lateral continuity and cover wide area

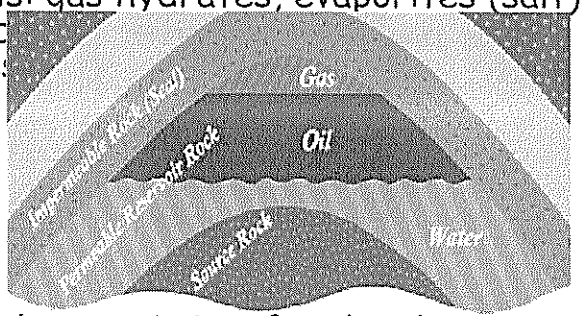
Common reservoir rocks

- Sandstone (about 50%)
  - High primary porosity, normally in the range of 20-40%
  - Coarse grained, well sorted
- Carbonate (Limestone and dolomite) (about 30%)
  - Low to moderate primary porosity
  - High secondary porosity

Seals or cap rocks

Seals or cap rocks: a unit with low permeability that impedes the escape of hydrocarbons from the reservoir rock

- –Regional seal (determines migration pathway)
- –Local seal (seals the trap)
- –Best seals: gas hydrates, evaporites (salt), organic ric carbonate



Important characteristics of seal rocks:

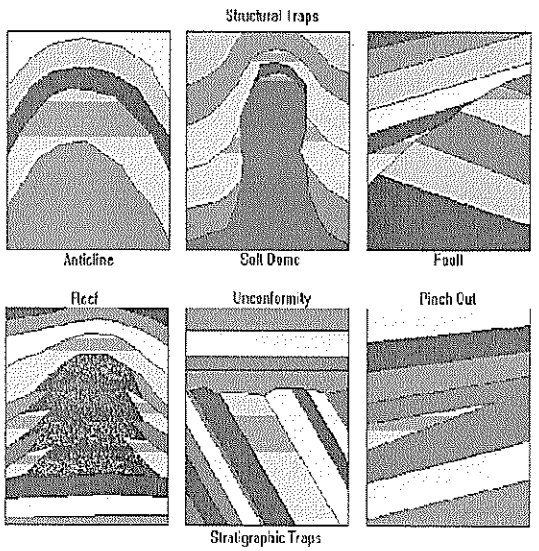
- Low permeability
- Ductility (otherwise they are easily fractured during deformation

Hydrocarbon Traps

Trap is the stratigraphic or structural feature that ensures the juxtaposition of reservoir and seal

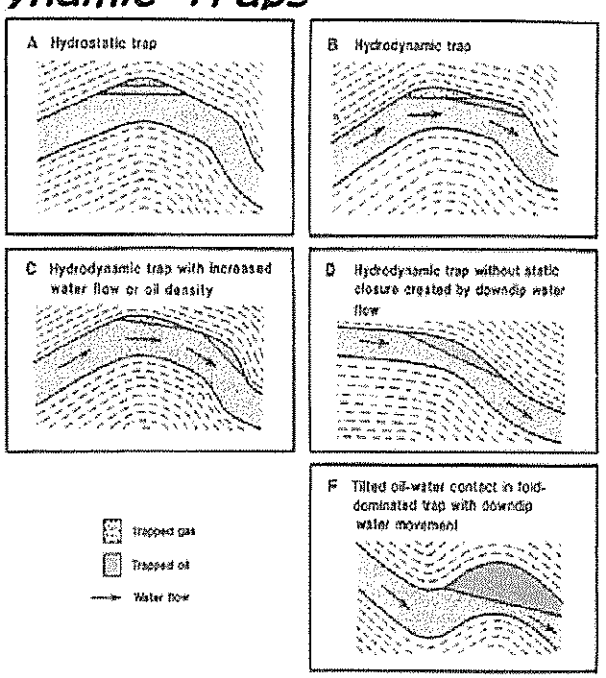
Classification of traps

1. *Structural Traps*
   - Fold related
   - Fault related
   - Diapirs : Salt Dome
2. *Stratigraphic traps*
   - Related to unconformities
   - Sedimentological : Reef
   - Pinchout
3. *Hydrodynamic traps*
4. *Combination traps*

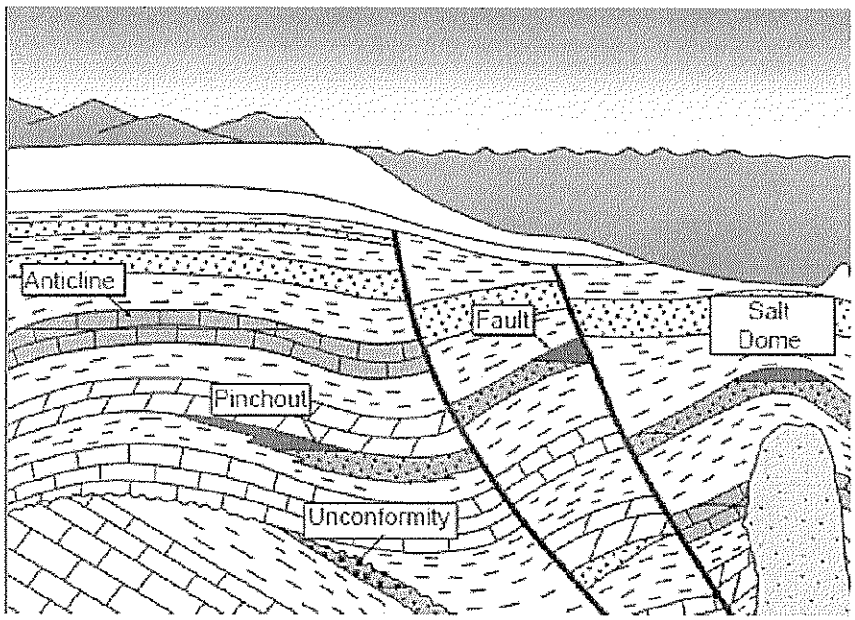


Hydrodynamic Traps

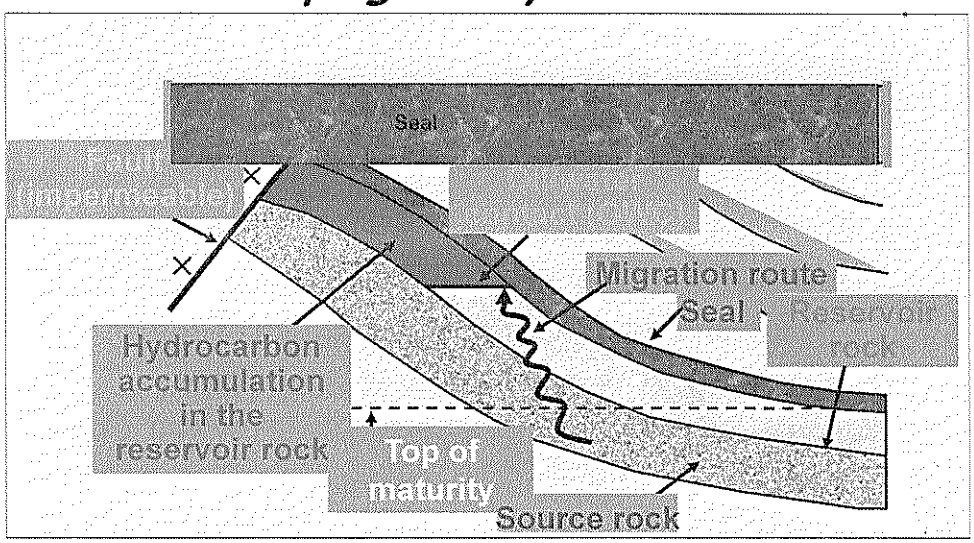
The movement of water can modify the geometry of an oil accumulation (tilted OWC is the most common example)



Combination Traps



Summary: Generation, Migration, and Traping of Hydrocarbon



Reservoir Fluids and Pressure

Types of reservoir Fluids

Fluid: any substance that will flow; oil, water and gas.

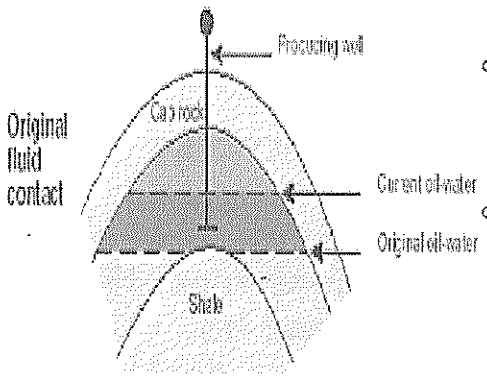
1. Water:
   - Connate water: the water in the formation when development of the reservoir was started.
   - Bottom water: occurs beneath the oil accumulation
   - Edgewater: occurs at the edge of the oil zone on the flanks of the structure.

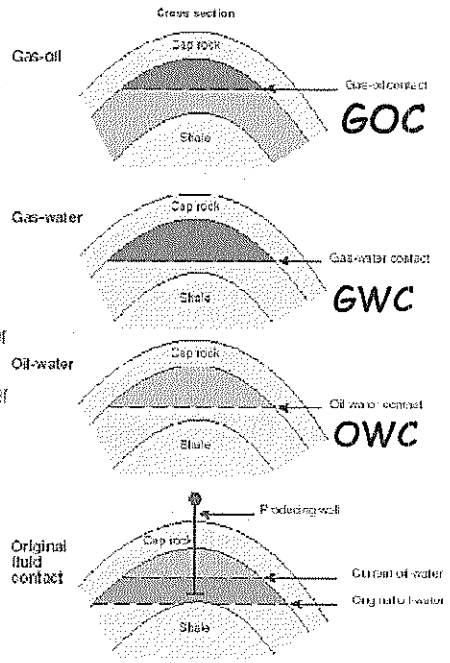
Types of reservoir Fluids (cont.)

2. Oil: lighter than water and not mix with water

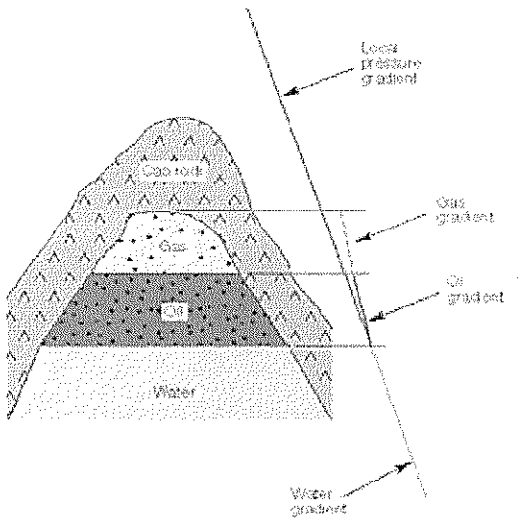
3. Gas: it is associated with oil and water in reservoirs in two principal ways;
   - Solution gas: High Pressure & Low Temp.
   - Free gas: it is not dissolved in oil- to accumulate in the highest structural part of a reservoir (call gas cap)

Fluid Distribution





Reservoir pressure



Reservoir Pressures are normally controlled by:

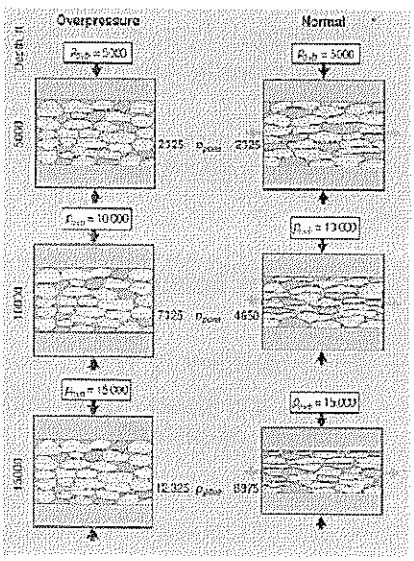
1. Pressure Gradient in the reservoir
2. Gravity (drilling low pt. in formation)
3. Capillary action (fluid has been flow into tiny opening)

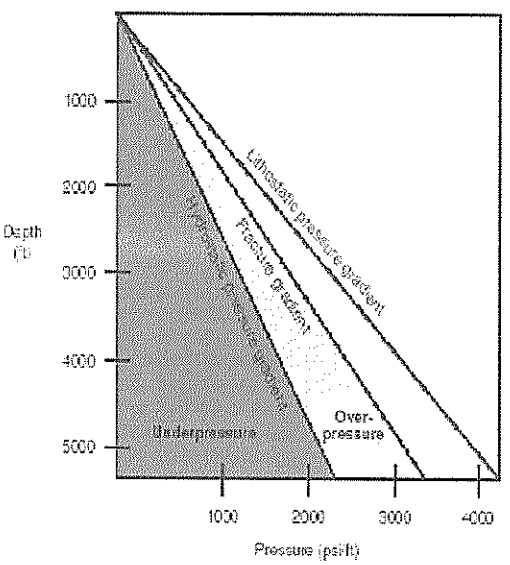
Type of Reservoir Pressure

1. Normal Pressure
2. Abnormal Pressure :

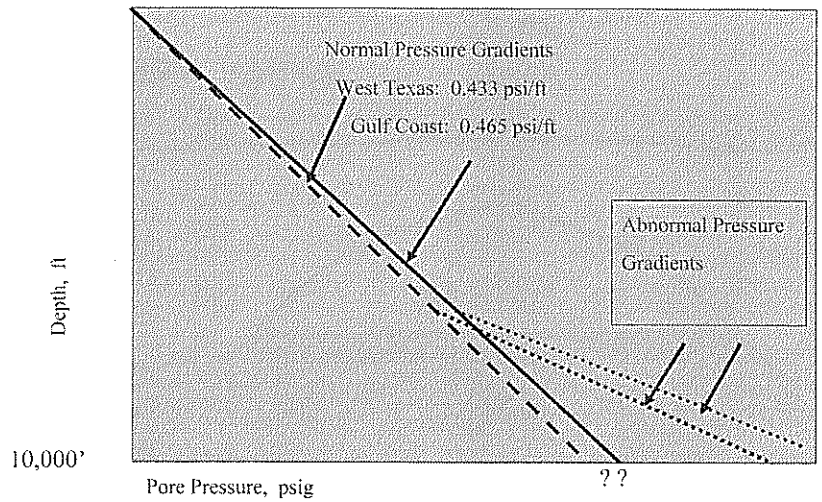
Formation pressure tends to increase with depth according to the hydrostatic pressure gradient, in this case 0.433 psi/ft. Deviations from the normal pressure gradient and its associated pressure at a given depth are considered abnormal pressure

Normal & Abnormal Pressure





Normal and Abnormal Pore Pressure



Some Causes of Abnormal Pressure

1. Incomplete compaction of sediments
   - Fluids in sediments have not escaped and are still helping to support the overburden.

2. Tectonic movements
   - Uplift
   - Faulting

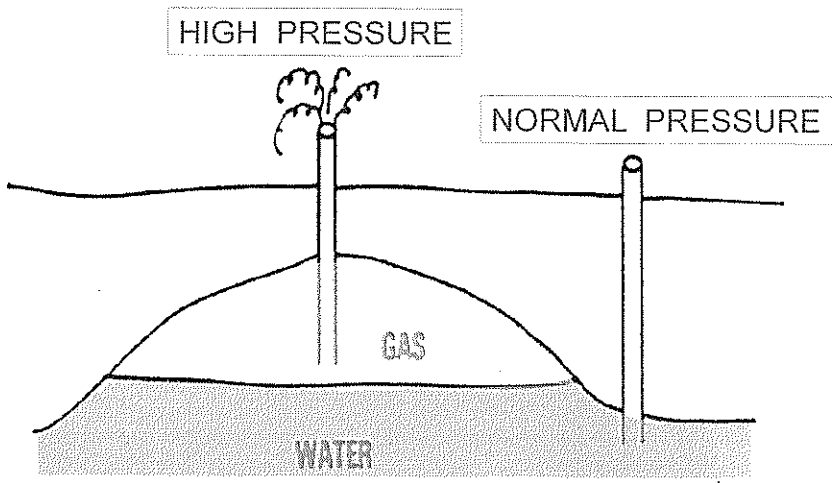


Figure 1-4. High pressure occurs at the upper end of the reservoir.

Hydrostatic pressure gradient is lower in gas or oil than in water.

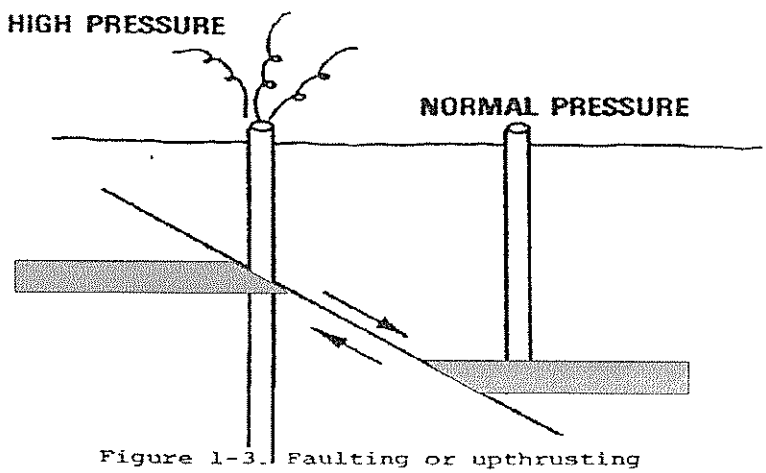


Figure 1-3. Faulting or upthrusting

When crossing faults it is possible to go from normal pressure to abnormally high pressure in a short interval.

Indications of Abnormal Pore Pressures

Methods:

1. Seismic data
2. Drilling rate
3. Sloughing shale
4. Gas units in mud
5. Shale density
6. Chloride content
7. Change in Mud properties
8. Temperature of Mud Returns
9. Bentonite content in shale
10. Paleo information
11. Wire-line logs

Chapter 3
Petroleum Exploration

Course Contents

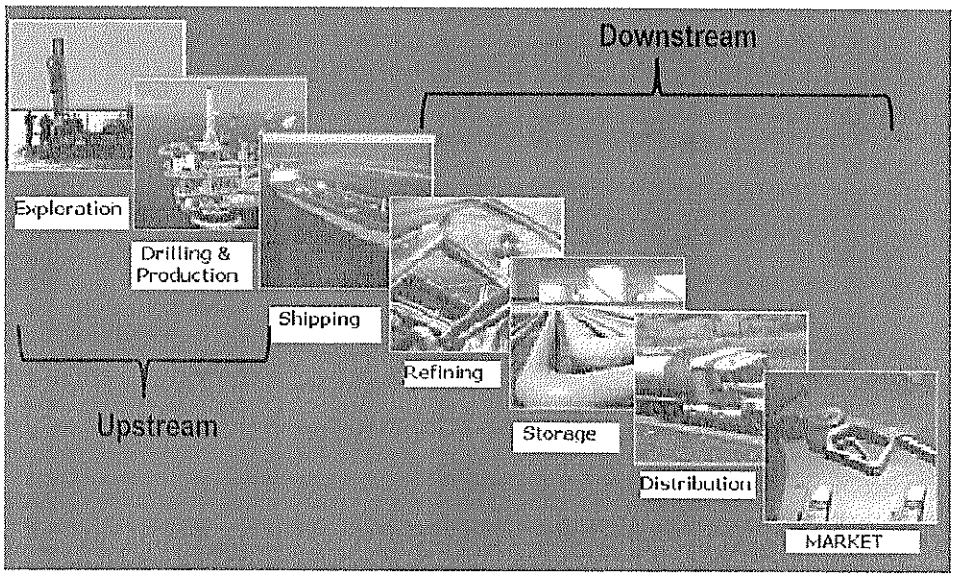
- Surface geographic studies
- Data collection
- Geophysical surveys
- Reservoir development tools

Petroleum Industry Functions

❖**Upstream**
- Exploration
- Development Drilling and Production

❖**Downstream**
- Crude Oil Transportation and Storage
- Refining and Petrochemical
- Product Distribution and Marketing

Petroleum Industry Functions



Requirements for Commercial Petroleum

- ✓ **Source:** material from which oil is formed and matured
- ✓ **Reservoir Rocks:** The hydrocarbons are contained in a reservoir rock. This is a porous and permeable sandstone or limestone, in which the petroleum may migrate and accumulate after being formed
- ✓ **Migration Part:** connecting source rock to reservoir rock.
- ✓ **Traps:** subsurface condition restricting further movement of oil and gas such that it may accumulate in commercial quantities.
  - + **Seal or cap Rock:** The hydrocarbon trap has to be covered by an impermeable rock known as a seal or cap-rock in order to prevent hydrocarbons escaping to the surface

Petroleum Systems

Elements	Processes
➢Source Rock ➢Migration Route ➢Reservoir Rock ➢Seal Rock ➢Trap	▪Generation ▪Migration ▪Accumulation ▪Preservation

Aim of Exploration

- To predict and identify the presence of geological structure that may contain hydrocarbons in commercial quantities

The occurrence of hydrocarbons is linked to sedimentary basin

1. What are sedimentary basin?
2. Where on the earth do we find them?
3. Are they all similar or are there many different types?
4. What is required for a basin to be propective?

A Prospective basin must

- ✓ Contain source rocks and reservoir/seal pairs
- ✓ Be sufficiently deep/thick so that source rocks have reached maturity to expel hydrocarbons.
- ✓ Have all the parameters occurring in a favorable combination, so that hydrocarbons can migrate updip into a sealed reservoir.
- ✓ Have undergone sufficient deformation prior to the source rocks having reached maturity to allow trap formation before hydrocarbon migration.

Exploration Method

1. Gathering information and planning geological field work
2. Seismic acquisition, processing and interpretation
3. Prospect generation, potential evaluation and prospect ranking
4. Drilling plan and well proposal
5. Drilling
6. Well evaluation, update exploration plan and delineation plan (if success)
7. Production

Petroleum Exploration Processes

1. *Regional studies*
2. *Land acquisition*
3. *Exploration*
4. *Risk Assessment (Prospect evaluation)*
5. *Drilling an exploratory well*
6. *Well completion and testing*
7. *If the well produces oil or gas: Development*
8. *If the well produces mostly water: Abandonment*

Exploration Tool

1. Geological Tools
   - Geologic map
   - Structural map
   - Stratigraphic correlation
   - Geological modeling

2. Geophysical Tools
   - Seismic
   - Magnetic
   - Gravity

Exploration Tool

3. Geochemical Tools
- Source rock evaluation
- Whole-rock analysis; (cutting, core, outcrop), TOC, pyrolysis , Rock Eval Vitrinite recflectant(VR)
- Kerogen analysis; V.R
- Bitumen analysis; Gas Chomatography Masspectroscope (GCMS)

4. Drilling and Testing
- Mudlog
- Wireline log
- Rock sample, core, cutting, side wall core
- Fluid sample
- Testing; DST

Petroleum Exploration

1) **Geological Exploration:**
- Surface survey and Mapping: field work (geological map, topography contour map, cross-section)
- Subsurface survey and mapping : cutting, core sample, well logs, seismic survey (isopachous map, cross-section)

2) **Geophysical Exploration**
- Gravity
- Magnetic
- Resistivity
- Seismic: Refraction (แบบหักเห) and Reflection (แบบสะท้อน)

3) Drilling Exploration

1) Geological Exploration

1.1 Surface Mapping

+Surface Geographical Studies
+Surface Geological Surveys
+As clues to subsurface features

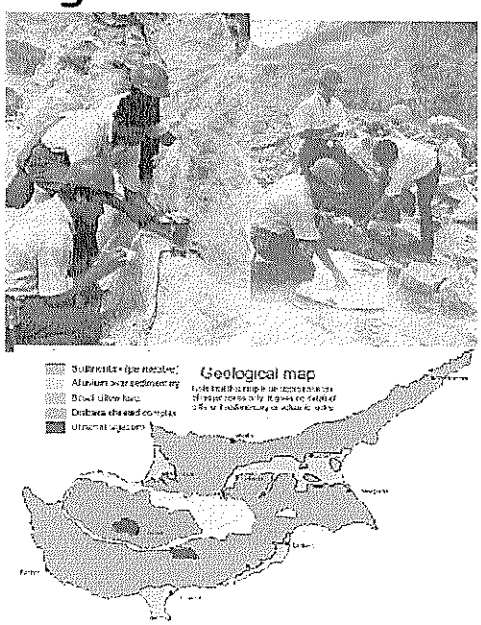
1.2 Subsurface Mapping can be defined into 3 type:

- Structural contour maps:elevation
- Isopachous maps: bed thickness
- Cross Section Maps: position and thickness of strata

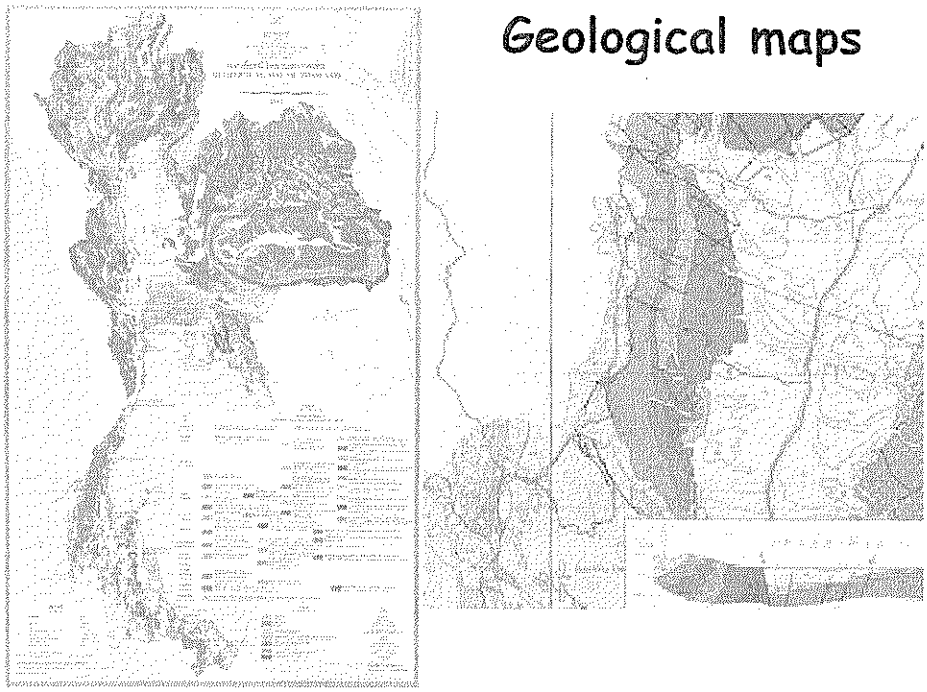
Sources of subsurface map
- Well Logs: mud logs, drilling logs, electric logs, Radioactivity logs etc.
- Seismic data
- Core drilling and analysis
- Strata test

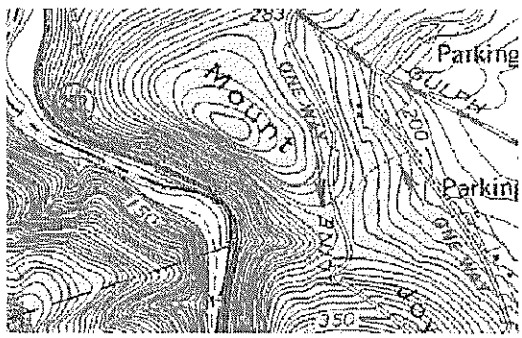
Mapping

- If rocks are exposed at the surface then mapping them can give a clear indication of the geology not only on the surface but also underground.
- You may be able to work out an underground cross section.

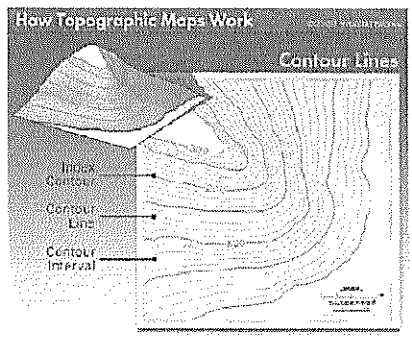


Geological maps

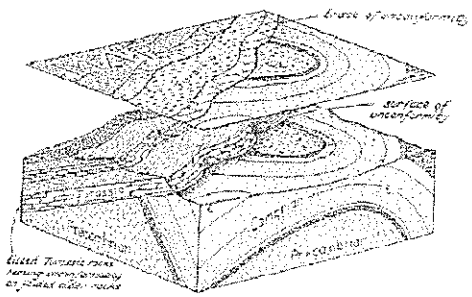




Topographic contour maps



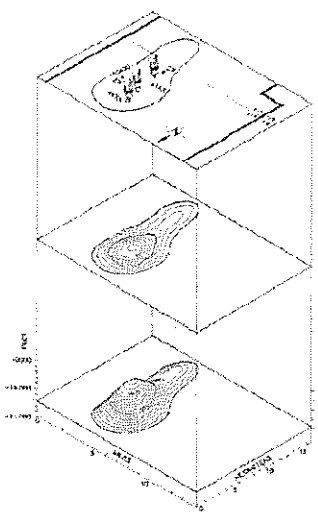
Surface Geology, Geological Cross-Sections



: Surface geological mapping is the oldest and cheapest exploration tool.

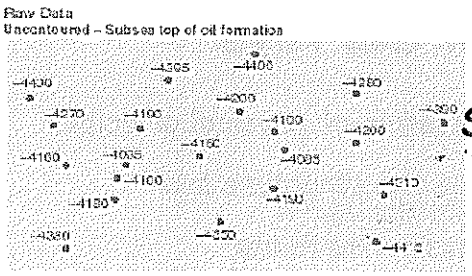
: A geological map contains a wealth of information about the stratigraphy, structure, and geological history of an area.

Subsurface Geological Maps

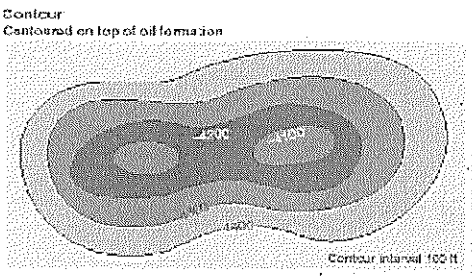


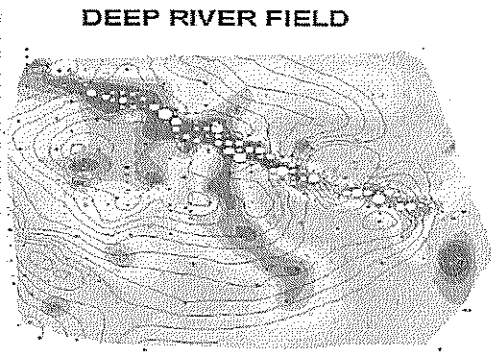
1. **Subsurface structure contour maps**
   - ▣ to represent geological structure in petroleum exploration.
   - ▣ Structure contour maps are very similar to topographic contour maps.

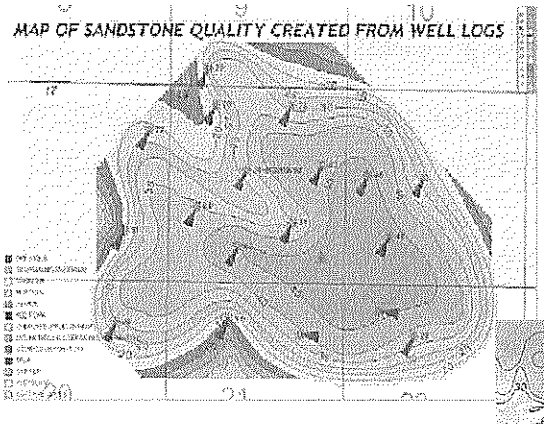
2. Isopach maps: Contours of equal stratigraphic thickness. These maps are often used to find the thicknest part of the reservoir.



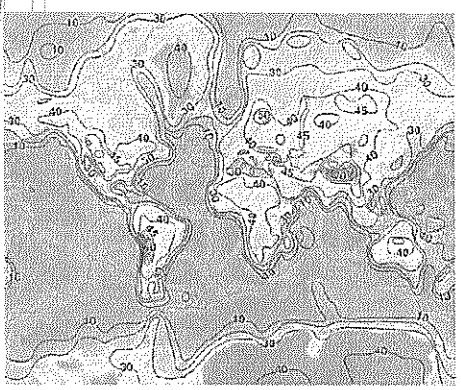
Structural contour maps







Isopachous maps



Other variables that are commonly contoured are:

- Net pay
- Porosity
- Oil saturation
- Pressure
- others

2. Geophysical Surveys

- ✓ Geophysics concern the application of physical principle to the studies of the Earth.
- ✓ The objective is to determine the structure and properties of the rocks within the earth.
- ✓ Some common type of geophysical methods.
  - ➢ Seismic
    - ➢ Reflection 98.6%
    - ➢ Refraction 0.1%
  - ➢ Gravity 0.5%
  - ➢ Magnetic 0.5%
  - ➢ Electrical and radioactivity 0.3%
- ✓ Petroleum industry accounted for 97% of geophysical expenditure.
- ✓ Gravity and magnetic are employed at the beginning of the new venture. These methods are used to obtain the general view of the sedimentary basin.

Gravity Survey

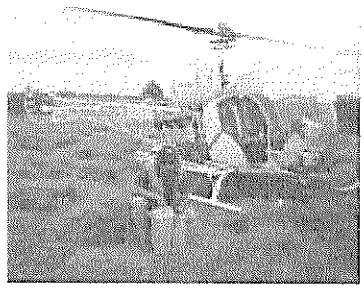
- ⊡ Measures small variations of the Earth's gravity field caused by density variations in geological structures.
- ⊡ ... is used as a supplementary method to raw materials exploration and as reconnaissance to design seismic works.

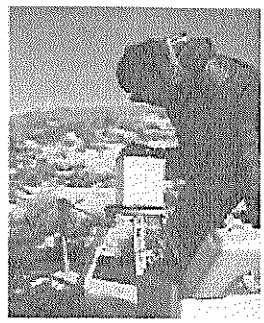
Gravity survey is used to determine:

- mapping deep structures in sedimentary cover and consolidated basement
- tracing density-lithological boundaries and tectonic features
- exploring structures prospective for hydrocarbon accumulation (find basin)

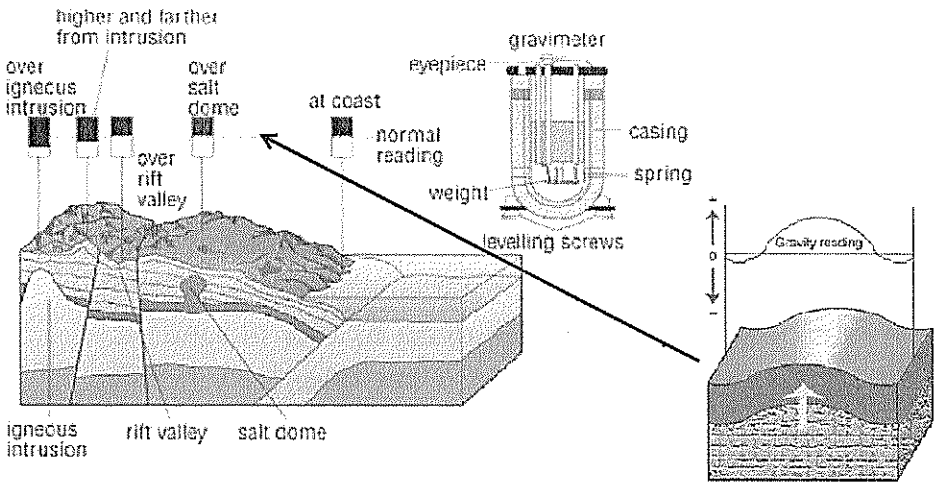
Gravity Surveys

- These use a gravimeter that measure the gravity at a given point.
- These can be carried in planes, ships or carried by hand.
- If there are denser rocks below (ores) they will give a positive gravity anomaly.
- If there are less dense rocks (salt/halite) there will be a negative anomaly.



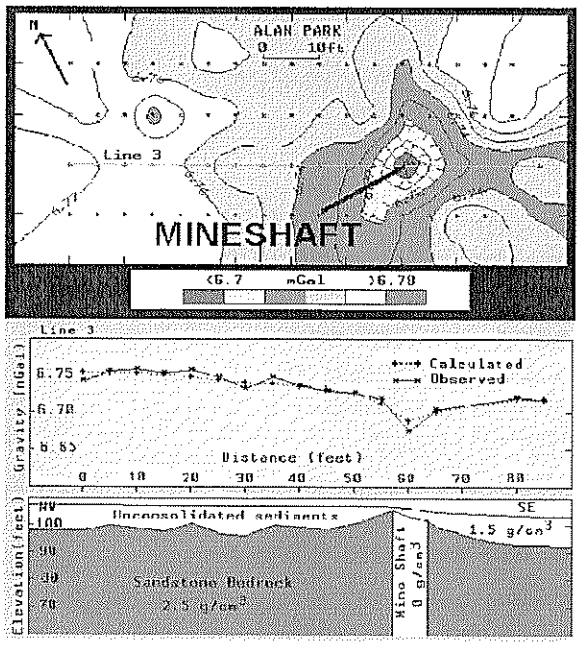


Gravimeter



- Gravity meter or Gravimeter : unit in mgal (milligal)

Gravitational Anomaly



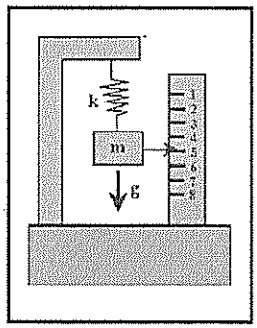
Magnetic Surveys

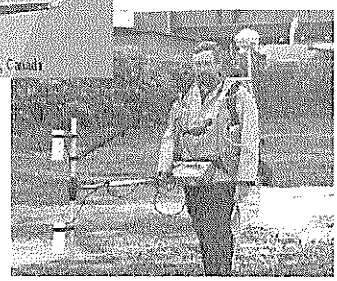
- Detects changes in the earth's magnetic field caused by variations in the magnetic properties of rocks
- Use for determining depth to basement
- For basin analysis, the area of low magnetic intensity usually indicate a sedimentary basin.
- Sedimentary rocks are not magnetic (negligible)

Magnetometer

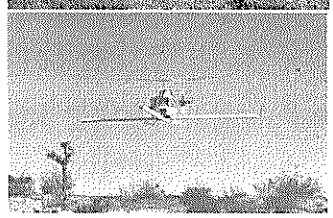
- ✓ Unit of measurement is in gamma (γ)
- ✓ Magnetic data, like gravity survey, are usually displayed in form of map.

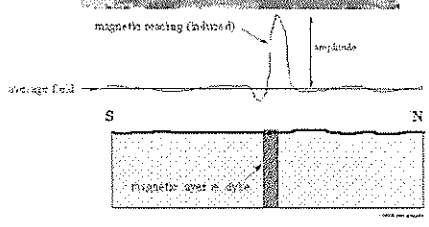
Magnetometer





Magnetic survey using a magnetometer





Benefit of Magnetic method

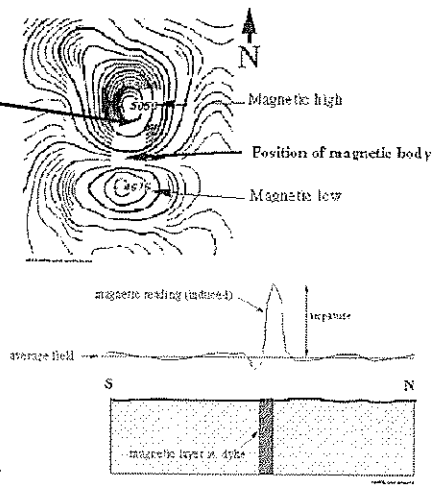
1. Fast & Low cost
2. Provide information about the distribution of rocks occurring under thin layers of sedimentary rocks
3. Useful when trying to locate orebodies
4. Aeromagnetic surveys are taken from a moving plane.

Applications of Magnetic Method

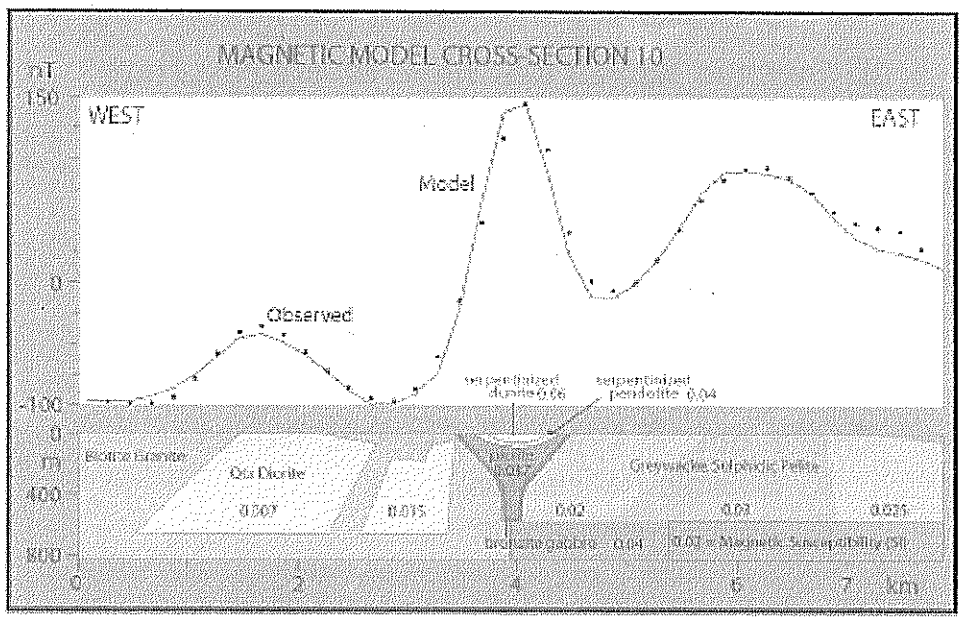
- Shallow (Engineering and Environmental): contaminants, toxic waste, pipes, cables and metal inclusions
- Archeology: buried walls, old fire pits
- Mining: iron sulfide deposits
- Oil and groundwater: depth to magnetic basement in basins, structure and shape of basin, and detection of fault.

Magnetic survey using a magnetometer

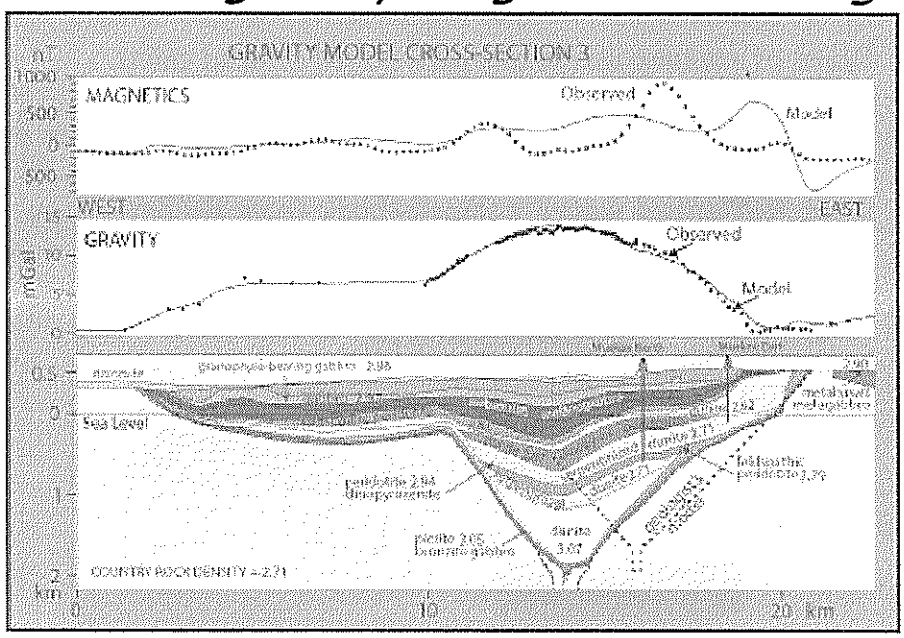
- **The data for a survey can be plotted as a contour map using lines which join points of equal "magnetic" value.**
- **From these maps geoscientists can locate magnetic bodies (even if they are not outcropping at the surface), interpret the nature of geological**



Magnetic Model



Basin gravity-magnetic modeling



Seismic Survey

- **Seismic waves** are wave of energy that travel through the earth or other elastic bodies.
- The propagation or velocity of seismic wave depends on acoustic properties of the rocks, e.g. elasticity, density, discontinuity, etc.

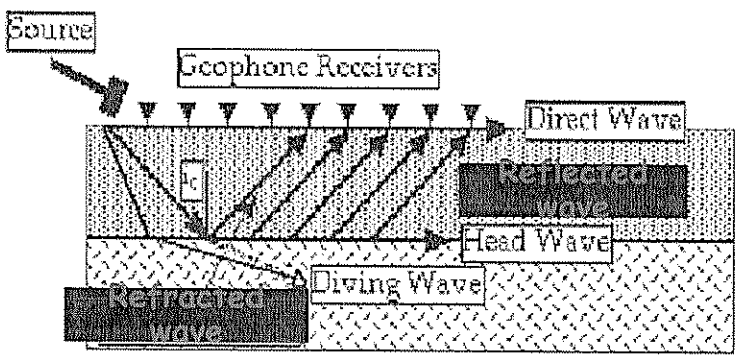
There are 2 type of Seismic waves:

1. **Seismic Refraction**
2. **Seismic Reflection**

Characteristics of Seismic Waves

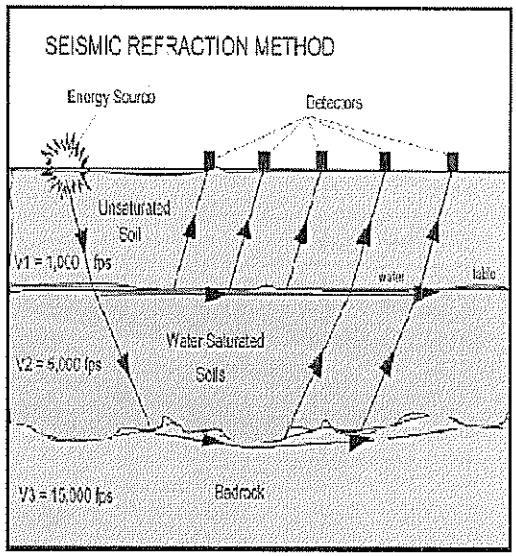
Types of seismic waves are generated at shot point.

1. **Direct wave:** travel near surface of the ground
2. **Refracted wave:** travel through the second layer of the rock with different angle.
3. **Reflected wave:** reflects back from the interface between two rock layers.



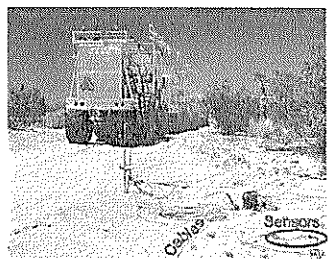
Seismic Refraction (แบบหักเห)

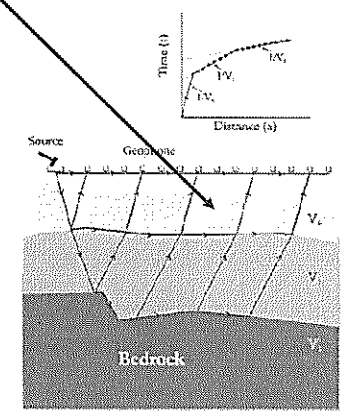
- Used in a shallow depth survey
  - Groundwater
  - Mining
  - Engineering site investigation

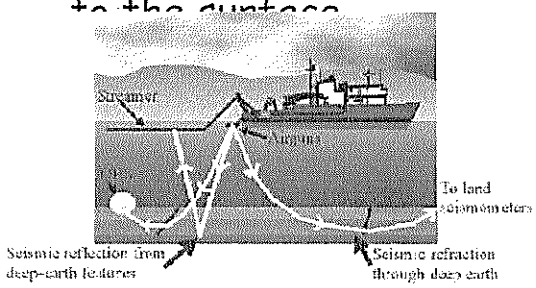


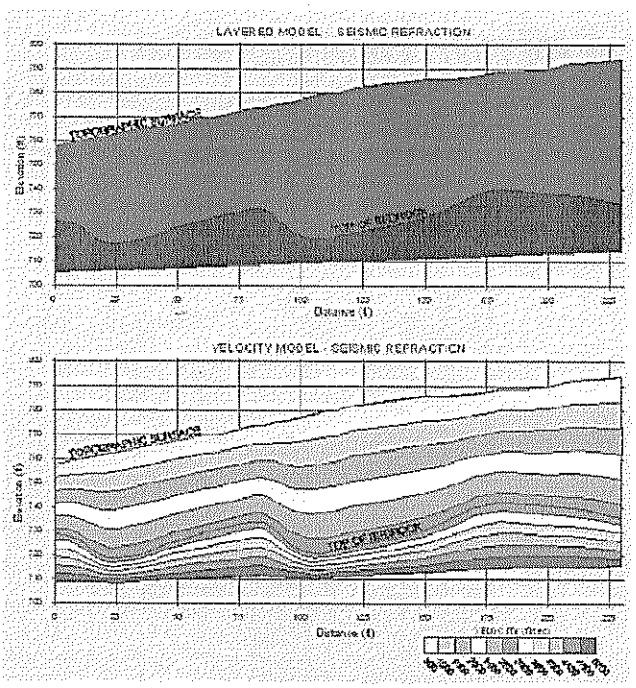
Seismic Refraction

- ✓ The waves are refracted through the layers before returning to the surface.
- ✓ These waves hit the boundary between 2 rocks and then travel along the boundary before returning to the surface







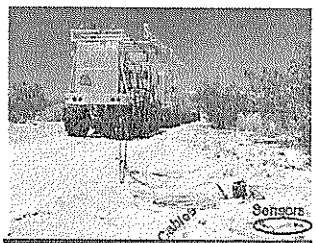


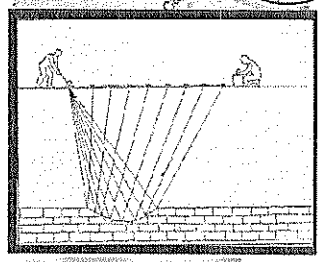
SEISMIC REFRACTION SURVEY FOR ESTIMATING RIPPABILITY & DEPTH TO BEDROCK

Seismic Reflection (แบบสะท้อนกลับ)

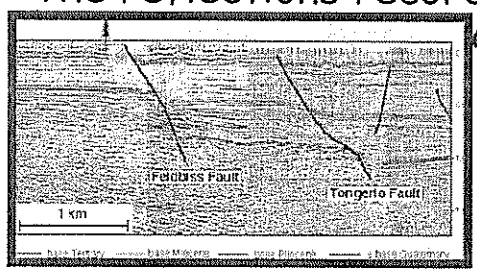
- ✓ Widely used in petroleum exploration.
- ✓ Used to locate geological structure, in some case stratigraphic feature favorable for oil and gas accumulation.
- ✓ As a tool for stratigraphic studies.
- ✓ Reconstruct depositional history of the area.
- ✓ In some cases, seismic reflection can be used to directly locate the hydrocarbons themselves.

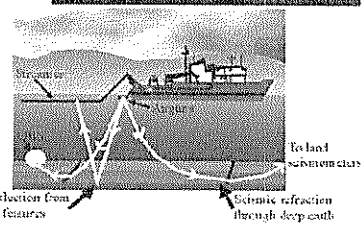
Seismic Reflection





- ✓ The seismic reflection method works by bouncing sound waves off boundaries between different types of rock.
- ✓ The reflections recorded es on





Seismic Sources and Detectors

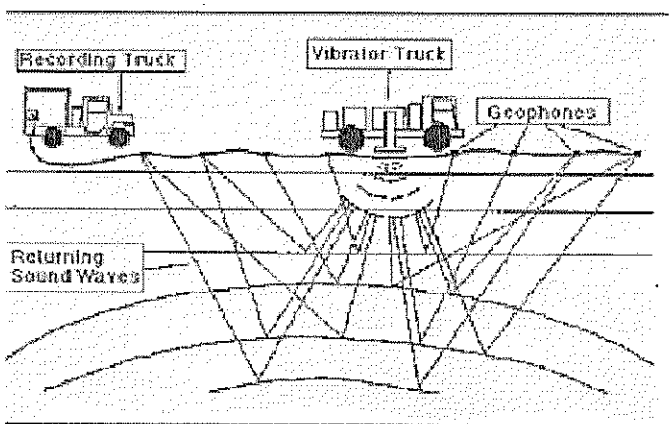
In seismic surveys, a shock wave is created by the following:

1. **Compressed-air gun** - shoots pulses of air into the water (for exploration over water)
2. **Thumper truck** - slams heavy plates into the ground (for exploration over land)
3. **Explosives** - drilled into the ground (for exploration over land) or thrown overboard (for exploration over water), and detonated

The reflections of the shock waves are detected by sensitive microphones or vibration detectors :

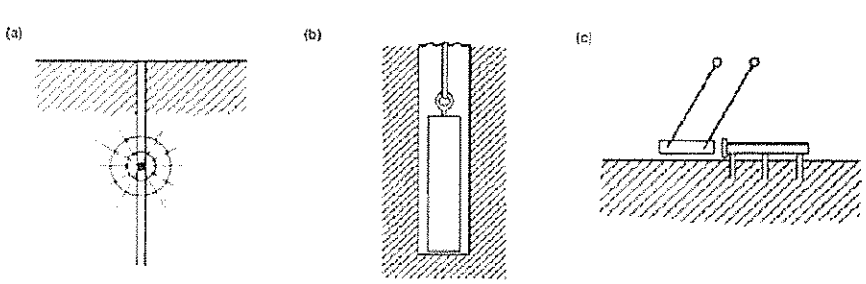
1. **Hydrophones** over water,
2. **Geophone (seismometers)** over land

Seismic Reflection in Onshore



Vibrator truck = Source of shock waves
Geophones = Detector

Seismic Source in Onshore

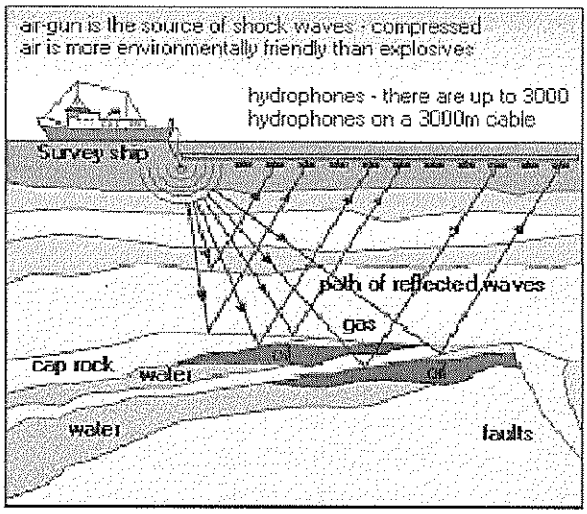


(a) dynamite

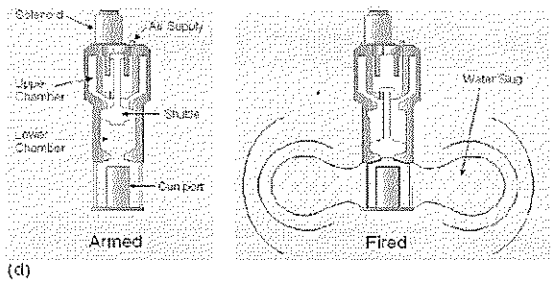
(b) falling-weight sources

(c) horizontal-force source

Seismic Reflection in Offshore

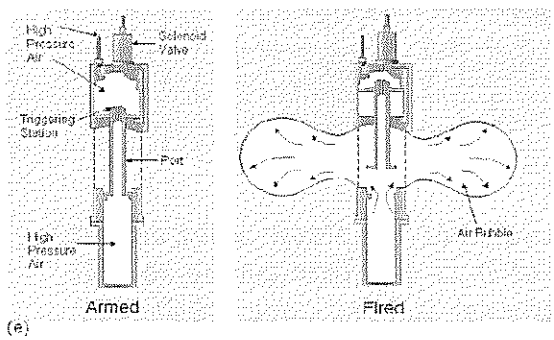


Air gun = Source of shock waves
Hydrophones= Detector



(d)

Watergun



(e)

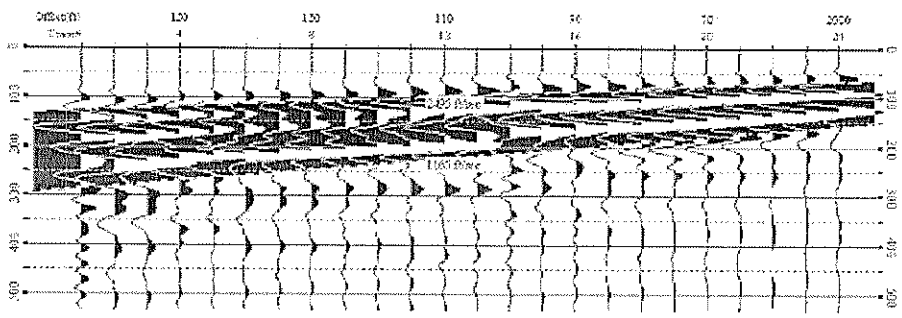
Airgun

Steps in Seismic Survey

Seismic Survey

Acquisition	Processing	Interpretation
The data is gathered by a specialized company	Intense computer processing is required to transform the field data into a meaningful seismic	This is the task of geologist/geophysicist who are familiar with the geology

Raw Seismic Data

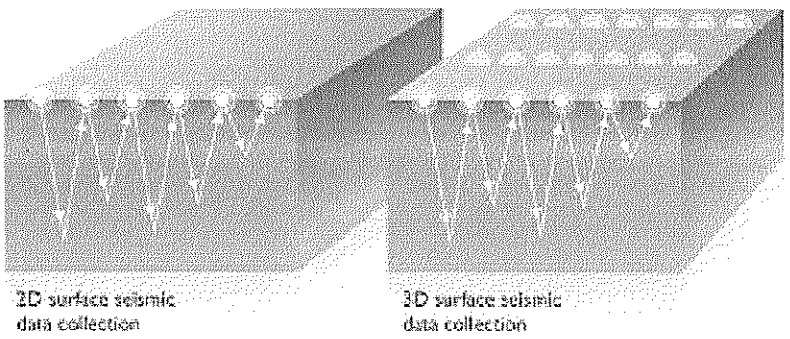


The weighted average value of the shear wave velocity data within the depth of 0 to 100 feet can be used to determine the International Building Code (IBC) site classification.

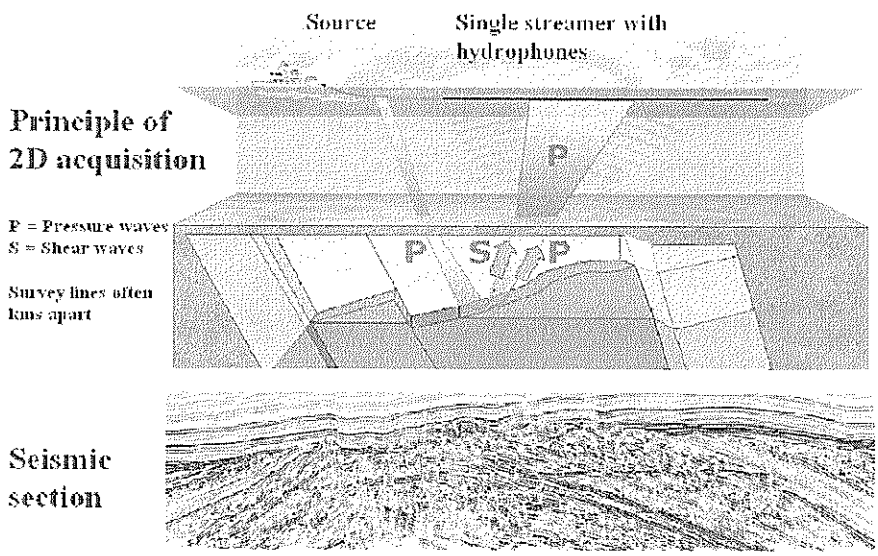
Geological Interpretation of Seismic Reflection Data

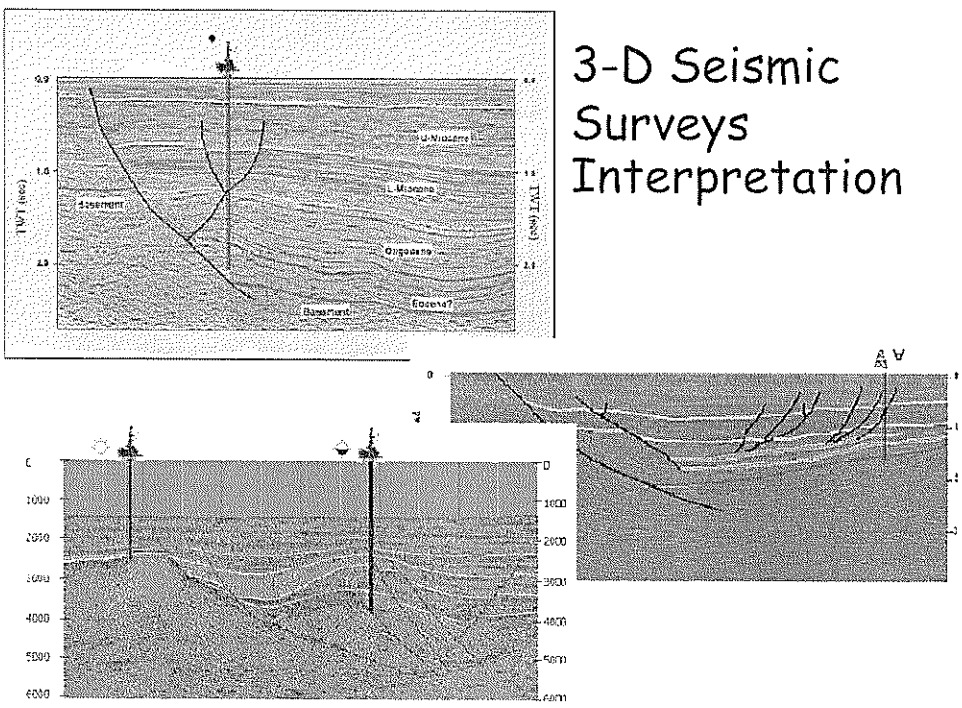
1. Outlining of a sedimentary basin
2. Locating geological structures
   - Fault
   - Fold
3. Direct detection of hydrocarbon (Bright spots)
4. Reconstruction of structural contour map of the interested sedimentary layers.
5. 1-D, 2-D, 3-D and 4-D Seismic

2-D and 3-D Seismic Surveys

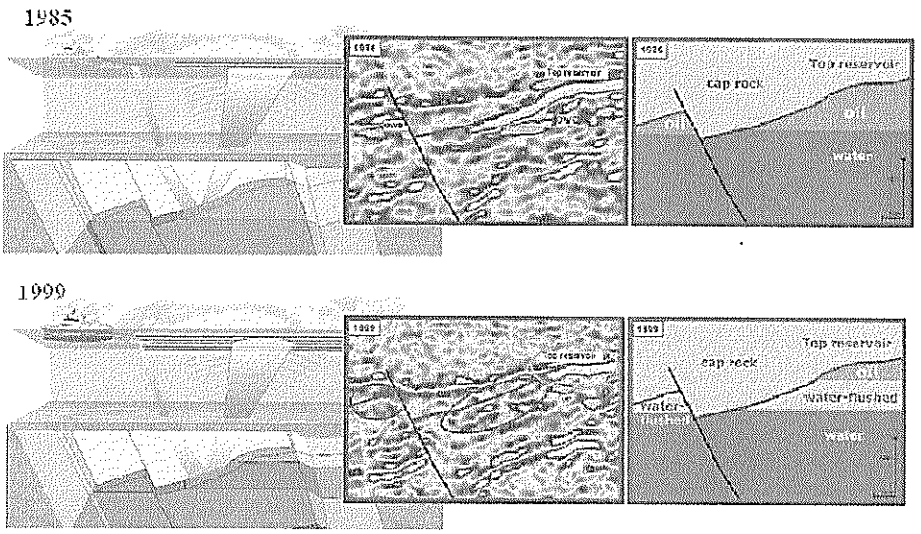


Line showing *Cube showing*

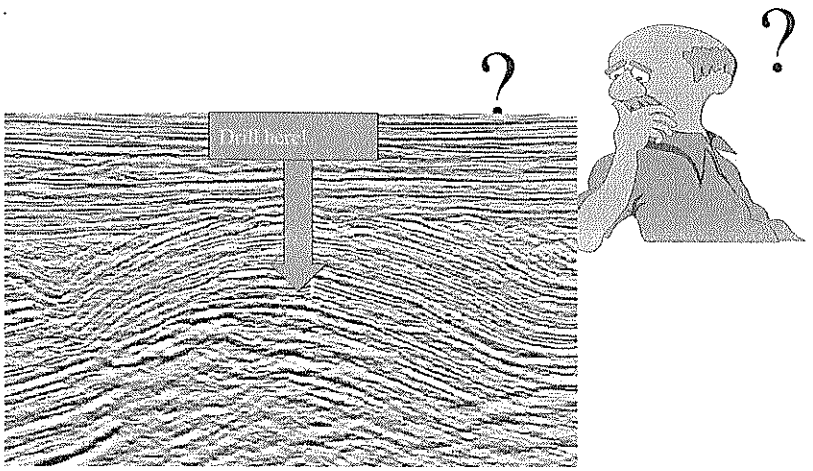

Source
Single streamer with hydrophones
Principle of 2D acquisition
P = Pressure waves
S = Shear waves
Survey lines often kms apart
P
P
S
P
Seismic section


3-D Seismic Surveys Interpretation

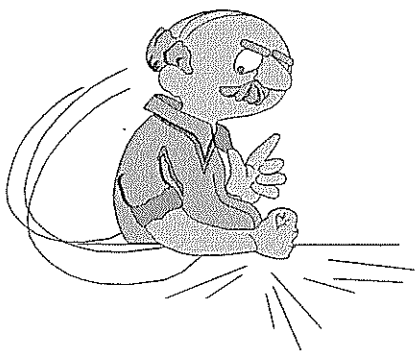
4D model



What do we do after we find a reservoir?

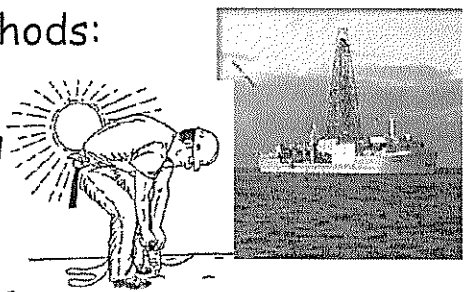


We Drill Into It ! ! !



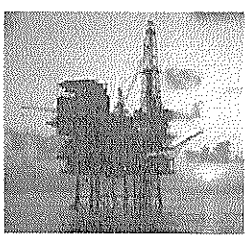
Direct exploration methods:

- There are 2 main methods:
  - Drilling
  - Subsurface Mapping



Drilling

- Drilling in an area is often the only way of being absolutely sure what is underground.
- The geochemical and geophysical methods will give a clue.

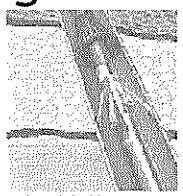


Stratigraphy: A Prospecting Tool

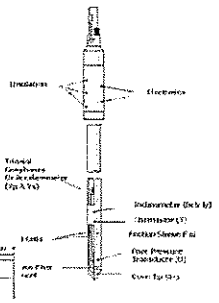
- Stratigraphy is study of the origin, composition, distribution and succession of rock strata.
- Stratigraphy correlation consists of matching strata, fossils, rock hardness or softness and electrical data from one well to another or from one outcrop to another.
- The data are collected by well logs (driller's, sample, electrical, radioactive and acoustic logs)

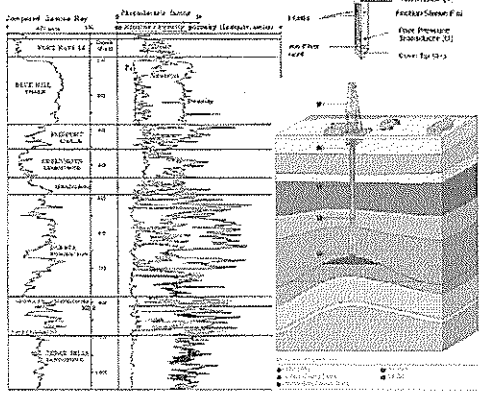
Down hole logging surveys.

- In the oil industry, many types of geophysical survey can be carried out by placing instruments down the exploration borehole.
- Such things as:
  - +Resistivity
  - +Sound wave velocity
  - +Gamma ray radiation
- These give clues about:
  - +Porosity and permeabilit
  - +Dip of beds
  - +Fluid pressures



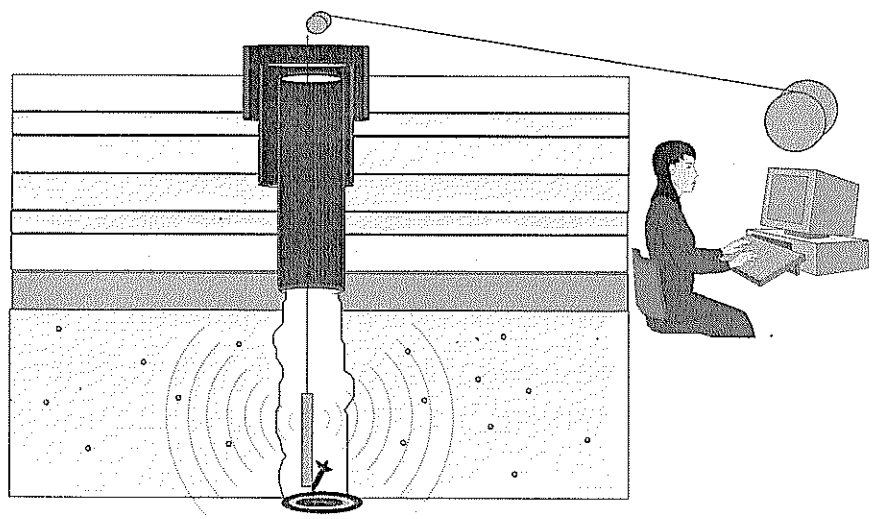
Multi-Finger Imaging Tools



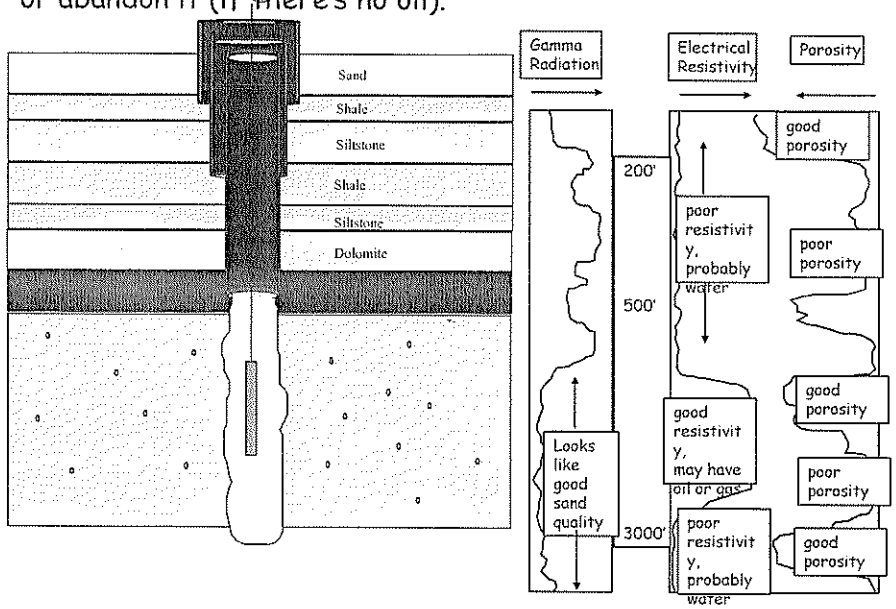


How do Geologists tell if the reservoir has oil or gas?

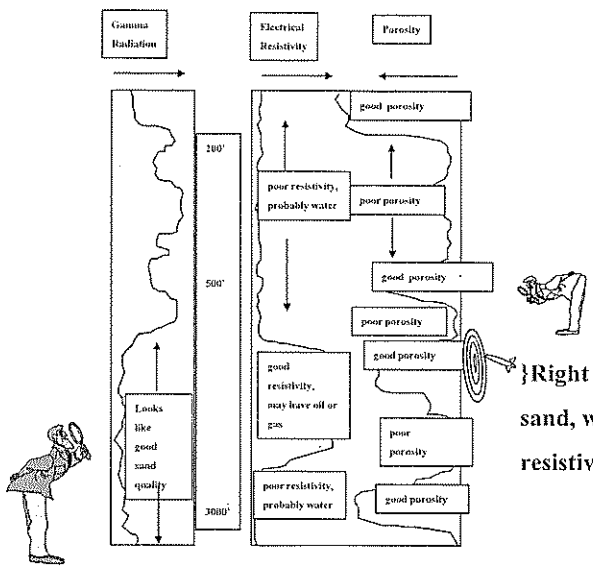
Logs are tools run on electric cable ("wireline") which record the physical properties in the rock such as resistivity, porosity, density, radioactivity, and pore pressure.



Here's an example of what a log looks like. Geologists look at logs to decide whether or not to complete a well (if there is oil), or abandon it (if there's no oil).



Can you tell where the geologist would complete this well?



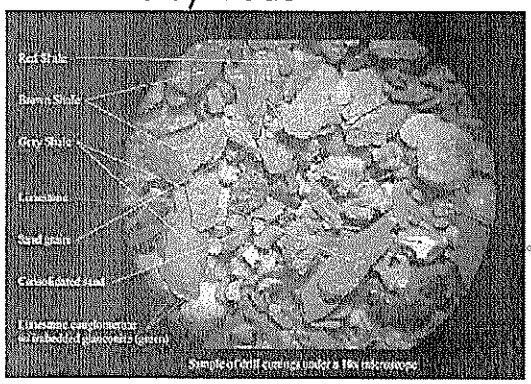
}Right here! This shows a clean sand, with good porosity and resistivity.

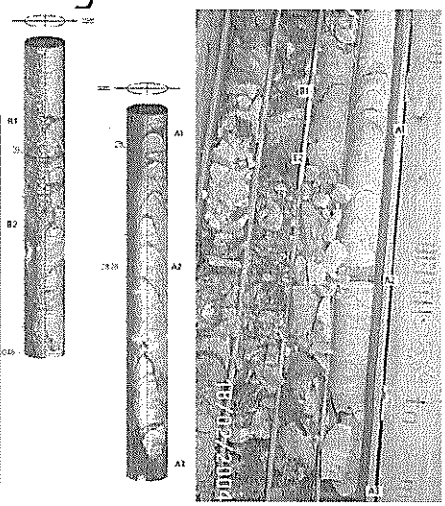
Driller's Logs

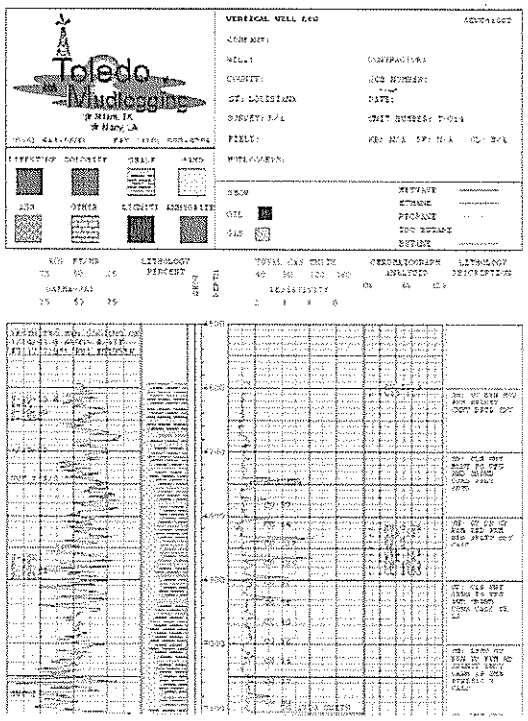
- Common and basic information
  - ✓Depth
  - ✓Kind of Rocks
  - ✓Kind of Fluids
  - ✓Others

Sample Logs

- Logs get from well cutting and cores
  - Lithology sequence
  - Key beds

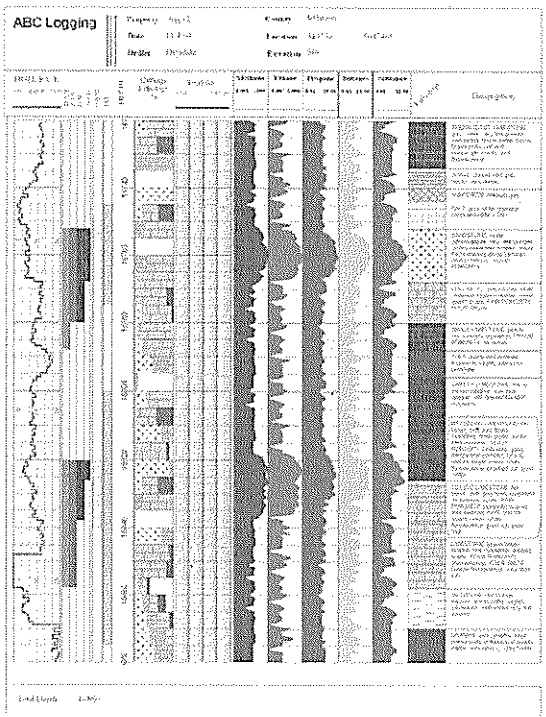






Sample Log

- Formation boundary
- Lithology (Description+symbols)



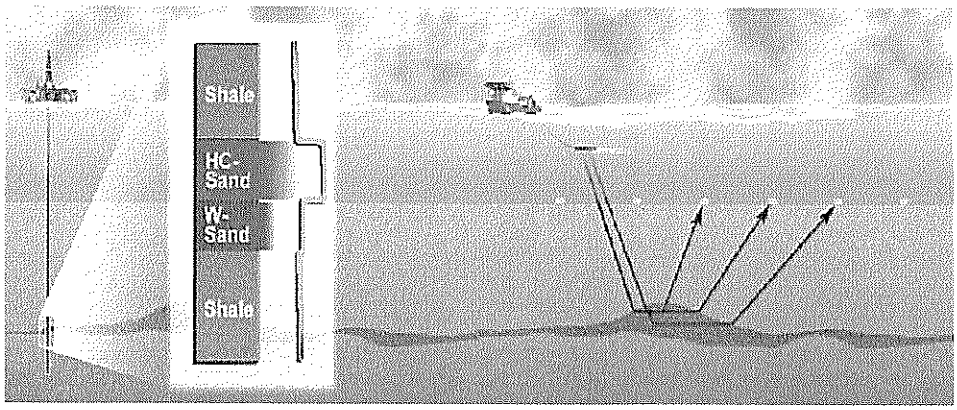
Mud Log

- Rate Of Penetration (ROP): Drill Rate
- Lithology (Description+ Symbol)
- Hydrocarbon: Gas & Oil show

Electrical logs

- ✓ Record the conductivity of the interstitial water in the rock.
- ✓ Record the movement of the drilling mud into porous beds
- ✓ Record the movement of formation water into the wellbore

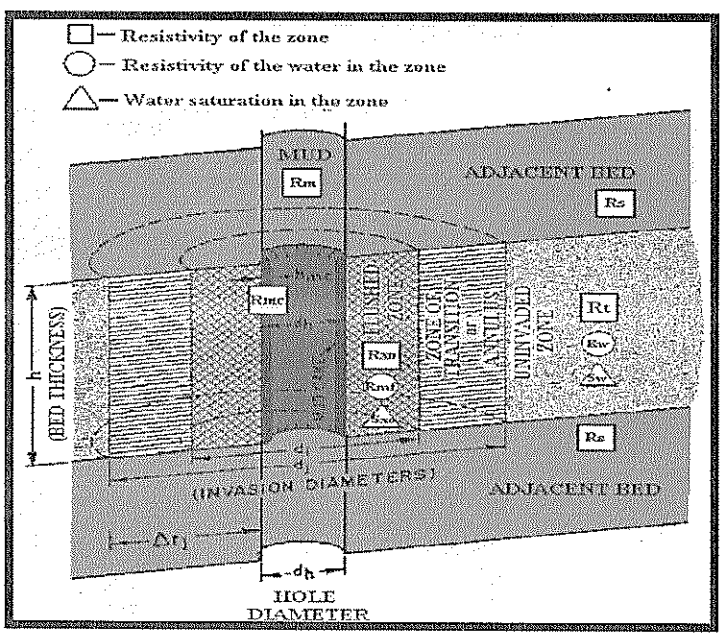
Electrical Log Interpretation



Borehole principle

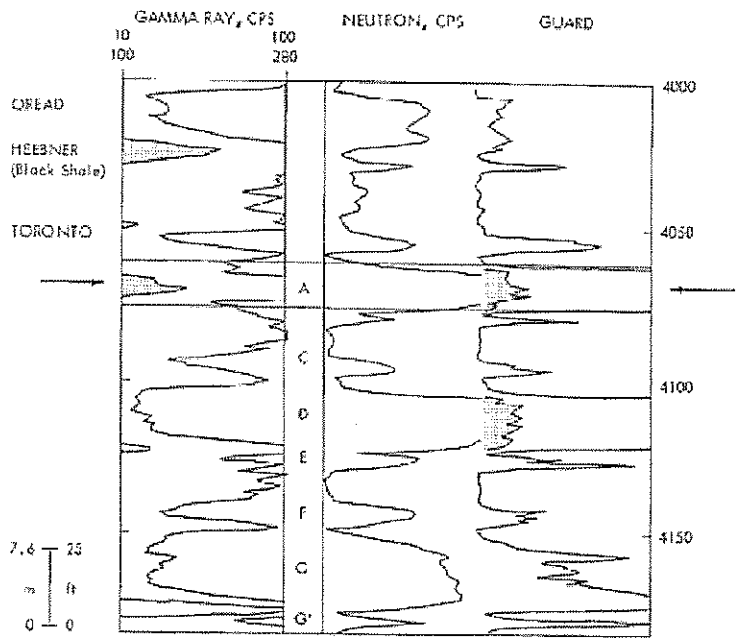
Shale – very low resistivity; Water-bearing sandstone – low resistivity;
Hydrocarbon-bearing sandstone – high resistivity

Borehole condition



Radioactivity logs (or radiation logs)

- ✓ Record the natural or induced radioactive characteristics of subsurface formation.
- ✓ Consist of gamma-ray and neutron
- ✓ Both give an indication of the type of rocks and types of fluids contained in the rocks.
- ✓ Run in a cased or uncased hole.



Gamma ray tool

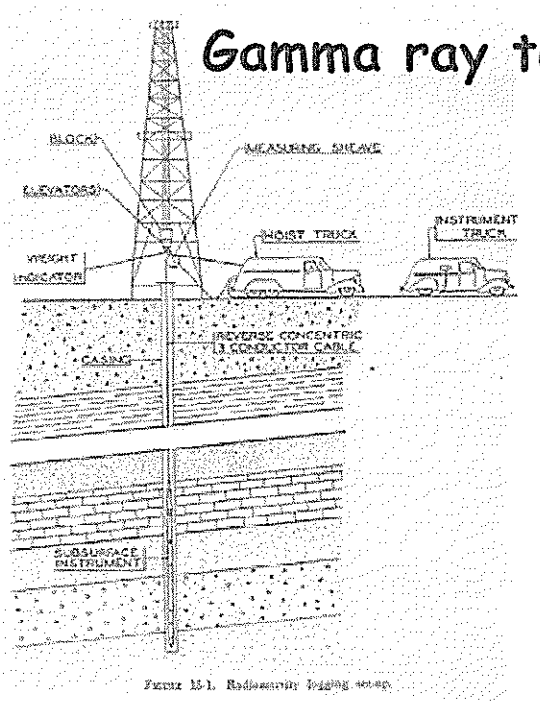
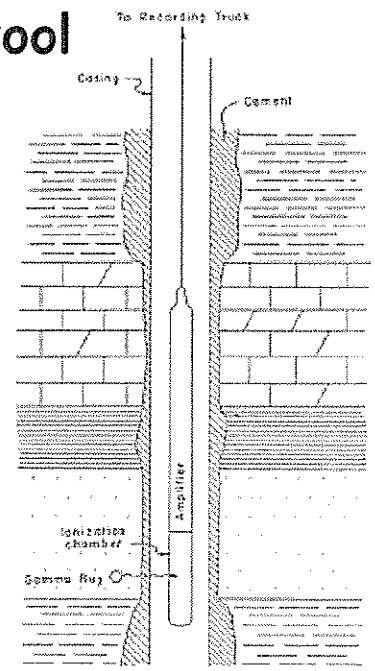
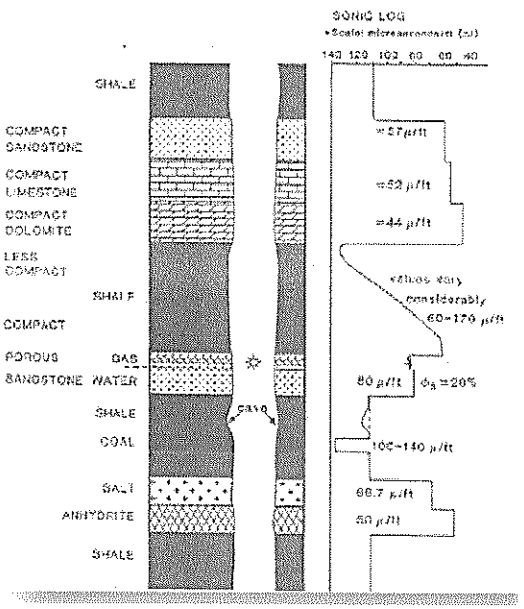


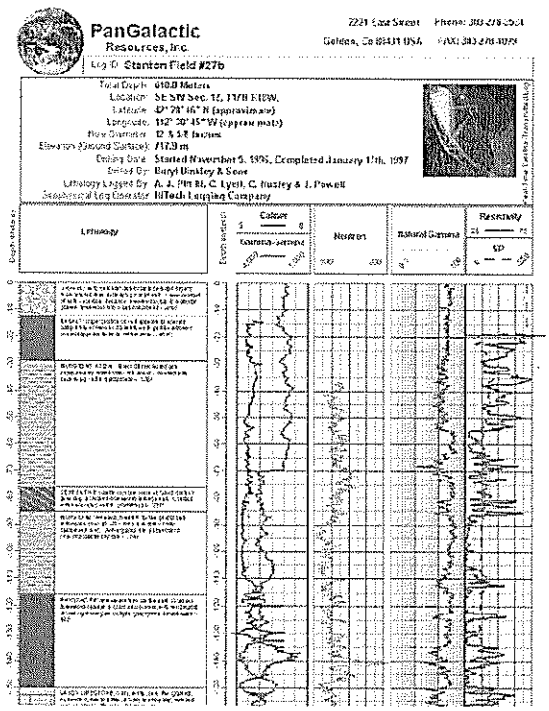
Figure 15-1. Radioactivity logging setup.



Acoustic logs (or sonic logs)

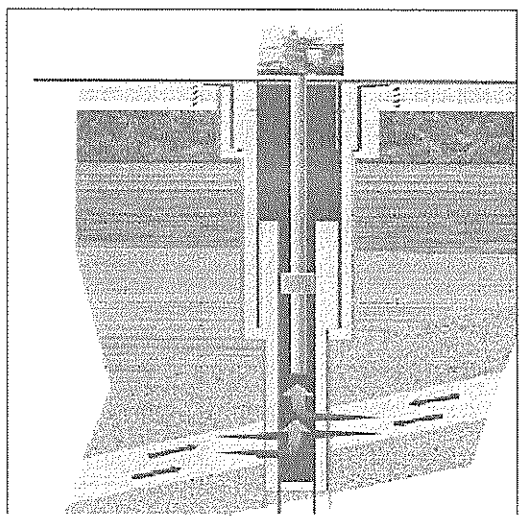
- ✓ Use to determine the porosity of a formation.
- ✓ Measure the time it takes for a sound impulse.





Chapter 4

Drilling Operation



Content

- ✓ **Drilling operation**
  - Development of drilling for oil
  - Drilling contracts
  - Rotary drilling systems
  - Routine drilling operations
  - Development of offshore drilling
  - Mobile offshore drilling units
  - Offshore drilling plateforms
  - Directional drilling
  - Fishing
  - Air and gas drilling

Why drilling?

จุดประสงค์ เพื่อค้นหาและนำปิโตรเลียมซึ่งอยู่ภายในแหล่งกักเก็บใต้ผิวดินขึ้นมาใช้

<u>หลักการของการเจาะ (Principle of Drilling)</u>

1. เจาะหลุมเพื่อให้ถึงชั้นปิโตรเลียมที่เราต้องการหาโดยใช้น้ำโคลนหรือของไหลชนิดอื่นๆ (Drill the well to the targets with circulating fluid)
2. การควบคุมหลุมเจาะขณะทำการเจาะ (Well control while drilling operations)
3. การทำ Logging, Casing and Cementing well
4. การทดสอบหลุมเพื่อที่จะทำการผลิต (Complete well for production) เมื่อการทดสอบการไหลและปริมาณสำรองคุ้มค่าต่อการลงทุน
5. ถ้าทำการทดสอบหลุมแล้วประเมินความเสี่ยงทุกอย่าง หากไม่คุ้มค่าต่อการลงทุน หรือเป็นหลุมแห้ง (dry well) หรือทำการผลิตแล้วเอาปิโตรเลียมขึ้นมาหมดแล้ว ก็ทำการปิดหลุมผลิตและละทิ้งหลุมเจาะ (Plug and abandon well) :ซ:

Overview of Steps to Drill a Gas/Oil Well

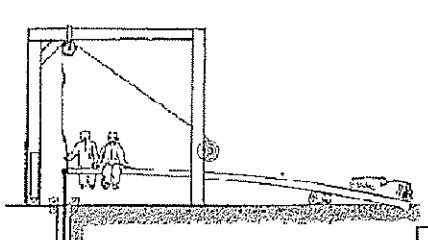
1. หลังจากทำการสำรวจ seismic, ทำ wire line log รวบรวมข้อมูลต่างๆเสร็จแล้ว
2. ทำการขอเช่าสัมปทาน (concession) จากรัฐบาล
3. คำนวณหาปริมาณสำรองและประเมินความคุ้มค่ากับการลงทุน
4. ถ้าปริมาณสำรองนั้นมากพอต่อการลงทุนก็ทำการขุดเจาะ
5. การขออนุญาตจากรัฐบาลหรือหน่วยงานที่ดูแล
6. เตรียมโครงการการขุดเจาะและทดสอบหลุม (drilling and completion program)
7. การคัดเลือกหรือเปิดประมูล drilling contractors ให้ตรงตามที่ได้จัดทำโครงการการเจาะ
8. ถ้าจำเป็นก็อาจต้องปรับเปลี่ยนหรือปรับปรุง program ให้เข้ากับเครื่องและอุปกรณ์ของผู้รับเหมา(contractor)

Steps to Drill a Well - cont.

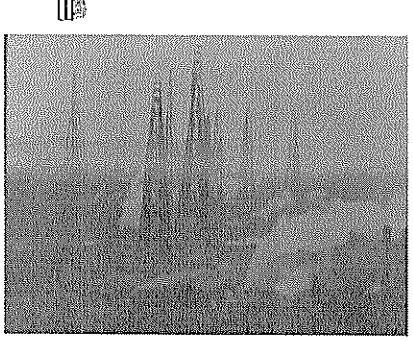
9. ทำการก่อสร้างถนน วางตำแหน่ง platform และติดตั้งอุปกรณ์ที่อยู่ในทะเลอื่นๆ ใน site.
10. การประชุมทุกฝ่ายเพื่อตกลงความเข้าใจของบริษัทและรวมถึง contractor เรียกว่า pre-spud meeting: การตกลงทำความเข้าใจก่อนการเริ่มขุดเจาะ
11. ทำการขุดเจาะ (drilling)
12. เมื่อเจาะถึงชั้นกักเก็บปิโตรเลียมทำการโยกย้ายผู้รับเหมาการขุดเจาะออกไป
13. ทำการทดสอบหลุมเจาะ (Complete well): โดยการทำ Core sampling, DST และ Wire line logging
15. ติดตั้งอุปกรณ์การผลิต (Install surface facilities)
16. ในขณะที่ทำการผลิต ต้องมีการทำการวิเคราะห์ ในช่วงการผลิต โดยวัดค่าความดัน อัตราการไหลของน้ำมัน

History of drilling

Years	Technical achievments
25000-15000 B.C.	Simple methods of rotation. Drilled stones, teeth, bones.
15000 - 3000 B.C.	Instruments made of stones.
3000 - 2000 B.C.	Simple drilling bits made of stones.
2000 - 1500 B.C.	Instruments made of bronze.
1500 - 500 B.C.	Instruments made of iron.
1450 B.C.	Triple bow drill invention in Egypt.
500 B.C.	Development of Chinese drilling up to 600 m depth.
221 B.C.	Production of oil and gas from the well drilled for salt production (China).
1126	Drilling of water well in France, Artoi.
1420	Information about well construction by Jiovanni Fontana,
1714	Italia.
1751	Description of rotary drilling by Leman (Leipzig).
1847	Description of rotary drilling in Encyclopedia (France).
1878	First oil well drilled in Baku.
1888	Patent of two-cone drill bit (Hughes).
1896	Patent of rotary table.
	Project of offshore drilling.



DEVELOPMENT OF DRILLING FOR OIL



Antique drilling Rigs in Zigong, China

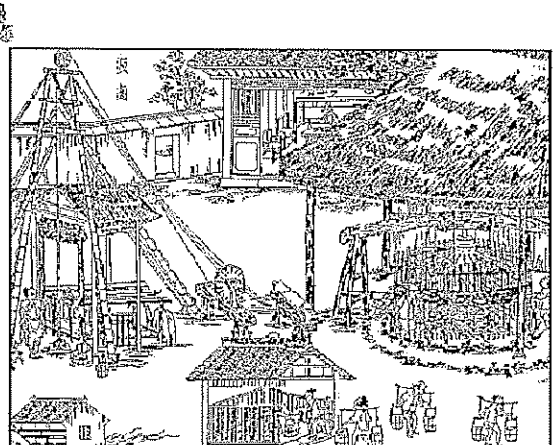
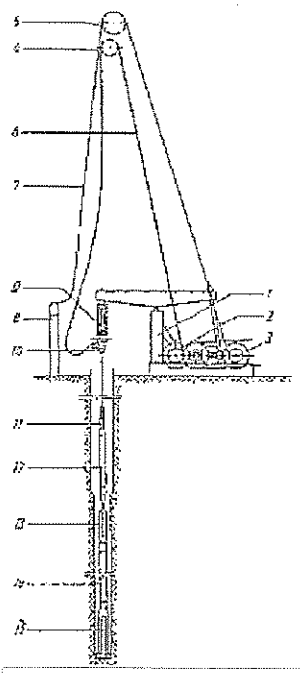
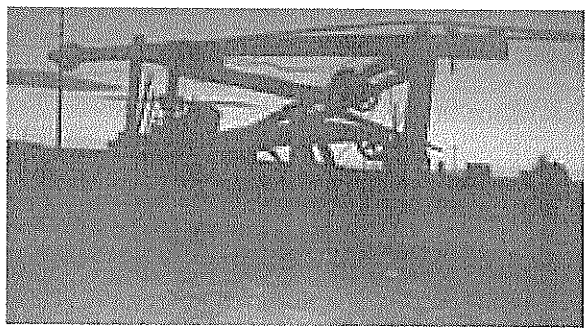


Fig.: Drilling installation in China with percussion device in ca. 600 before Chr.





Antique drilling rig now on display at Western History Museum in Lingle, Wyoming. It was used to drill many water wells in that area—many of those wells are still in use

Drilling Contracts

1. Drilling rigs ส่วนใหญ่หมายถึง บริษัท oil and gas exploration and production ที่ทำการขุดเจาะและผลิต

2. Drilling rigs ส่วนใหญ่เป็นเจ้าของที่ให้บริการบริษัทน้ำมันในการสำรวจและขุดเจาะที่เรารู้จักกันในนามของ **drilling contractors**

Drilling contractors นี้มีอุปกรณ์ขุดเจาะ (drilling equipment), ผู้เชี่ยวชาญและแรงงาน (expertise and labor) ที่พร้อม ที่ทำงานให้กับบริษัทนำมัน ซึ่งบริษัทน้ำมันที่ว่าจ้างนั้นมั่นใจว่าการว่าจ้างผู้รับเหมาแล้วจะได้ข้อมูลและประสบผลสำเร็จโดยเจาะพบน้ำมันหรือก๊าซที่จะได้ผลกำไรจากการลงทุนมหาศาล

Drilling Contract Types

ขึ้นอยู่กับข้อตกลงกับผู้รับเหมาว่าจะว่าจ้างแบบใด

1. **Day Work Contract.** A day work contract is "a contract for the drilling of an oil and gas well under which 'the drilling contractor furnishes the drilling crew and drilling equipment (การจ่ายค่าจ้างเป็นรายวัน)

2. **Footage Contract.** A footage contract provides that payment is made based on an agreed sum per foot of hole drilled. Much like a day work contract (การจ่ายค่าจ้างตามความลึกที่เจาะ)

3. **Turnkey Contract.** A turnkey contract is a contract wherein the drilling contractor drills the well, establishes production and turns the completed job over to the operator for the amount specified in the contract. (การแบ่งผลกำไรจากบริษัทน้ำมันที่ว่าจ้าง หรือการมีหุ้นส่วนจากการผลิต)
4. **Combination agreements: the based for payment are combination in the final agreement.**

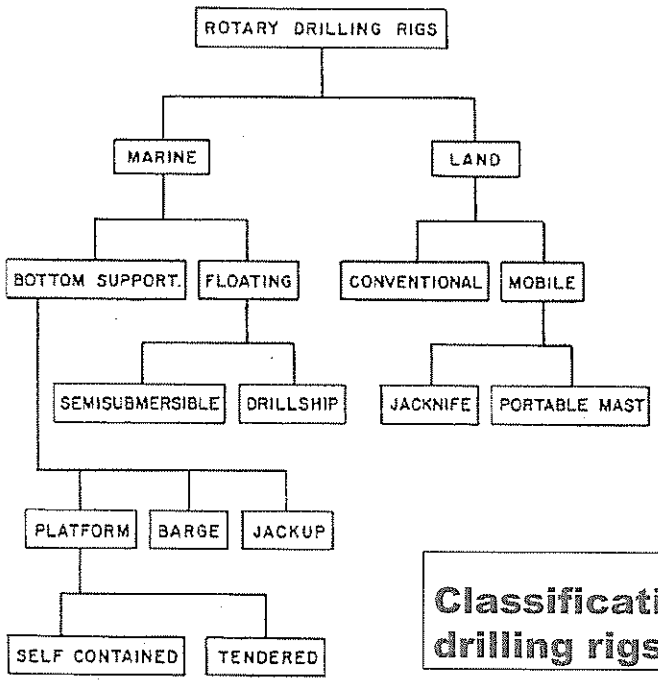
ประเภทของหลุมขุดเจาะ

สามารถแบ่งประเภทของหลุมตามจุดมุ่งหมายในการขุดเจาะ ออกได้เป็น 3 ประเภท ดังนี้

1. **Exploration Well** คือ หลุมที่ทำการขุดเจาะในโครงสร้างซึ่งยังไม่ทราบแน่ชัดว่าจะมีปิโตรเลียมกักเก็บอยู่หรือไม่ เป็นการขุดเจาะเพื่อค้นหาปิโตรเลียม

2. **Appraisal Well** คือ หลุมที่ทำการขุดเจาะหลังจากที่มีการค้นพบแหล่งกักเก็บปิโตรเลียมแล้ว เป็นการขุดเจาะเพื่อให้ทราบถึงขอบเขตและปริมาณสำรองของแหล่งกักเก็บ

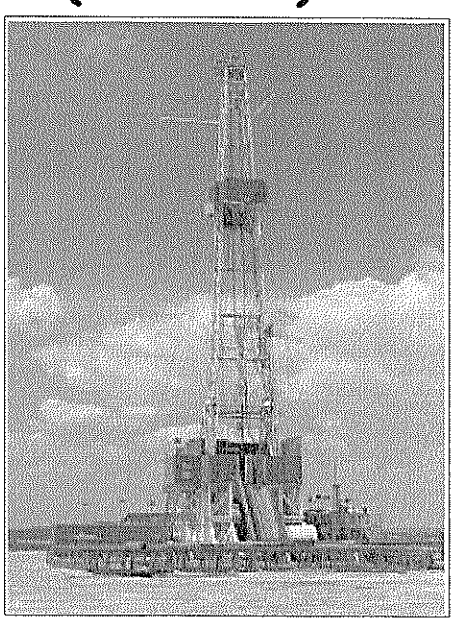
3. **Development or Production Well** คือ หลุมที่ทำการขุดเจาะในบริเวณซึ่งทราบแน่ชัดแล้วว่ามีปิโตรเลียมกักเก็บอยู่เป็นการขุดเจาะเพื่อนำปิโตรเลียมขึ้นมาใช้



Classification of rotary drilling rigs

1. การเจาะหลุมสำรวจบนบก (Onshore)

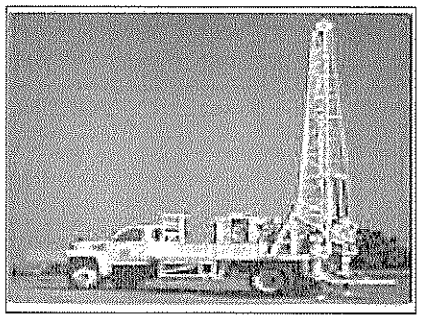
1.1 แท่นเจาะแบบคอนเวนชันแนล **(conventional drilling rig)** เป็นแท่นเจาะที่มีทั้งอุปกรณ์และส่วนประกอบต่างๆ ใหญ่ที่สุด สามารถเจาะได้ลึกมากอาจถึง 30,000-35,000 ฟุต

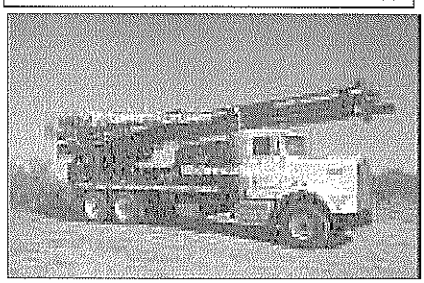


1. การเจาะหลุมสำรวจบนบก (Onshore) ต่อ

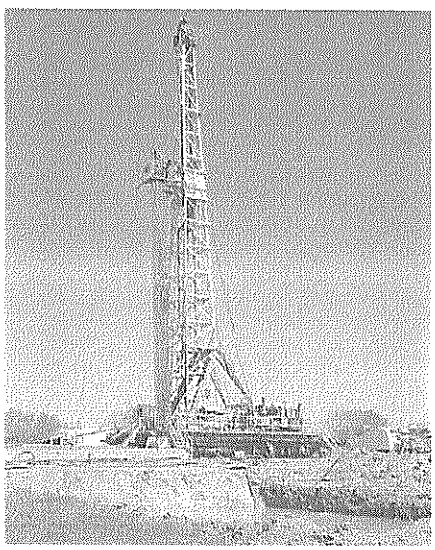
1.2 แท่นเจาะแบบเคลื่อนย้ายได้ (Moblie Rig)

เป็นแท่นเจาะที่มีลักษณะเป็นโครงสร้างแบบหอคอยซึ่งสามารถพับให้เอนราบได้ ติดตั้งอยู่บนรถบรรทุกขนาดใหญ่ ทำให้สามารถเคลื่อนย้ายแท่นเจาะได้อย่างสะดวก

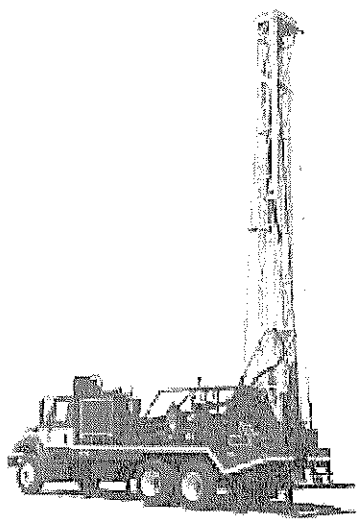




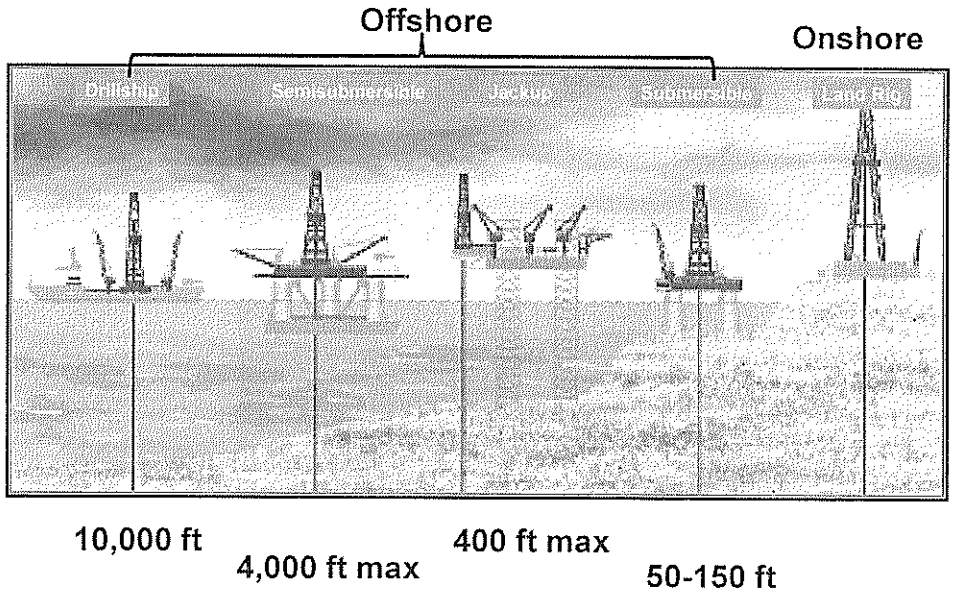
Mobile Land Rigs



Jacknife rig



Portable Mast rig



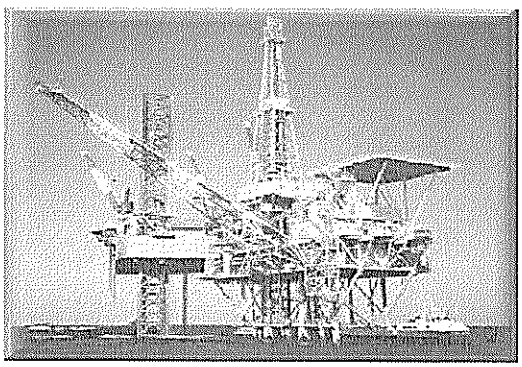
2. การเจาะหลุมสำรวจในทะเล (Offshore)

2.1 แท่นเจาะแบบหยั่งติดพื้นทะเล จะมีฐานหยั่งติดพื้นทะเล ซึ่งแยกเป็น 2 แบบ ตามลักษณะโครงสร้างของฐาน

2.1.1 แท่นเจาะแบบเจคอัพ (jack up)

มีฐานสำหรับรับน้ำหนักของตัวแท่นเจาะมีลักษณะเหมือนขาหยั่งลงไปถึงพื้นทะเล โดยจำนวนขาของแท่นเจาะอาจมีได้ตั้งแต่ 3-5 ขา โดยแต่ละขามีความยาวประมาณ 300-500 ฟุต ขึ้นอยู่กับความลึกของพื้นทะเลในบริเวณนั้น

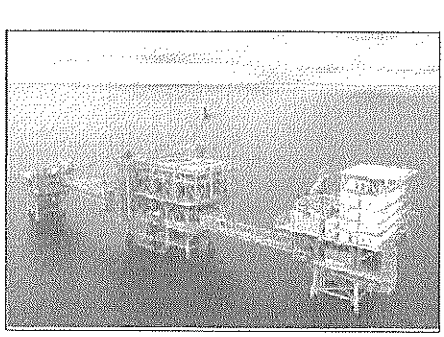
2. การเจาะหลุมสำรวจในทะเล (Offshore)

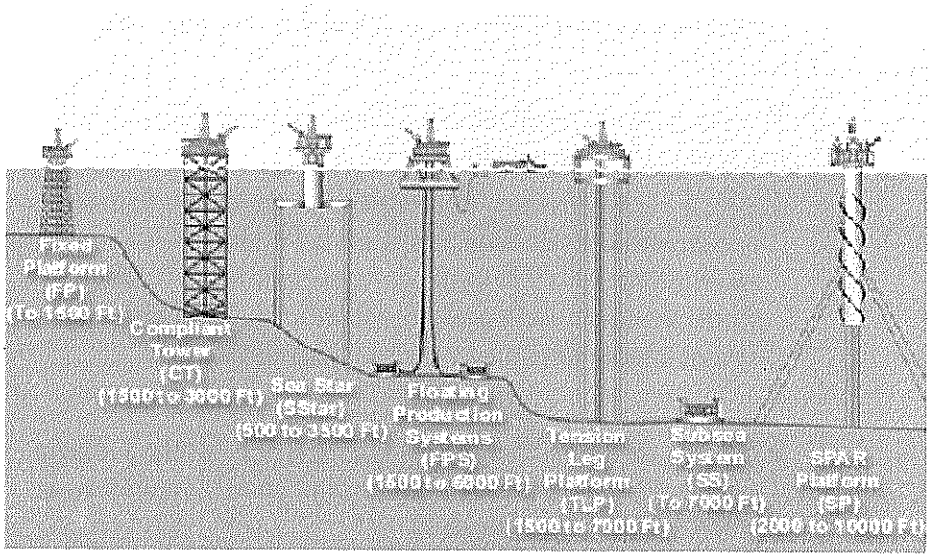


ภาพที่ 2.11 แสดงตัวอย่างของแท่นเจาะแบบแรกสัพ

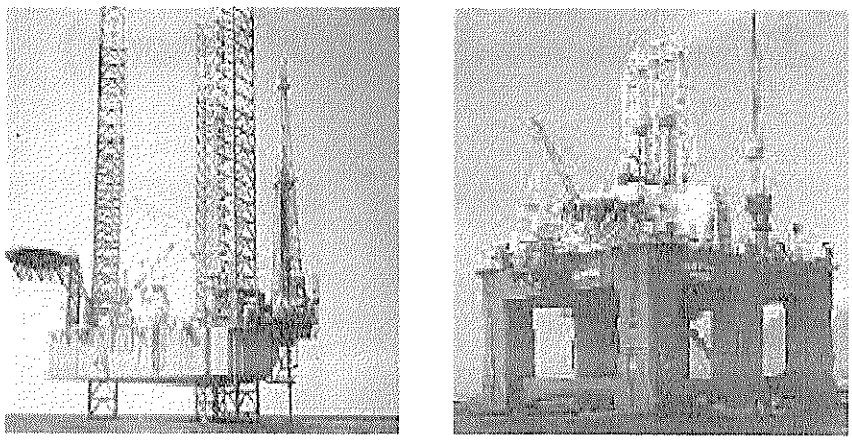
2. การเจาะหลุมสำรวจในทะเล (Offshore)

2.1.2 แท่นเจาะแบบฐานยึดติด (Fixed platform) เป็นแท่นเจาะที่นิยมใช้สำหรับการผลิตปิโตรเลียมหลังจากทำการเจาะหลุมเสร็จแล้ว เพราะเป็นการสร้างขึ้นเพื่อรองรับ การผลิตในระยะยาว จึงต้องมีการออกแบบและสร้างอย่างมั่นคง





ภาพที่ 2.12 แสดงรูปแบบทั่วไปของแท่นเจาะแบบฐานยึดติด



(a) (b)

ภาพที่ 2.13 แสดงตัวอย่างแท่นเจาะ (a) แบบเสาโลหะ และ (b) แท่นเจาะแบบโครงสร้างถ่าง ที่มา (a) TOSCO1. 2005. On-line (b) Kvaerner. 2005. On-line)

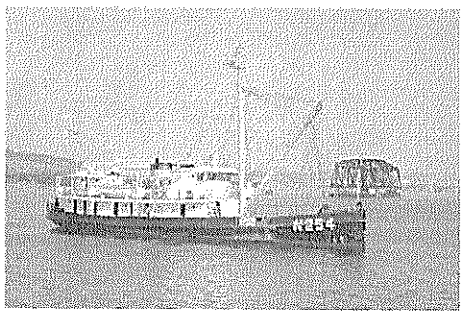
2. การเจาะหลุมสำรวจในทะเล (Offshore)

2.2 แท่นเจาะชนิดแท่นลอยโดยยึดติดกับพื้นทะเลด้วยสมอ เป็นแท่นเจาะที่ถูกออกแบบมาเพื่อให้สามารถเคลื่อนที่ได้ มี 3 แบบ

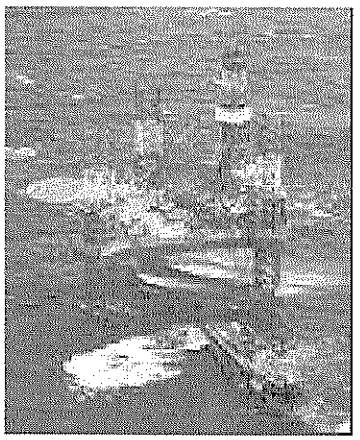
2.2.1 แบบเรือท้องแบน (barge) เป็นเรือท้องแบน มีอุปกรณ์การเจาะติดตั้งอยู่บนเรือ มักใช้เจาะบริเวณชายฝั่งน้ำตื้นหรือบริเวณทะเลสาบ ที่มีระดับน้ำไม่ลึกมากนัก น้ำจะถูกปล่อยเข้าตัวเรือในส่วนที่เรียกว่า ห้องอับเฉา เพื่อเป็นการถ่วงน้ำหนักเรือไม่ให้เคลื่อนที่ในขณะที่ทำการเจาะ เมื่อเจาะเสร็จก็จะทำการสูบน้ำออกเพื่อให้เรือลอยขึ้น

2.2.2 แบบเรือขุดเจาะขนาดใหญ่ (Drilling Ship) เป็นเรือขนาดใหญ่มีอุปกรณ์การเจาะติดตั้งอยู่บนเรือ มักใช้เจาะบริเวณที่มีระดับน้ำไม่ลึกมากนัก โดยเฉพาะในทะเล

2. การเจาะหลุมสำรวจในทะเล (Offshore)

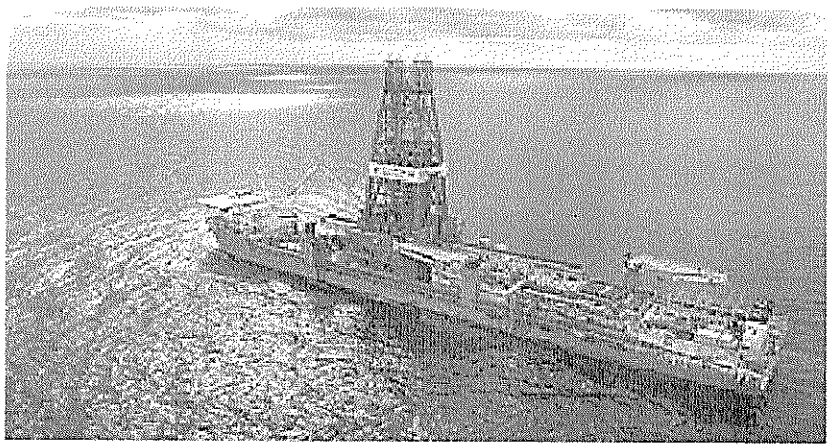


รูปที่ 2.14 แสดงตัวอย่างแท่นเจาะแบบเรือท้องแบน

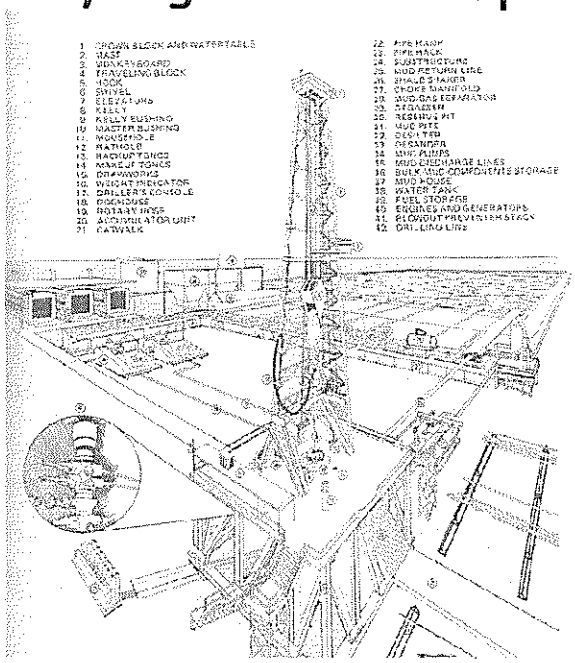


Barge

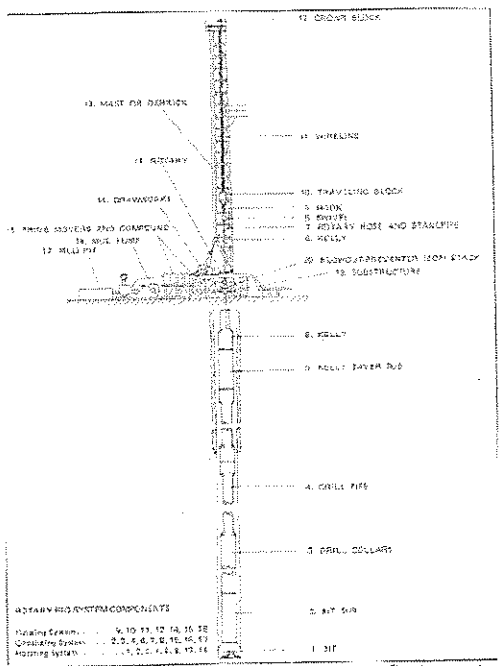
Drilling Ship

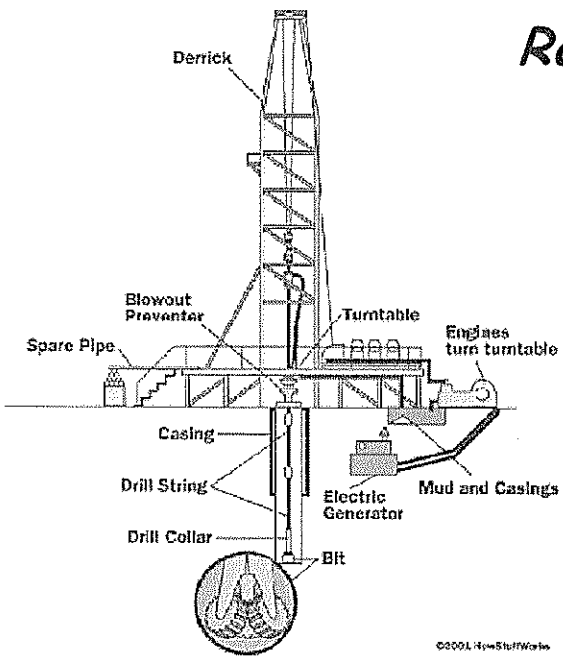


The Rotary Rig and Its components



Major Components of a Rotary drilling Rig

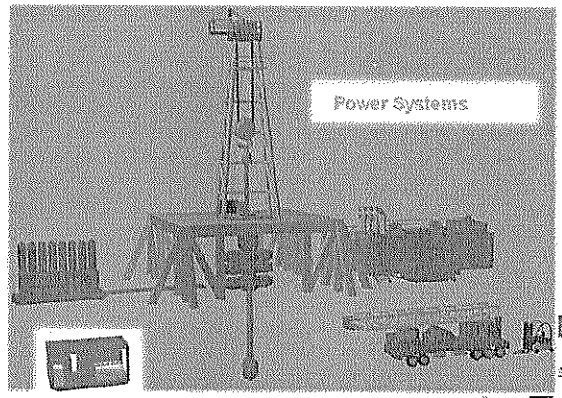




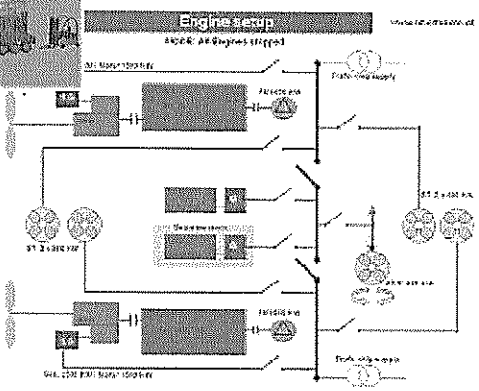
Anatomy of an oil rig

Rotation Drilling Systems

1. *Power System*
2. *Hoisting System*
3. *Rotating System*
4. *Circulation (mud) Sys.*
5. *Well control system*
6. *Well monitoring system*



1. A Rotary Rig Power System



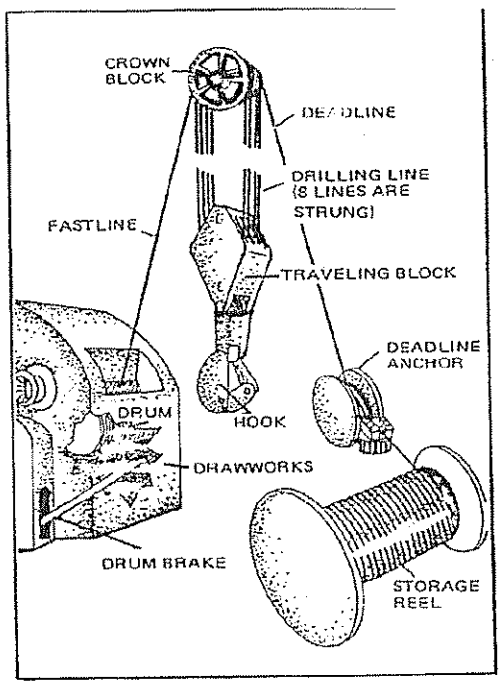
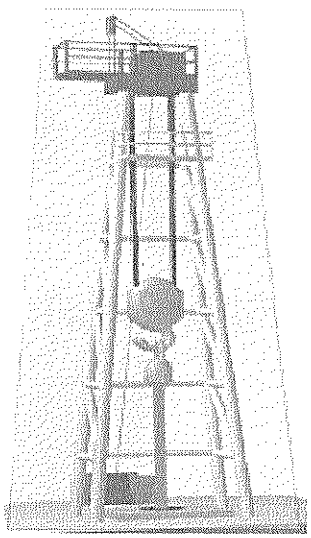


FIGURE 9. A ROTARY RIG HOISTING SYSTEM

2. A Rotary Rig Hoisting System



3. Rotating System

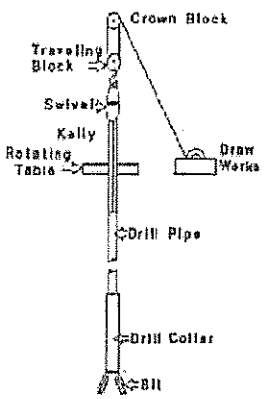


Figure 17-4 The rotary system

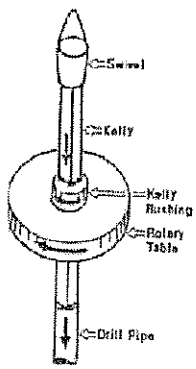
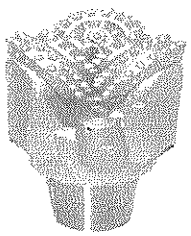


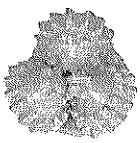
Figure 17-5 Close-up of the rotary system showing how the kelly fits into the rotary table

- Kelly
- Swivel
- Rotary table
- Drill pipe
- Drill collars
- Bit

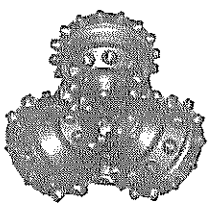
Type of drilling bits

1. Roller Cone (Rock) Bit

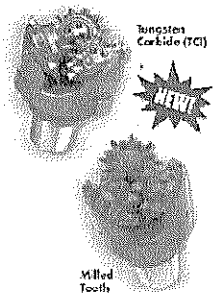




Mill tooth



Tungsten carbide Insert



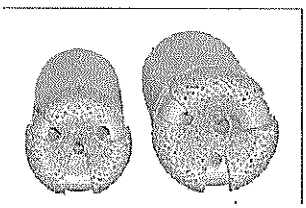
2. Polycrystalline diamond compact(PCD) Bit

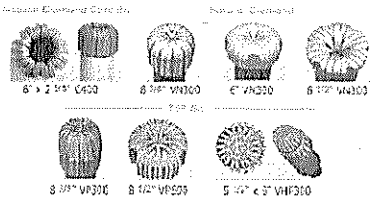
matrix body

steel body

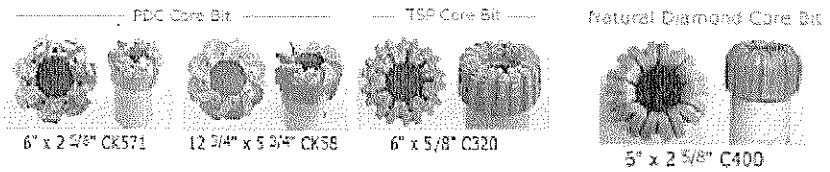
Type of drilling bits (Cont.)

3. Diamond Bit: natural diamond, thermal stable polycrystalline diamond (TSP)





4. Other Application Bits: core bits, bi-center bit, drillable shoe casing drilling bit



4. Circulation or Mud System

- The mud system is used to pump drilling mud down the drill string and back up to the surface.

Function of circulation:

1. Control the subsurface pressure via mud weight
2. Blow-out preventers (valves)
3. Prevent the hole from collapsing
4. Cool the drill bit
5. Remove the drill cuttings

- Drilling mud is a key element of the drilling process. If the mud weight is too high the reservoir may be damaged, if too low there may be a blow out if a high pressure zone is encountered.

Drilling Fluid

Type of Drilling Fluid

1. Water base mud
   - Fresh water base mud
   - Chemically treated mud
   - Calcium treated mud
   - Salt water mud (brackish mud)
   - Oil-in water emulsion mud
2. Oil base mud
   - Oil base mud
   - Water-in-oil base emulsion mud (invert mud)

The Drilling Mud System

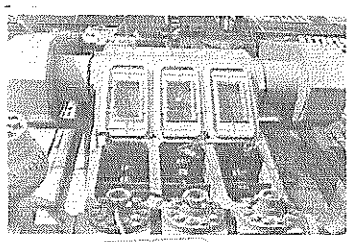


Figure 4.26. The mud pump pumps drilling fluid through the circulating system.

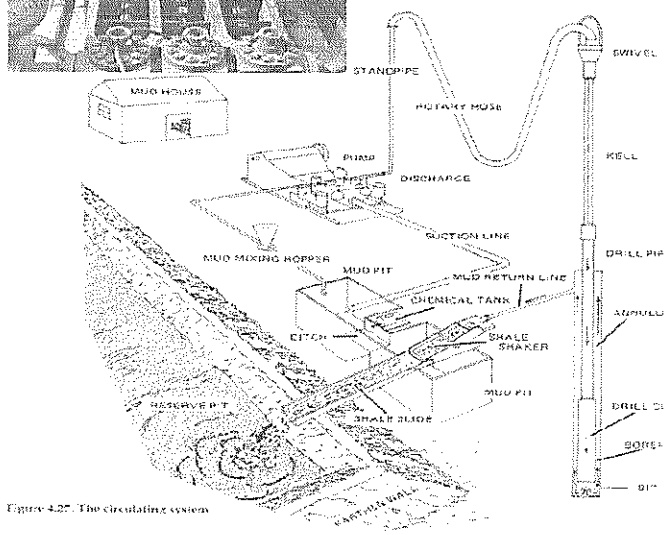
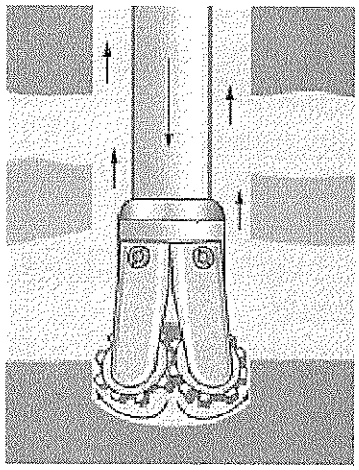
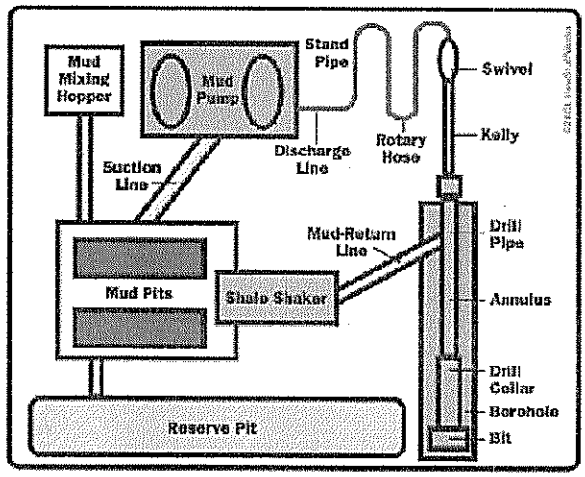


Figure 4.27. The circulating system

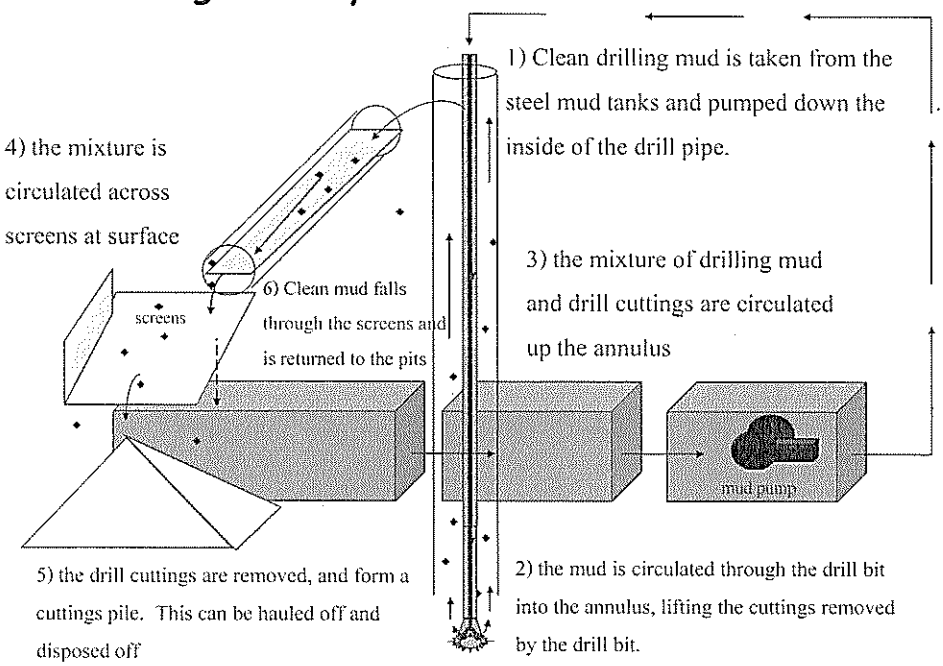
Circulation (mud) System



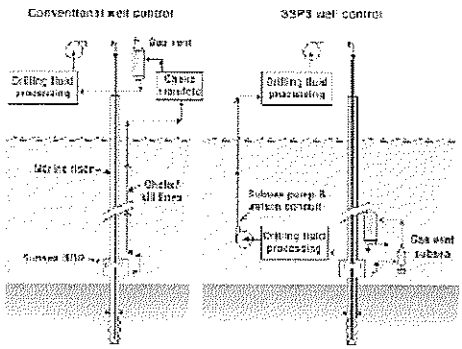


Mud circulation in the hole

The Drilling Mud System



5. Well control system



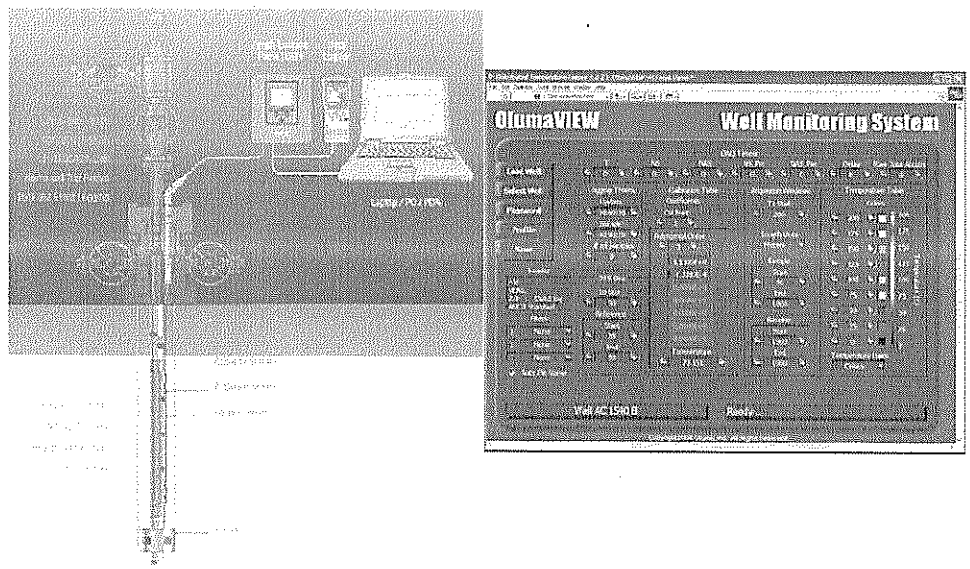
A conventional well control design (left) and the SSPS well control design (right).

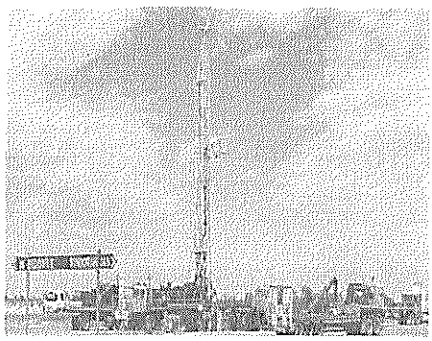
BOP system

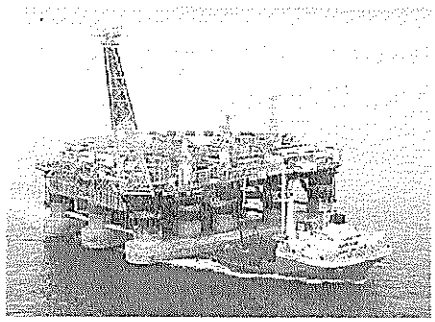
The activities involved in well control are:

1. Blowout Prevention Program (BOP)
2. Monitoring and Maintaining Mud System
3. Installing BOPs, Accumulator, and Choke Manifold
4. Testing BOPs Accumulators, and Choke Manifold
5. Maintaining Surface Control System

6. Well monitoring systems







Setting Up the Rig

Depending upon the remoteness of the drill site and its access

1. **Onshore Rigs:** *transported by truck, helicopter or barge.*
2. **Offshore Rigs:** *built on ships or barges*
   - work on inland water where there is no foundation to support a rig (as in marshes or lakes).

Drilling Operations
: Work by Field Engineers, Drilling Foremen

1. Well planning prior to SPUD (start to drill)
2. Monitor drilling operations
3. After drilling, review drilling results and recommend future improvements
   - prepare report.
4. General duties.

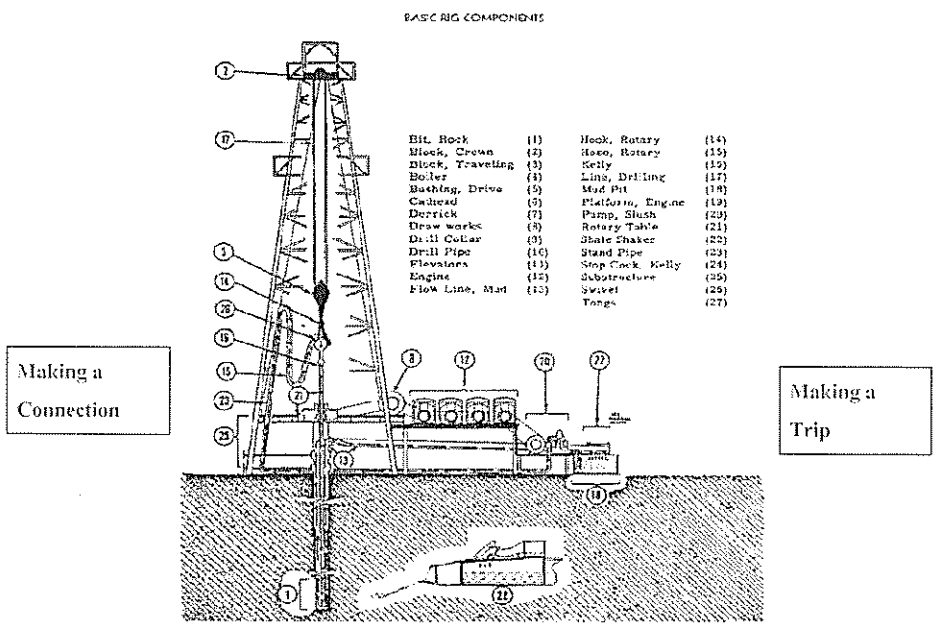
What are the well requirements?

Target: objectives, safety, cost

Routine Drilling Operation

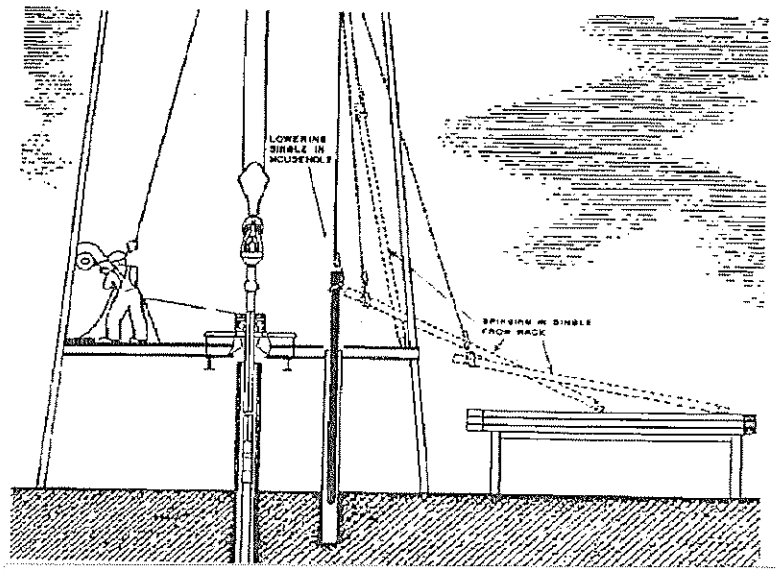
Drilling continues in stages:

- After SPUD (start to drill)
- Continues Drilling
- Then run and cement new casings,
- Then drill again. When the rock cuttings from the mud reveal the oil sand from the reservoir rock, (reached the final depth).
- At this point, remove the drilling apparatus from the hole and perform several tests to confirm this finding



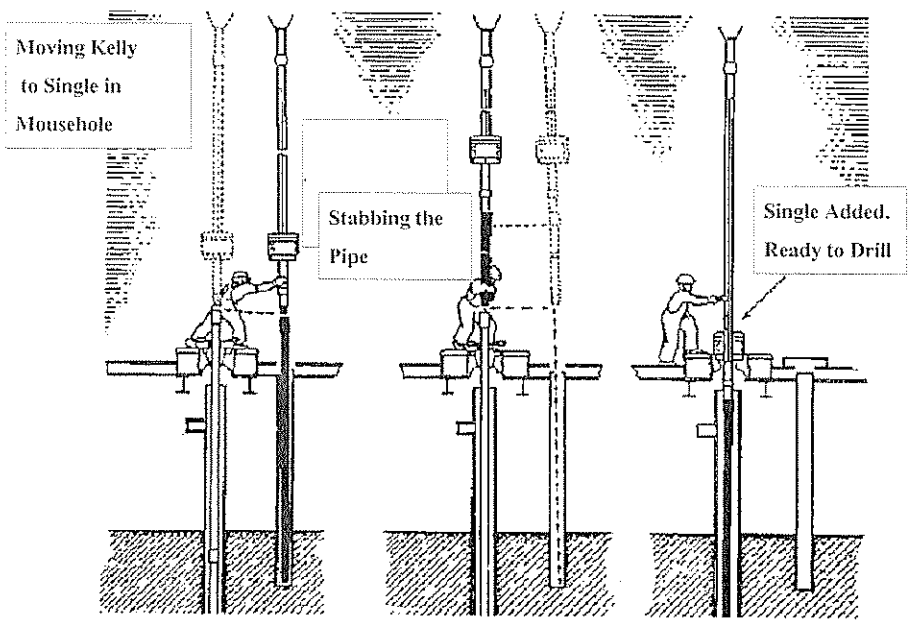
Basic components of a rotary drilling rig. Courtesy API.

Tripping: the operation of hoisting the drill stem out of and returning it to the wellbore



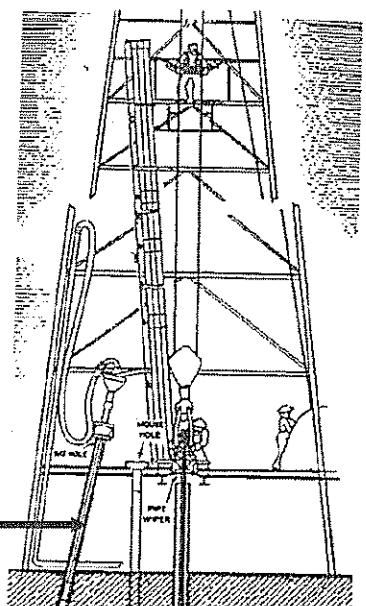
Making a mousehole connection

Mousehole เป็นหลุมที่มีไว้สำหรับพักท่อที่จะนำมาเปลี่ยนท่อ (tripping) โดยย้าย Kelly ไปต่อกับท่อที่ Mousehole ได้เลย



Making a mousehole connection - cont'd

Making a trip

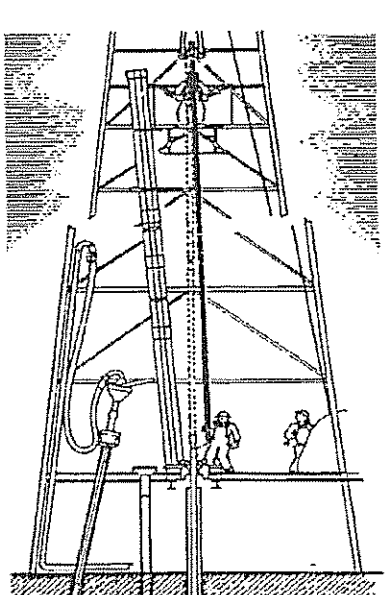


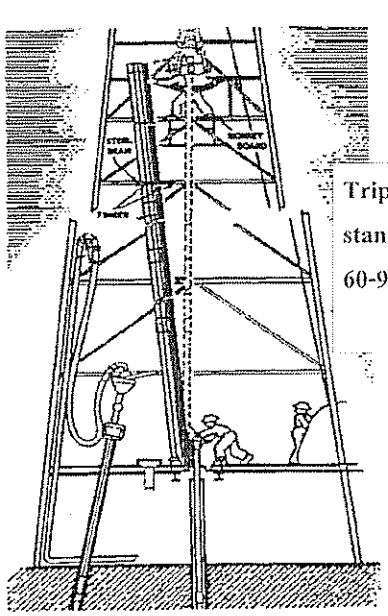
Why trip?

Use Elevators for tripping

Put Kelly in Rathole

Rathole เป็นหลุมที่มีไว้สำหรับพักท่อ Kelly ที่จะนำออกมาจากหลุมเพื่อจะทำการเปลี่ยนท่อ (tripping) โดยใช้ตัวยก





Tripping one stand at a time 60-90 ft

Making a trip - cont'd

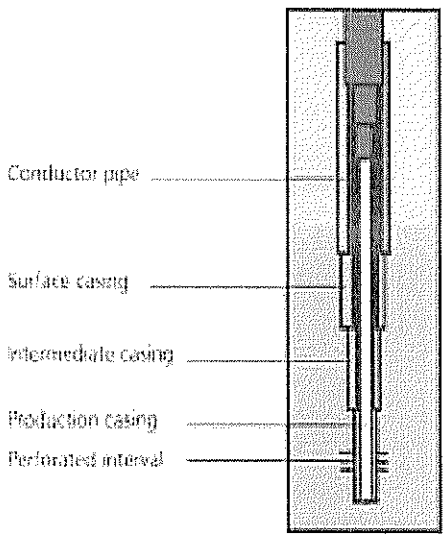
Casing

Function of casing

1. Prevents caving of the hole
2. Prevents contamination of fresh water zone
3. Excludes water from the producing formations
4. Confines production to the well bore
5. Provide the anchor for blowout preventers
6. Seals off troublesome zones to permit deeper drilling
7. Facilitates the installation of subsurface equipment required for artificial lift

Type of casing

1. Conductor pipe
2. Surface casing
3. Intermediate casing
4. Production casing
5. Liner or perforated interval



Function of Casing Type

1. **Conductor pipe:** the first pipe string run on location, it set by driving or hammer down on ground. It protect the soft formation from caving in. (structural base for BOP and well Christmas Tree)

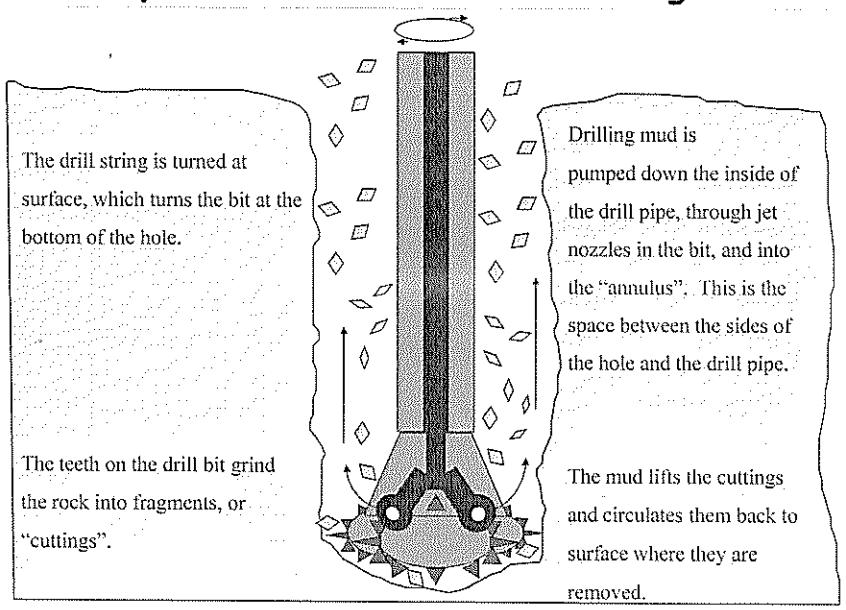
2. **Surface casing:** use for control gas and the protect freshwater zones (Rig up of BOP, required by Law)

3. **Intermediate casing:** secure the well against collapse, lost circulation, abnormal pressure and other down hazards.

4. **Production casing:** set at production zones and facilitate production tubing and other well completion equipments.

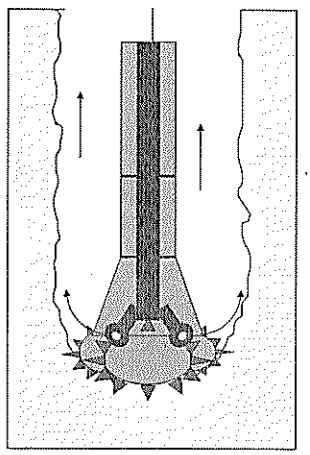
5. **Liner or perforated interval:** the pipe string which not come to surface but suspended from the casing above by using hanging device.

Here's a picture of the drill bit drilling the rock.

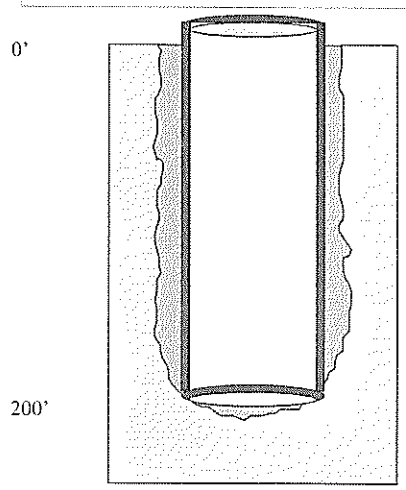


Here's a sequence showing how holes are drilled,

First, a large drill bit is used to drill a short interval of hole.

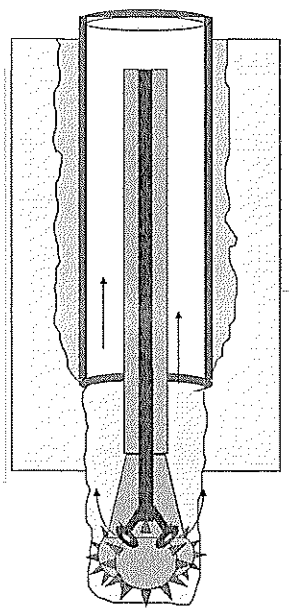


Then, steel casing is run and cemented on the outside to keep the hole from collapsing.

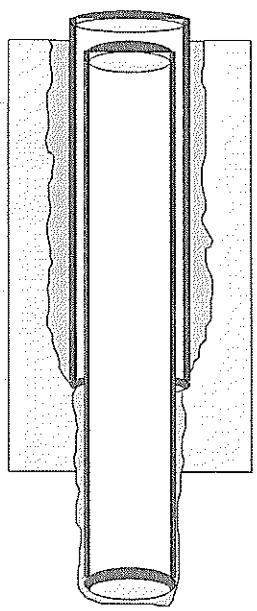


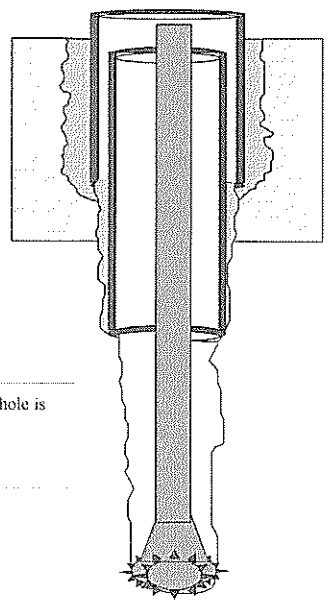
Next,
a smaller bit is run inside the first casing.

This bit drills out the bottom of the casing, and drills new hole.

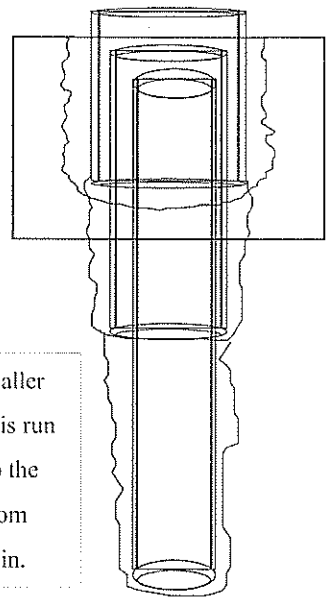


Then, this new hole is also cased off and cemented.





Again, a smaller hole is drilled out,



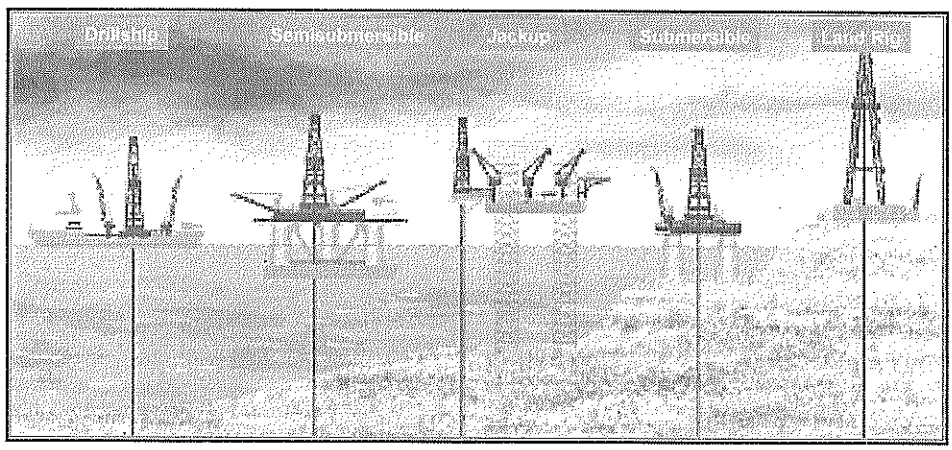
and smaller casing is run to keep the hole from falling in.

Development of offshore drilling

- **Offshore drilling** typically refers to the discovery and development of oil and gas resources which lie underwater.

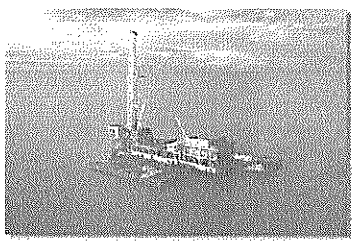
- **Start 1930's** petroleum exploration companies realized that oil and gas reservoirs existed in shallow waters offshore

Offshore drilling rigs

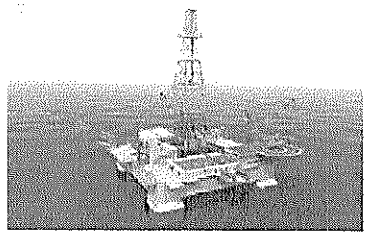


10,000 ft 4,000 ft max 400 ft max 50-150 ft

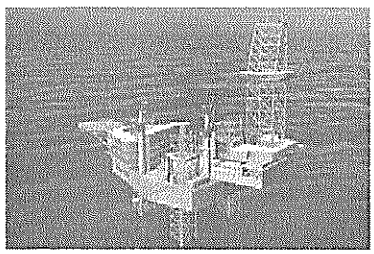
Mobile offshore drilling units (MODU)



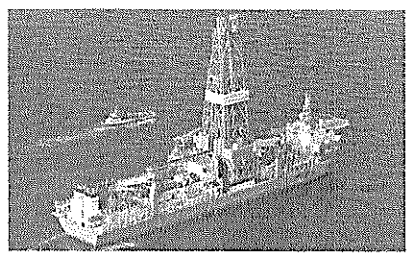
Submersible rig



Semi-Submersible rig



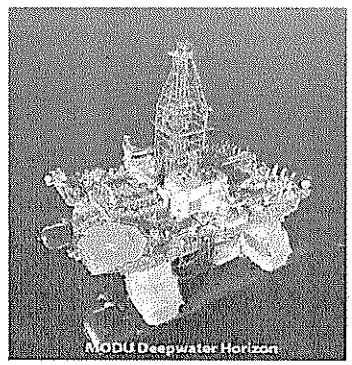
Jackup



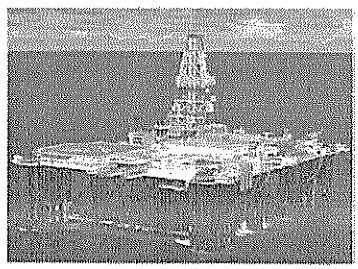
Drill ship

Mobile offshore drilling units (MODU)

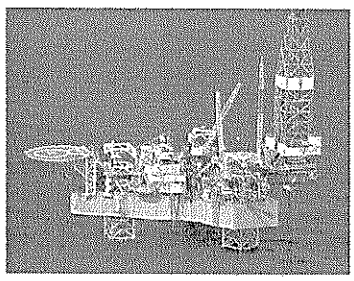
MODU is a genetic term for several classes of self-contained floatable or floating drilling machines such as submersible, jackups, semisubmersibles, and drilling shipe.



Mobile offshore drilling units (MODU)

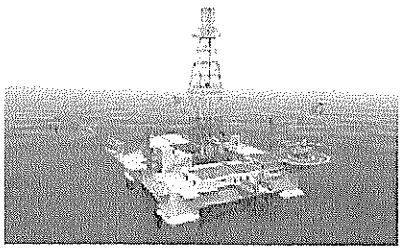


Submersible rig was a posted barge. It consisted of a barge with several steel posts attached.

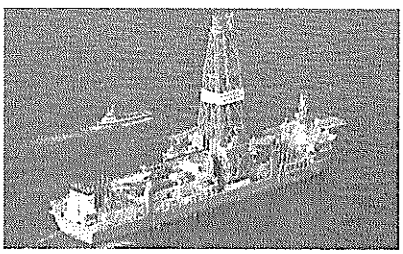


JACKUP Modu is a self-contained combination drilling rig and floating barge, fitted with long support legs that can be raised or lowered independently of each other.

Mobile offshore drilling units (MODU)

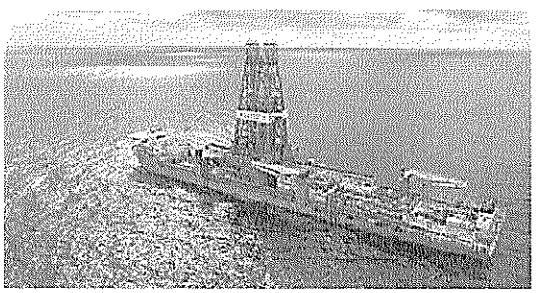


Semisubmersable is a particular type of floating vessel that is supported primarily on large pontoon-like structures submerged below the sea surface.

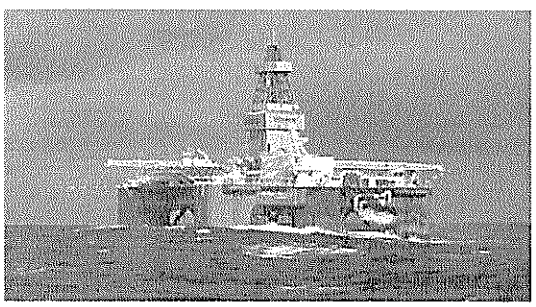


Drillship is a maritime vessel modified to include a drilling rig and special station-keeping equipment. The vessel is typically capable of operating in deep water.

Examples of drill ships

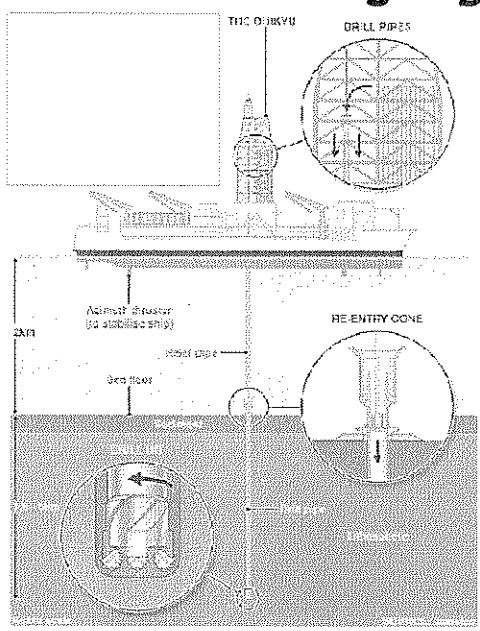


The *Discoverer Deep Seas* drill ship sits off the coast of Louisiana as Chevron drills for oil in the Gulf of Mexico.

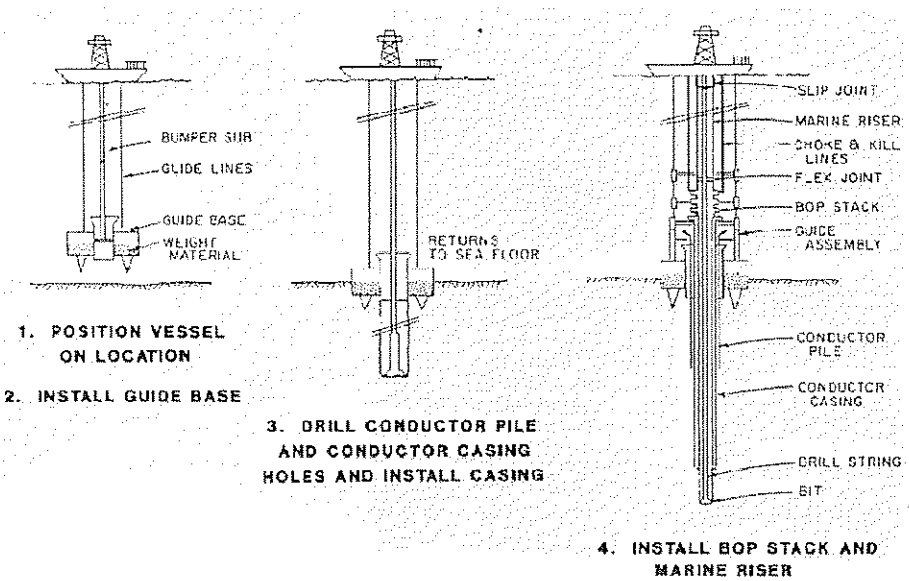


Drilling off the coast of Cuba.

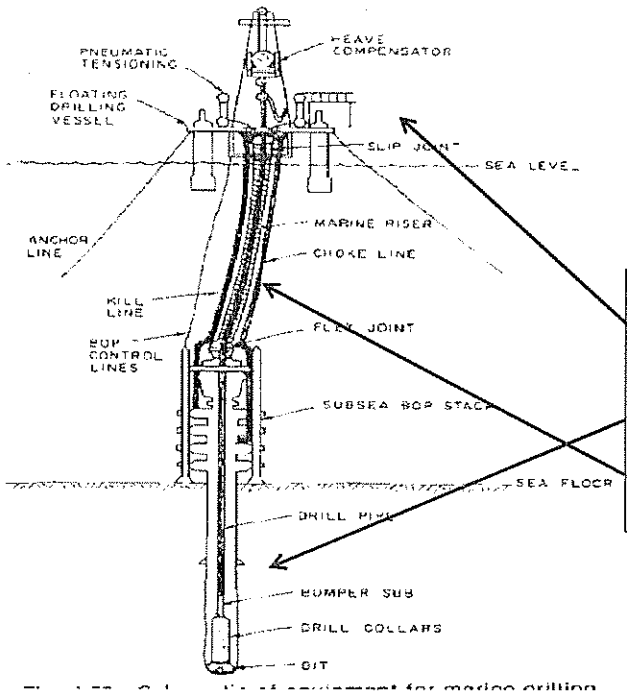
Offshore drilling rig.



Subsea Equipment Installation Procedure



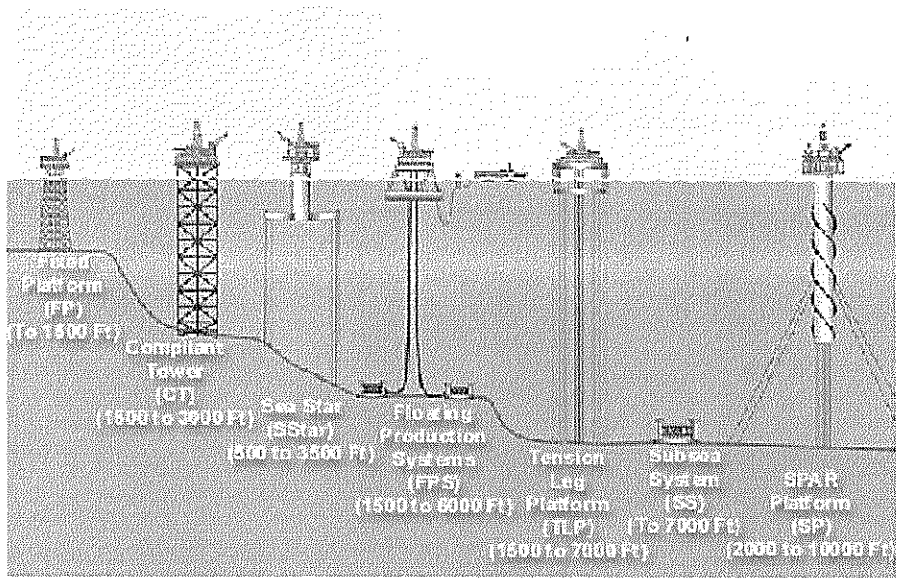
1. POSITION VESSEL ON LOCATION
2. INSTALL GUIDE BASE
3. DRILL CONDUCTOR PILE AND CONDUCTOR CASING HOLES AND INSTALL CASING
4. INSTALL BOP STACK AND MARINE RISER

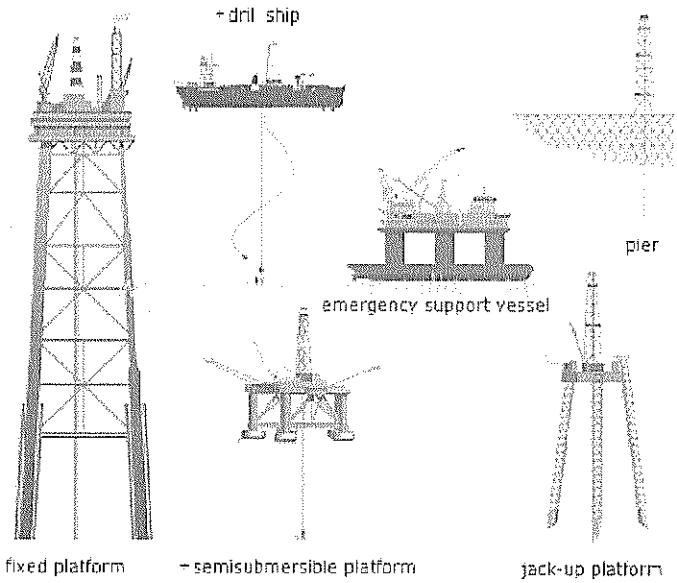


Schematic of Equipment for Marine Drilling

1. Floating Drilling Vessel
2. Rotary System
3. Riser System

Offshore Platform Type





A Tension Leg Platform

2,000-10,000 ft

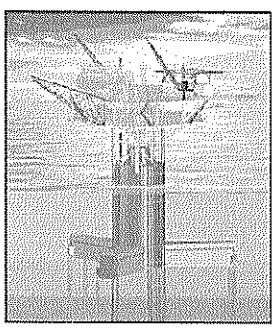


Figure 5.3: British-Borneo used the SeaStar TLP, pictured above, to develop Morpeth and Allegheny Courtesy of British-Borneo Exploration, Inc.

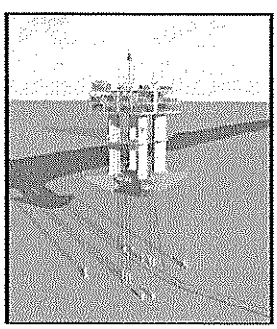
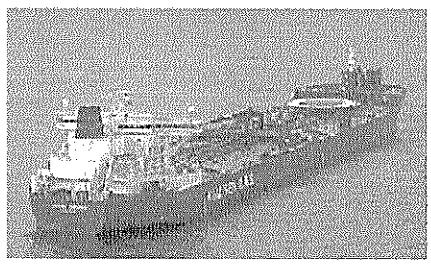


Figure 5.4: Modec's "Mercs" design is being considered by at least one GOM operator. Courtesy of Modec (U.S.A.) Inc.



A Floating Production System

(FPS)

1,500-8,000 ft

Platform installation

Erawan Platform

Ex: Erawan Platform

ประกอบด้วยโครงสร้างที่สำคัญดังนี้

1. แท่นหลุมผลิต (well platform) มีอยู่ทั้งหมด 12 แท่น จากแนว A-L เป็นฐานที่ใช้ขุดเจาะเพื่อนำปิโตรเลียมขึ้นมา
2. แท่นผลิตย่อย (remote processing platform) มี 4 แท่น คือ แท่น B, C, D และ E สร้างขึ้นคู่กับแท่นหลุมผลิต B, C, D, E เพื่อทำหน้าที่นำปิโตรเลียมจากแท่นผลิตมาเข้ากระบวนการแยก gas, condensate or oil and water ในขั้นต้นเพื่อนำส่งต่อไปยังแท่นผลิตกลาง
3. แท่นผลิตกลาง (central processing platform) เป็นแท่นเดียวในแหล่งนี้เป็นที่สำหรับรวบรวม petroleum ไปกักเก็บที่เรือ
4. แท่นที่พักอาศัย (living quarter platform) เป็นที่สำหรับที่พักอาศัยของพนักงานอยู่ในบริเวณเดียวกับแท่นผลิตกลาง และแท่นหลุมผลิต A
5. เรือกักเก็บปิโตรเลียม (Erawan Tanker or Floating storage unit) เป็นที่กักเก็บ condensate จากแหล่งต่างๆ เพื่อทำการขนถ่ายและจำหน่ายทั้งแก่ ปตท และส่งออกต่างประเทศ

Special Drilling Procedures

1. Directional Drilling
2. Fishing
3. Air and gas drilling
4. Foam drilling

1. Directional Drilling

What is Directional Drilling?

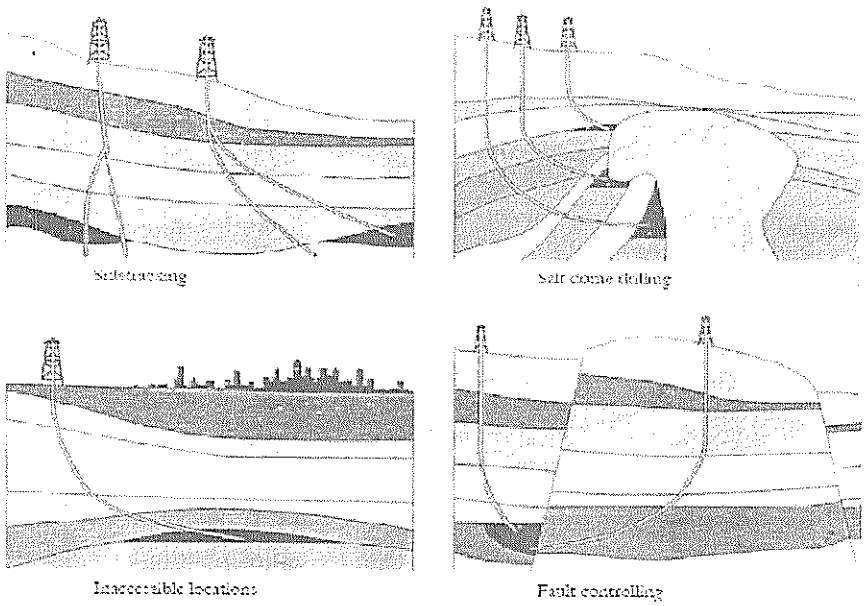
Directional Drilling (DD) is the well bore is deliberately deviated from the vertical along a predetermined course to a target reservoir.

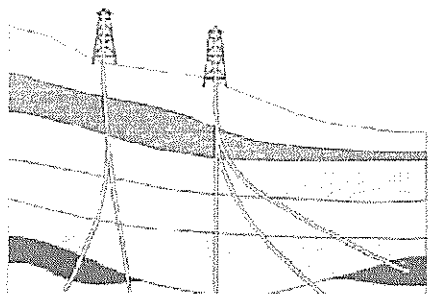
Basically it refers to drilling in a non-vertical direction. Even "vertical" hole sometimes require directional drilling techniques.

Objectives of directional drilling

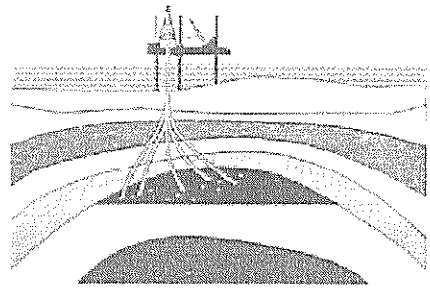
1. Multiple wells from single structure and/or location
2. Shoreline drilling
3. Fault control
4. Inaccessible location: under building
5. Stratigraphic traps (salt dome)
6. Relief well control
7. Sidetracing off the obstruction (fish)
8. Reducing well course to more promising targets

Directional Land drilling

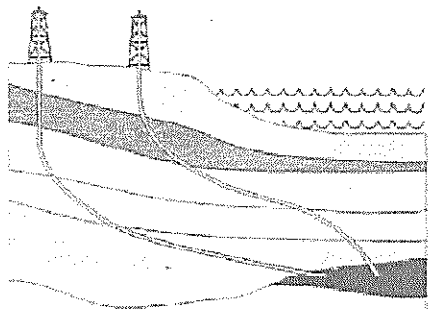




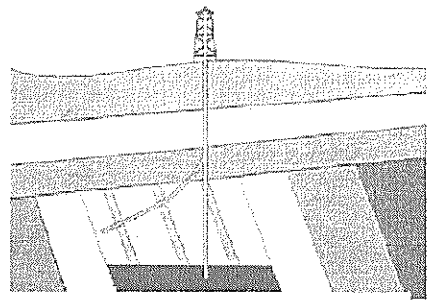
Multiple wells from a single well



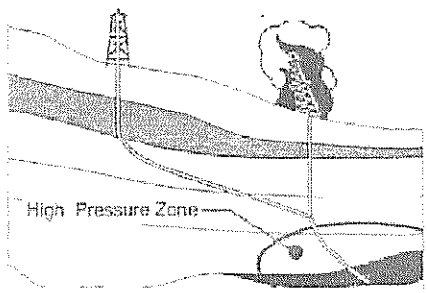
Offshore multi-well drilling



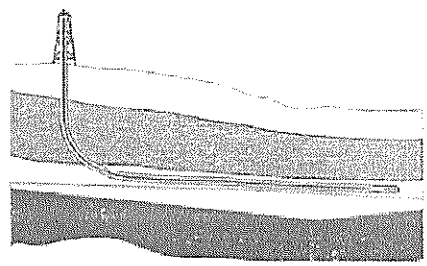
Under lakes



Multiple sands from a single wellbore



Drilling relief wells



Horizontal wells

Why not drill from top of mountain?

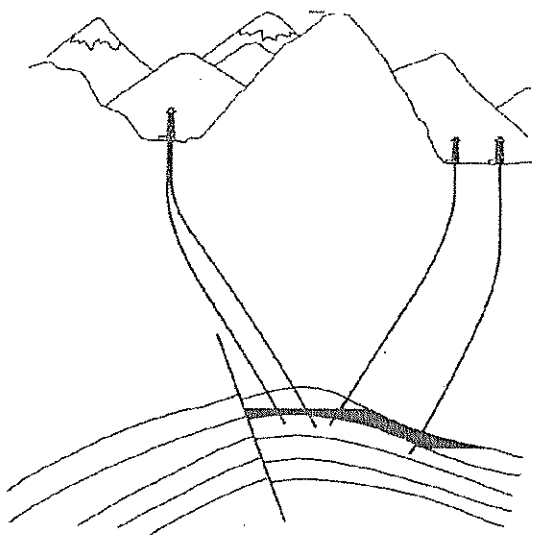
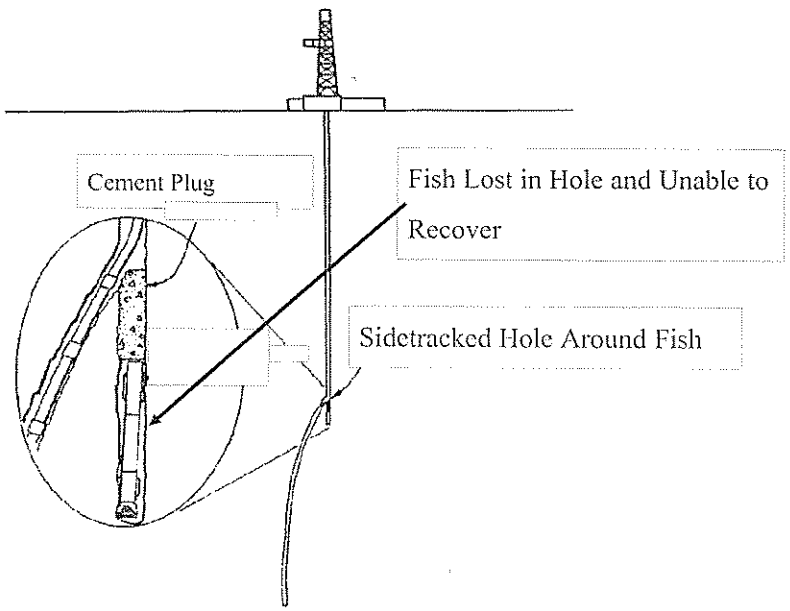
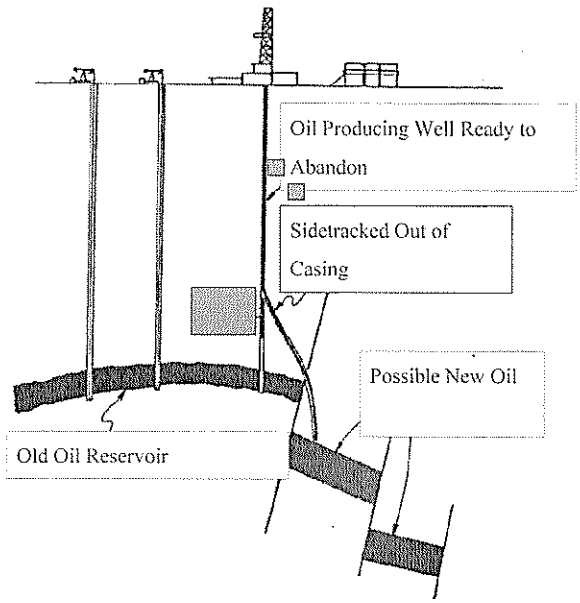


Fig: Drilling of directional wells where the reservoir is beneath a major surface obstruction.



Using an old well to explore for new oil by sidetracking out of the casing and drilling directionally.

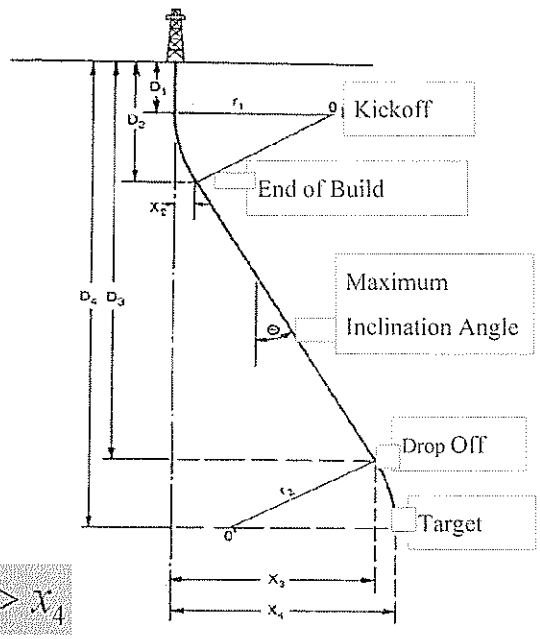


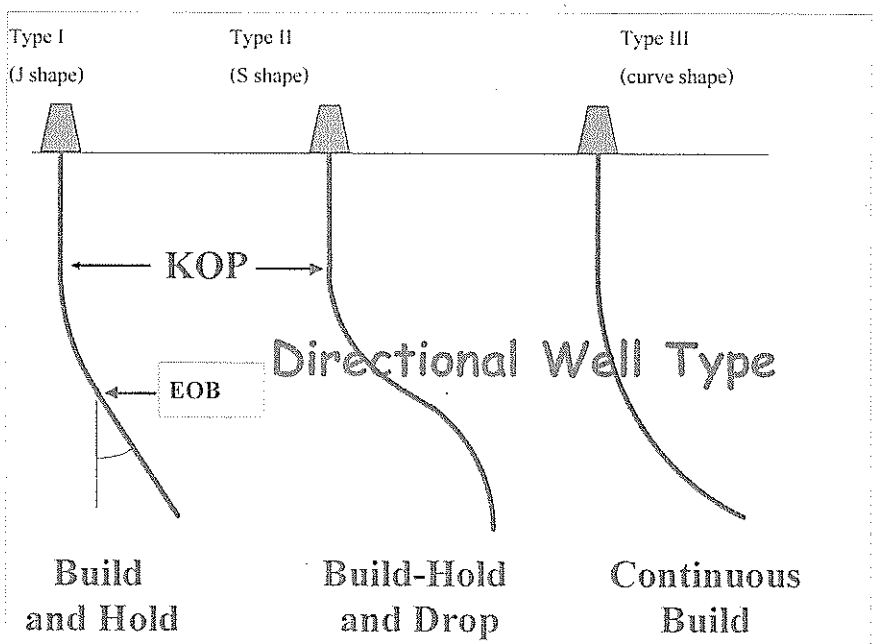
Directional Drilling

Type II

Build-hold-and drop for the case where:

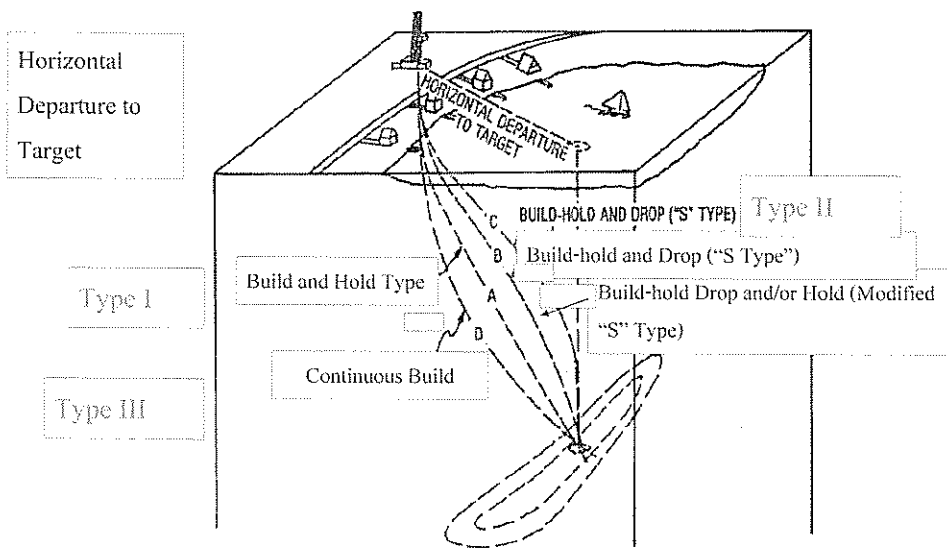
$$r_1 < x_3 \text{ and } r_1 + r_2 > x_4$$





Major types of wellbore trajectories

(วิถีเส้นทางการเจาะ)



Directional Tools

1. Whipstock
2. Jet Bits
3. Downhole motor (mud motor) and bent sub

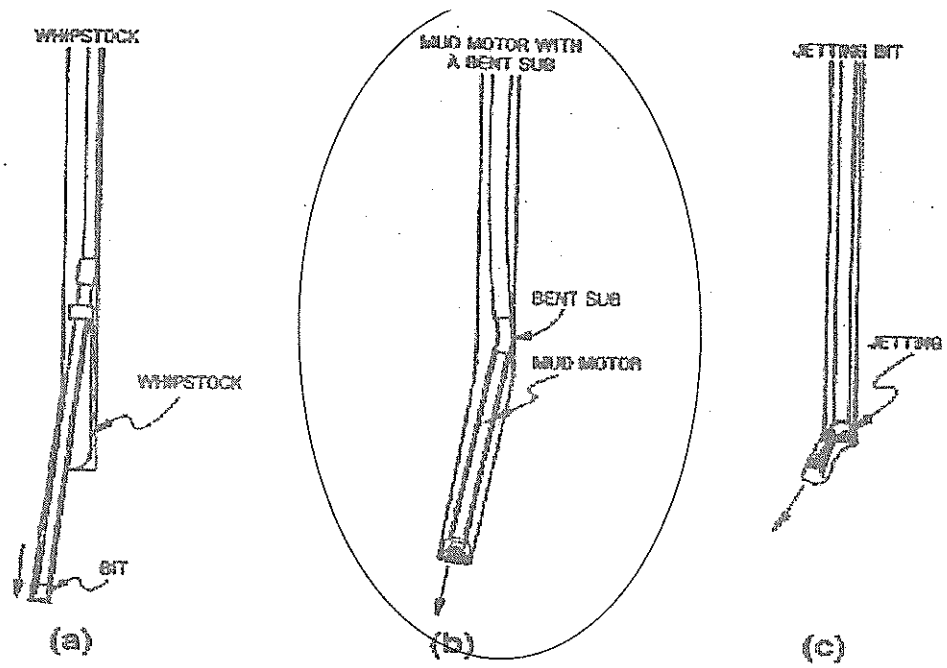
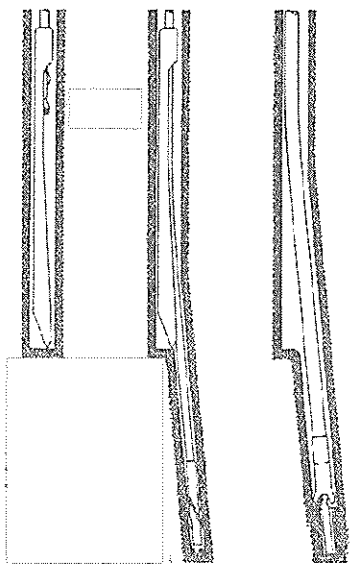


Fig. 8.23—Techniques for making a positive direction change.

1. Setting a Whipstock

- Small bit used to start
- Run whipstock to the KOP depth
- Apply weight to:
  - set chisel point & shear pin
- Drill 12'-20'
- Remove whipstock
- Enlarge hole

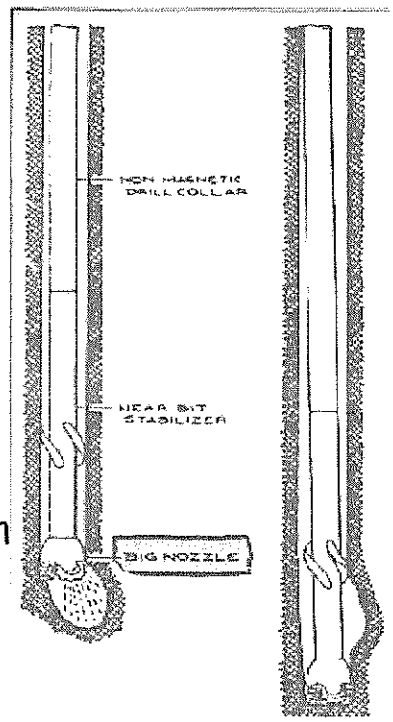


2. Jetting

- Wash out pocket (One nozzle: big boy)
- Return to normal drilling

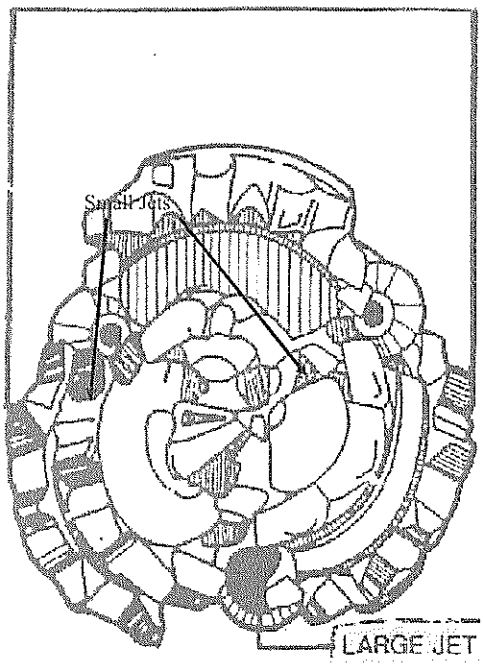
Survey

- Repeat for more angle if needed
- Good for soft and unconsolidated formation
- Good for anti-collision purpose

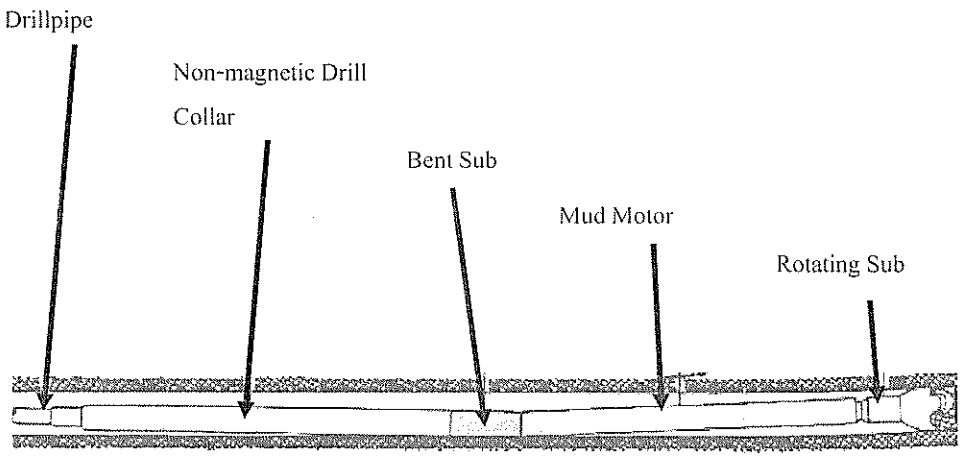


Jetting Bit

- Fast and economical
- For soft formation
- One large - two small nozzles
- Orient large nozzle
- Spud periodically
- No rotation at first



3. Mud Motors and Bent Sub

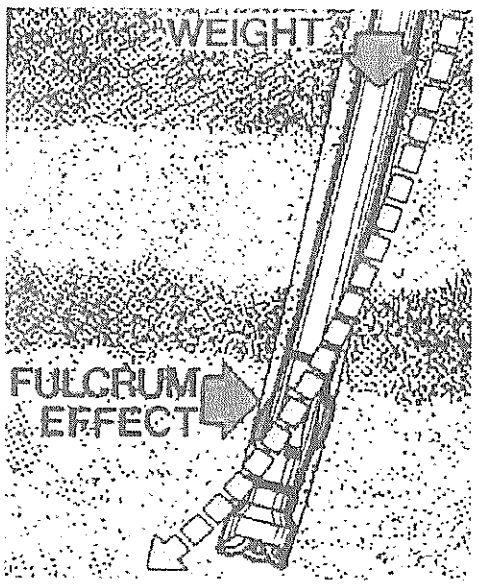


Directional drilling operation

1. Drill the vertical (upper) section of the hole.
2. Select the proper tools for kicking off to a non-vertical direction (inclination)
3. Build angle gradually

Increasing Inclination

- Limber assembly (อุปกรณ์ที่งอได้)
- Near bit stabilizer (ทำให้คงที่)
- Weight on bit to bend to low side of hole (ใส่น้ำหนักไปที่หัวเจาะเพื่อให้มันโค้งงอ)
- Bit face kicks up (ทำการเจาะโดยหัวเจาะต่อไป)

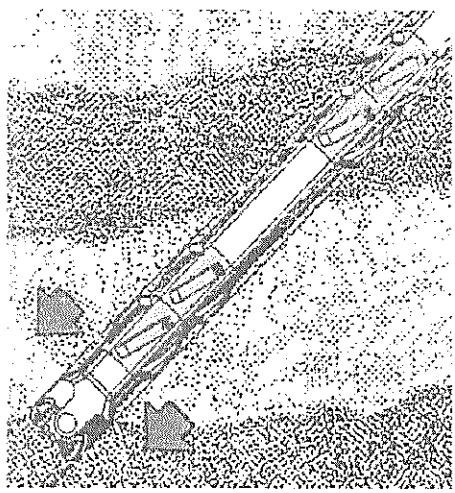


Hold Inclination

- Packed hole assembly

(ใส่อุปกรณ์เพิ่มเข้าไปอัด)

- Stiff assembly (อุปกรณ์ที่ใส่จะทำให้ท่อเจาะมันยืดตรง)
- Control bit weight and RPM (ควบคุมน้ำหนักของหัวเจาะและอัตราความเร็วของการเจาะ)

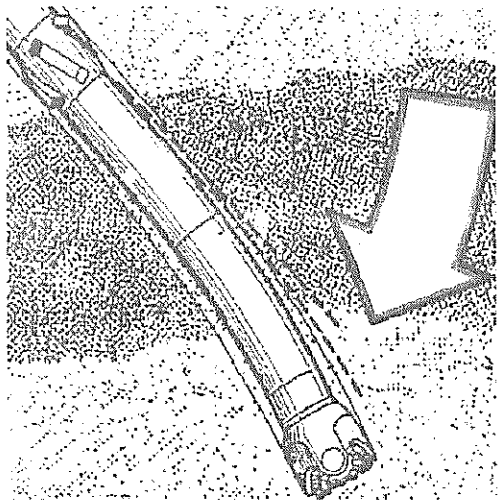


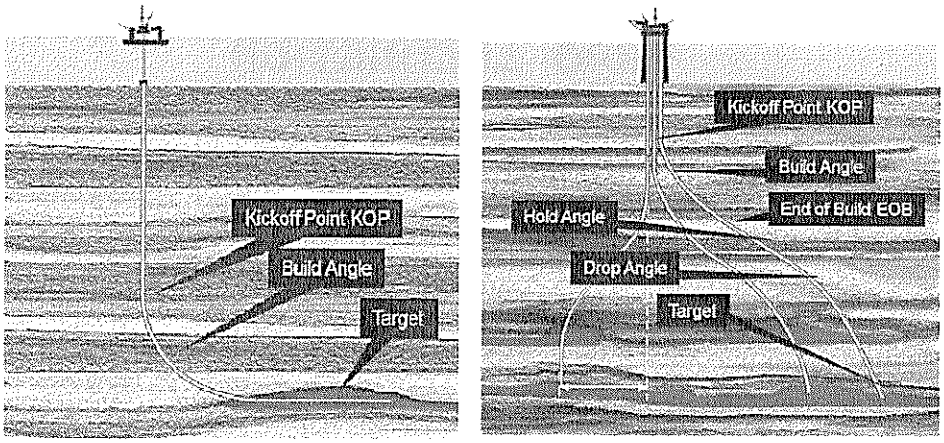
Decrease Inclination

- **Pendulum** effect

(ใส่ลูกตุ้ม)

- **Gravity pulls** bit downward
- **No** near bit stabilizer

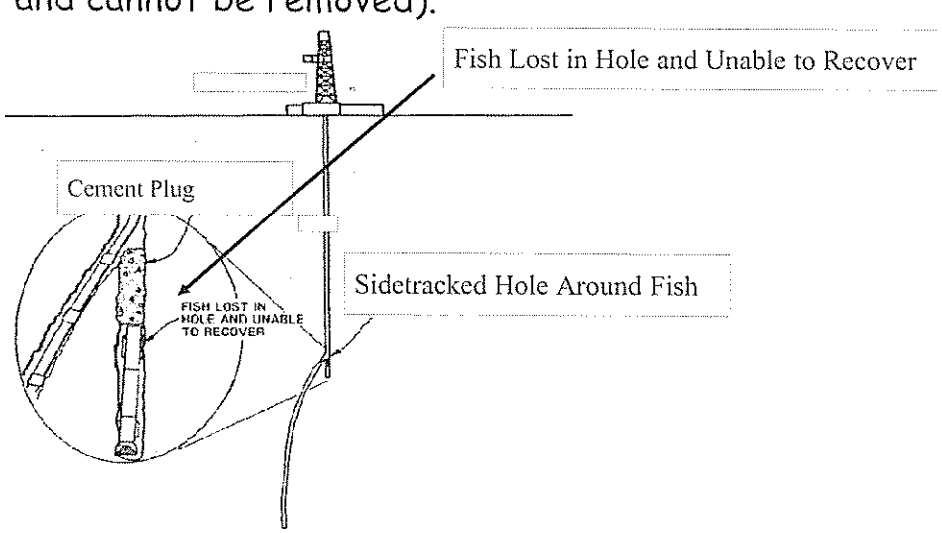




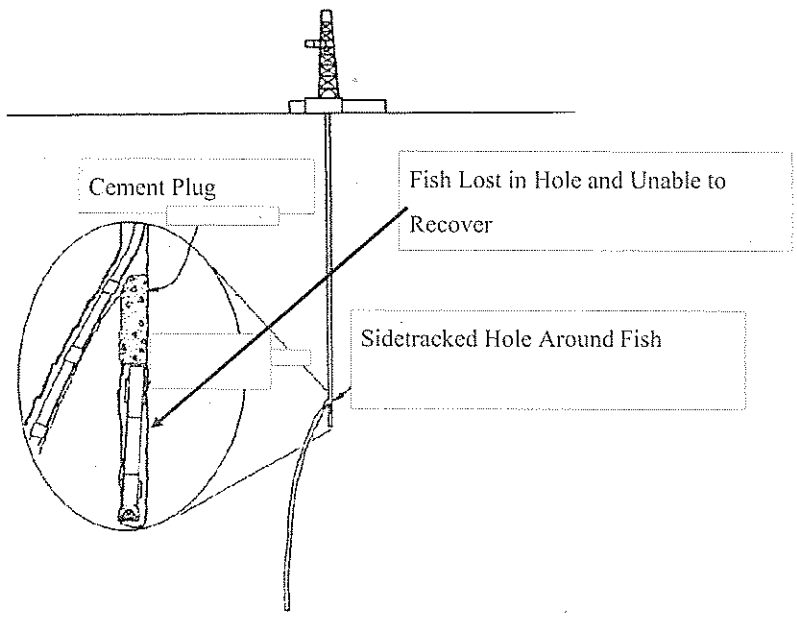
- Directional well bits can be used to straighten a hole, deflect the hole from the original dry well to intersect a reservoir, kill a wild well that is burning, or sidetrack around a "fish"

2. Fishing

"Fish" (an object that has become lodged in the hole and cannot be removed).

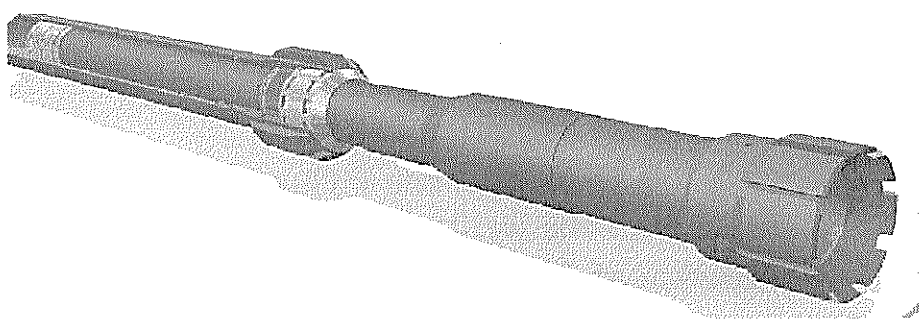


Sidetracking around a fish.



Fishing

- The application of tools, equipment and techniques for the removal of junk, debris or fish from a wellbore. The tools and techniques employed and the process by which the recovered fish will be handled at surface.



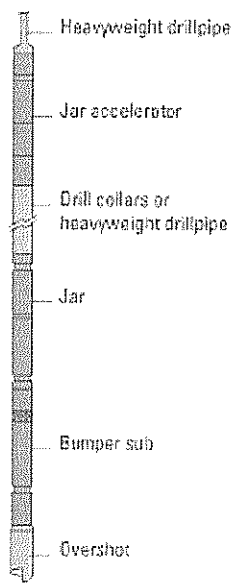
Fishing Tool

- A general term for special mechanical devices used to aid the recovery of equipment lost downhole.

These devices generally fall into four classes:

- Diagnostic (การตรวจหา การวินิจฉัย)
- Inside grappling (ตัวจับด้านใน)
- Outside grappling (ตัวจับด้านนอก)
- Force intensifiers or jars (ตัวกระชับ)

Typical Fishing String



3. Air and gas drilling

- A drilling technique whereby gases (typically compressed air or nitrogen)
- used to cool the drill bit and lift cutting out of the wellbore, instead of the more conventional use of liquids.

: **Advantages of air drilling**

1. Much faster than drilling with liquids
2. Decrease the lost circulation problems.

: **Disadvantages of air drilling**

1. Inability to control the influx of formation fluids into the wellbore
2. Absence of the wellbore pressure

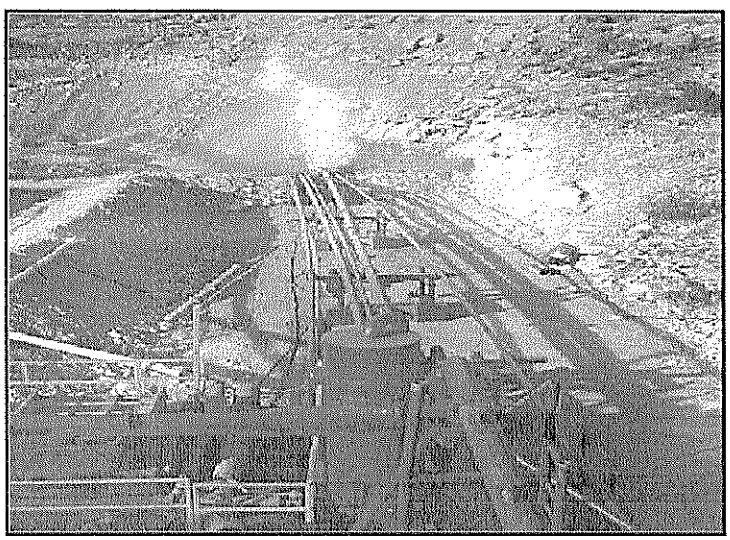
Gas Drilling

- First commercial drilling was with gas in the U.S. (1940's)

Common Drilling Gases

- Air.
- Natural gas.
- Nitrogen.
- Engine exhaust (Nitrogen).

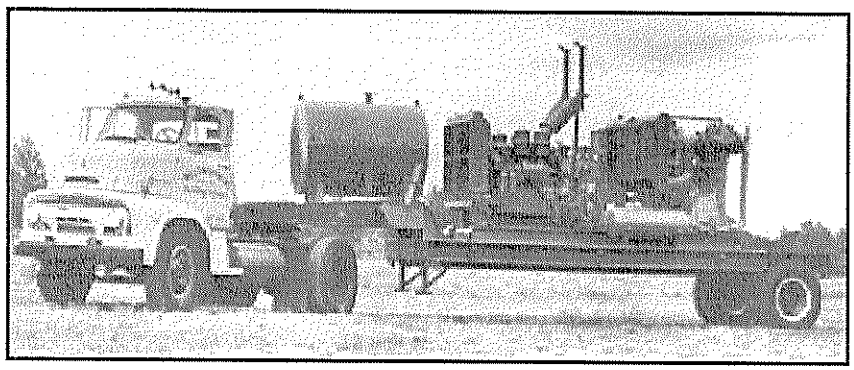
Gas Drilling, NG Producing 3MM SCF/day



Natural Gas for Unbalance (UB) Drilling

- Available.
- No downhole fires.
- No corrosion.
- Low cost, long term contracts.

Western Air Drilling, 1954



First Widespread use came with development of portable air compressors.

Advantages of Gas Drilling

- Increase drilling rate.
- No lost circulation*
- No differential sticking.
- Minimal reservoir damage.

Problems with Gas Drilling

- **Water.** (การทะลักเข้ามาของน้ำ)
- **Washouts, especially in coal.** (การชะล้าง เช่น ถ่านหิน)
- **Corrosion.** (กัดกร่อน)
- **Downhole fires with air.** (การลุกไหม้)
- **Crooked hole.** (การคดงอของหลุม)

4. Foam Drilling

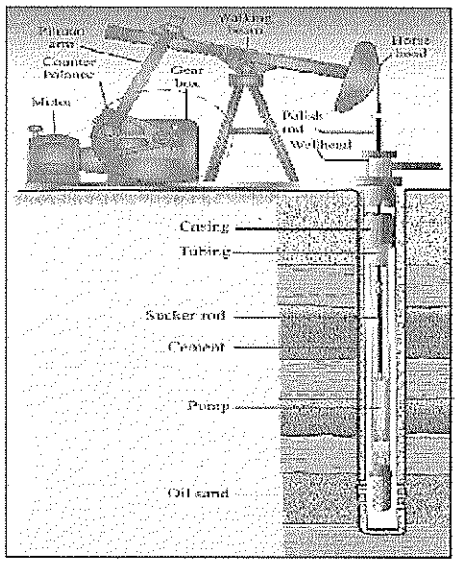
FOAM

Has the greatest potential of any of the "Light" fluids.

Advantages of Foam Drilling

- Great lifting capacity. (10X of mud)
- Controllable BHP (borehole pressure).
- Increase drilling rate.
- No lost circulation*
- Minimal reservoir damage.

Chapter 5
Petroleum Production

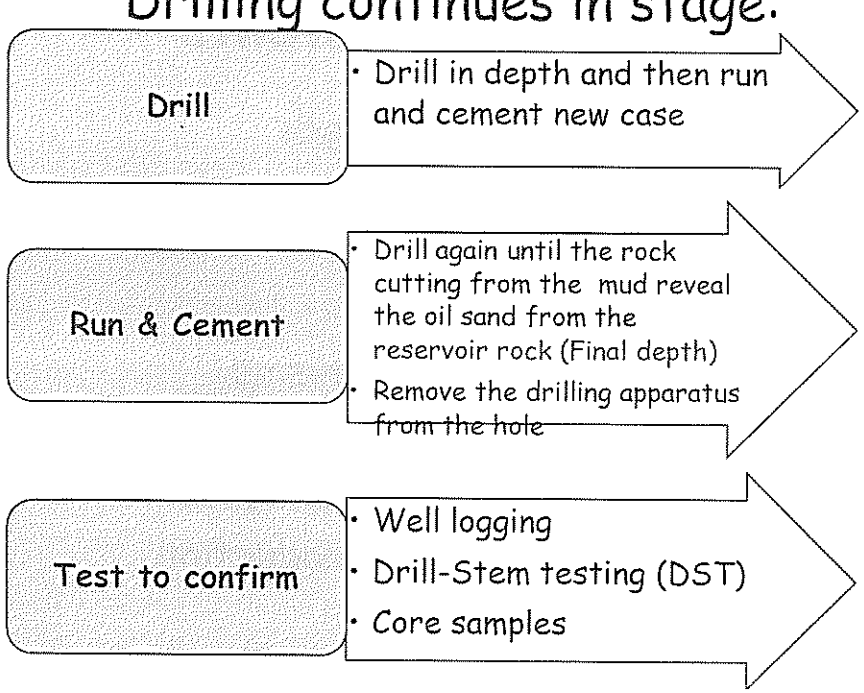


Course Contents

- Early production methods
- Well completion
- Well testing
- Reservoir stimulation
- Reservoir drive mechanisms
- Artificial lift
- Improved recovery techniques
- Offshore and arctic production
- Production Costs

Early production methods

Drilling continues in stage:



Test to confirm

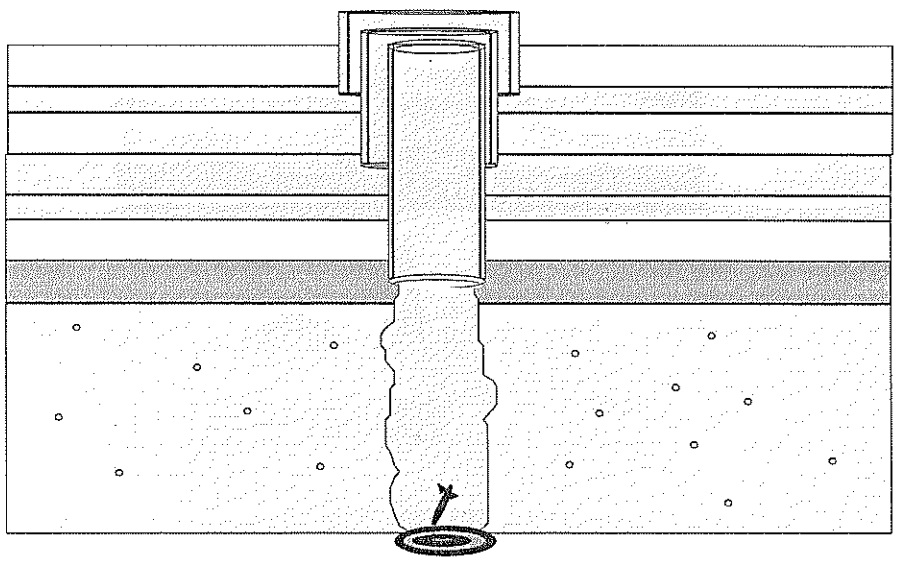
Perform several tests to confirm this finding:

1. **Well logging** - lowering electrical and gas sensors into the hole to take measurements of the rock formations

2. **Drill-stem testing** - lowering a device into the hole to measure the pressures, which will reveal whether reservoir rock has been reached

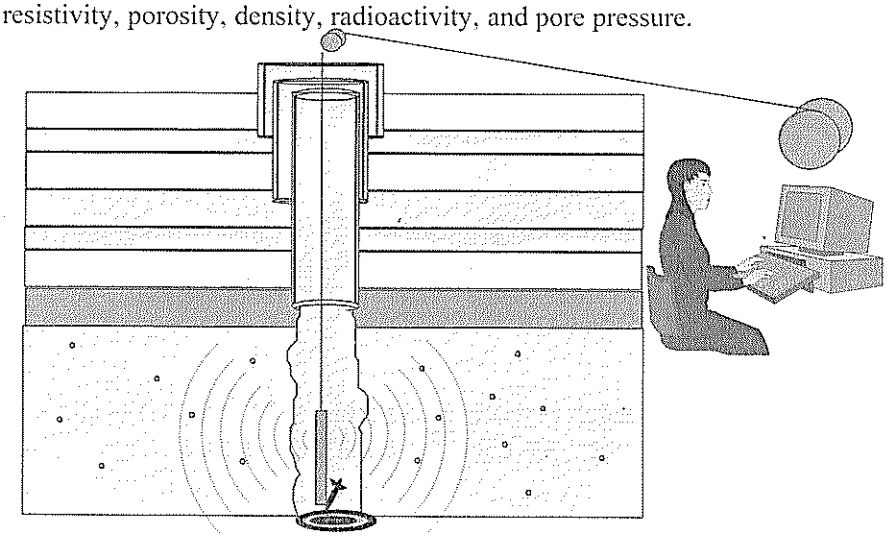
3. **Core samples** - taking samples of rock to look for characteristics of reservoir rock

In this way, the hole is drilled in stages, until the target reservoir rock is penetrated. At this point, the geologists must figure out if there is oil or gas in it.

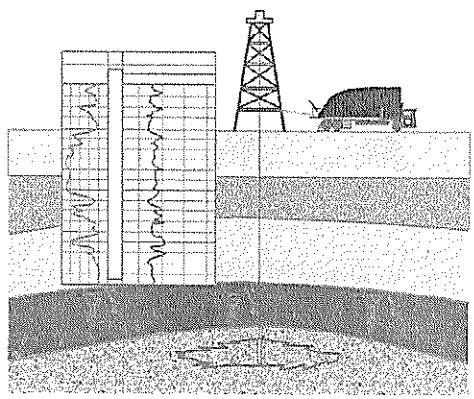


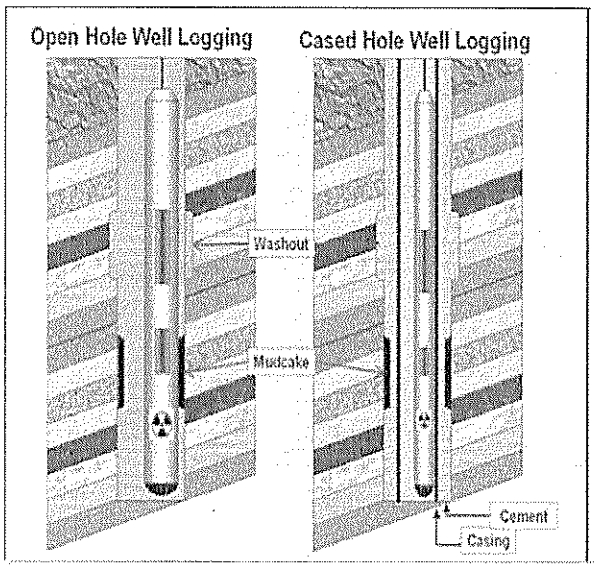
How do Geologists tell if the reservoir has oil/gas?

They do this by running logs across the zone. Logs are tools run on electric cable ("wireline") which record the physical properties in the rock such as resistivity, porosity, density, radioactivity, and pore pressure.



Well Logging





Well Logging Type

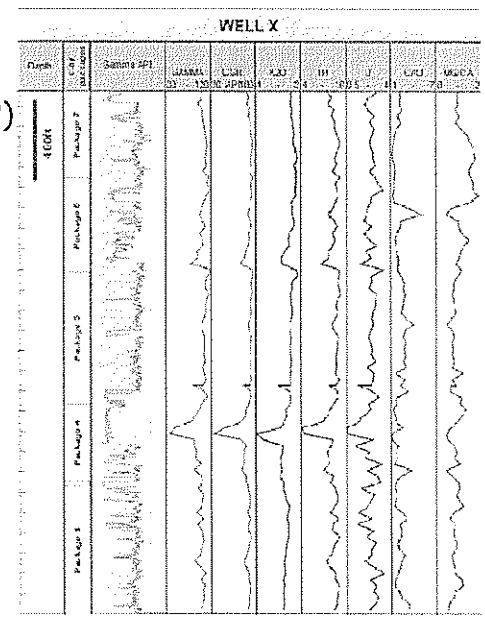
1. Open Hole

2. Cased Hole

Well logs are the main tool for characterizing a well. The book has a reasonable summary of the different types of logs available and the principles behind them.

Geological Well Logs

- Lithologic Logs
  - Spontaneous Potential (SP)
  - Gamma Ray (GR)
- Porosity Logs
  - Neutron
  - Density
  - Sonic
- Resistivity Logs (Fluid Type)
  - Resistivity
  - Induction
- Other
  - Dipmeter
  - Caliper
  - Temperature
  - Many more ...



Well Logging

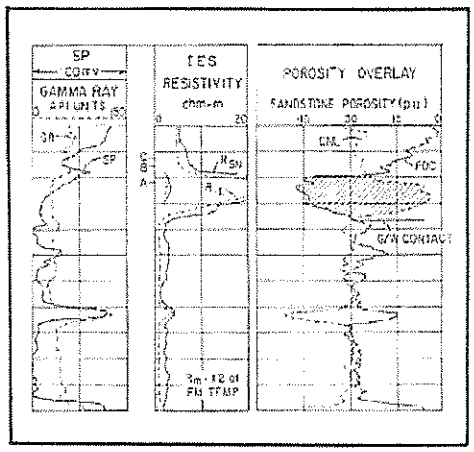


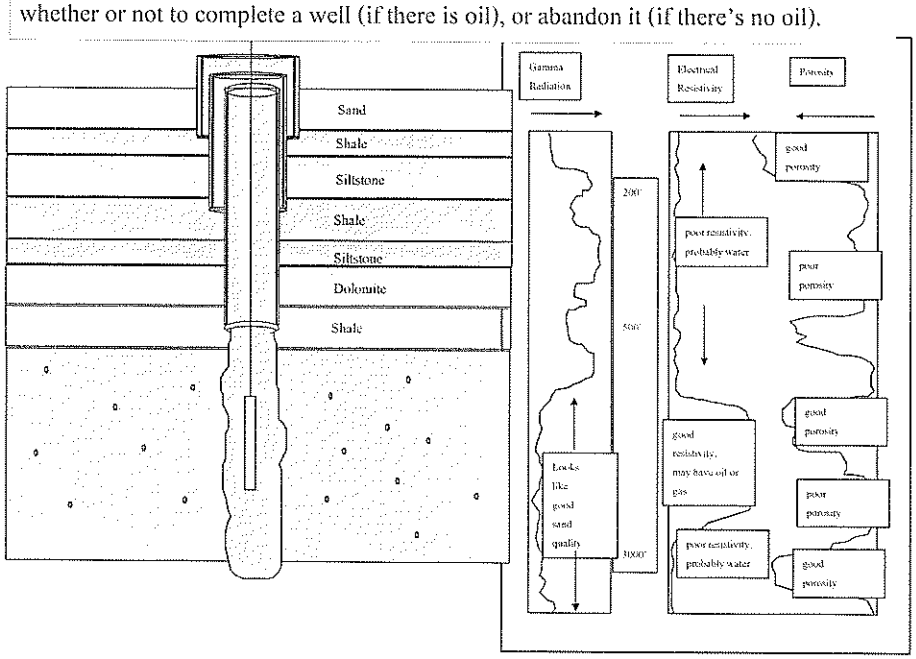
Fig. 3-4 — CNL-FDC overlay showing gas zone in cleaner part of sand. As shown by Gamma Ray the upper part of the interval is shaly. (From Ref. 1, courtesy of SPWLA.)

- Gamma ray (GR), SP, Resistivity (Rsn, Ril), *Neutron* (CNL), and *Density* (FDC) logs to identify a gas-rich zone.

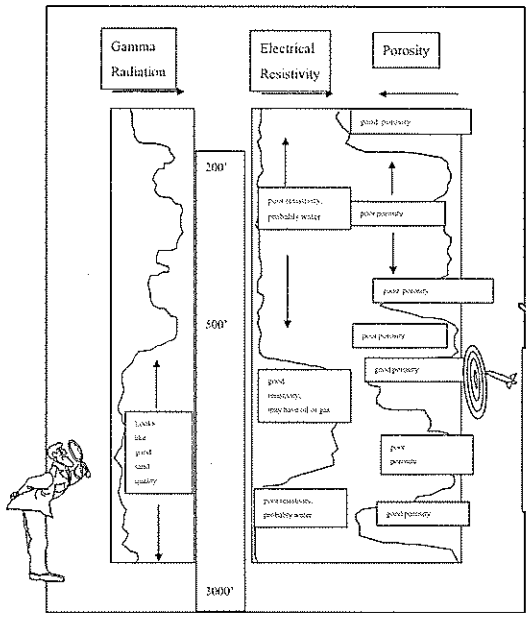
- The Gamma Ray and SP indicate the location of the reservoir bed, the high Resistivity at the top of the bed shows that it is saturated with hydrocarbons,

- The cross-over of the Neutron and Density logs shows that the hydrocarbon in question is gas.

Here's an example of what a log looks like. Geologists look at logs to decide whether or not to complete a well (if there is oil), or abandon it (if there's no oil).

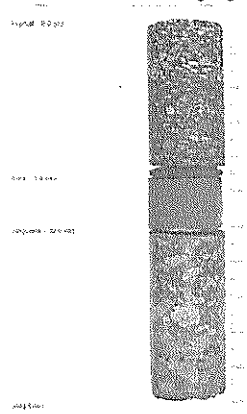


Can you tell where the geologist would complete this well?



}Right here! This shows a clean sand, with good porosity and resistivity.

Core Type



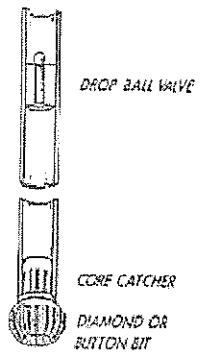


Figure 14-3 A rotary coring bit used to take a core.

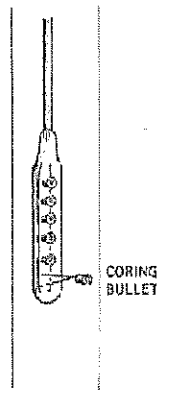
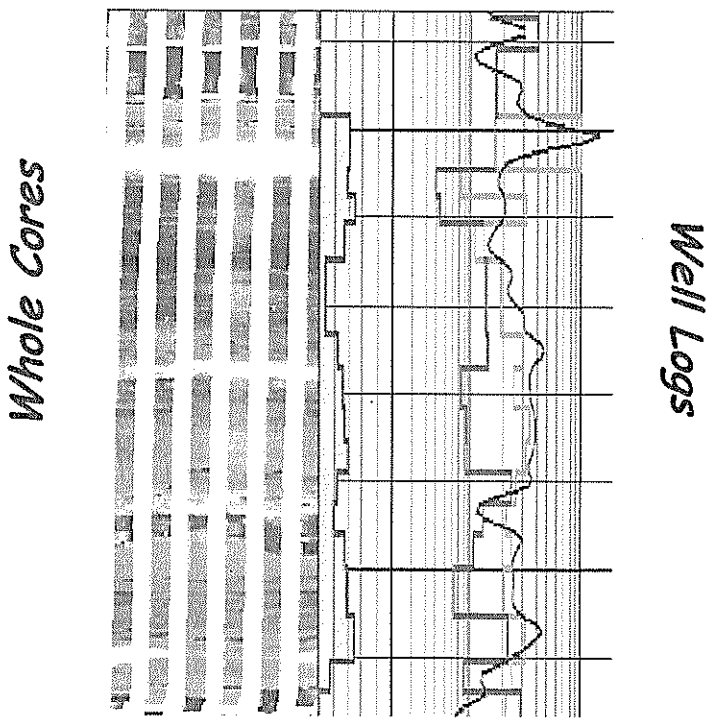
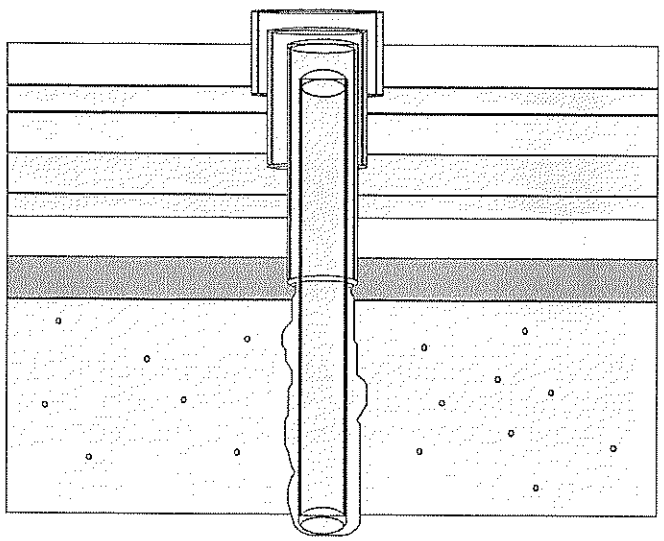


Figure 14-4 A sidewall coring device.

1. **Sidewall** cores are collected by lowering a tool that has hollow sampling bullets attached with a wire. Small cylindrical plugs are recovered when the tool is pulled back out.
2. **Conventional** cores are cut with a bit that cuts a cylinder of rock and traps it inside the drill string.



If the well looks good on the logs, we run a final string of casing across the production zone, and cement it in place.



Drill-stem-tests (DST)

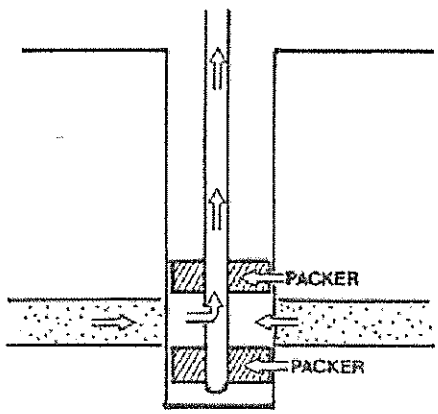
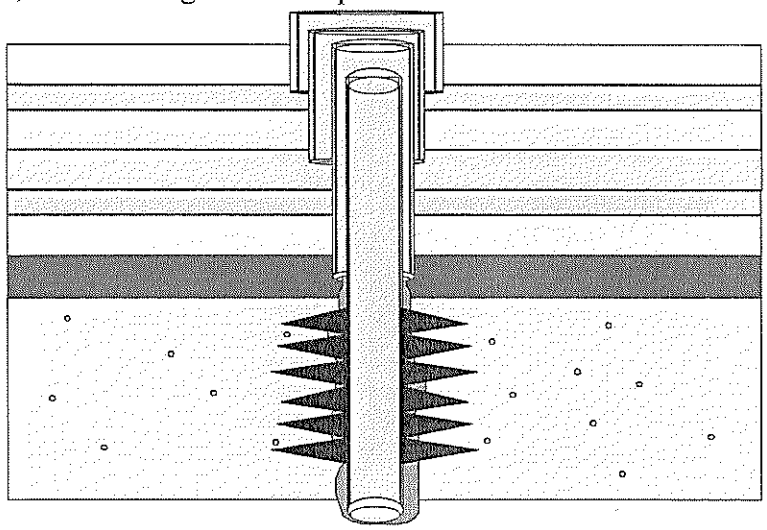


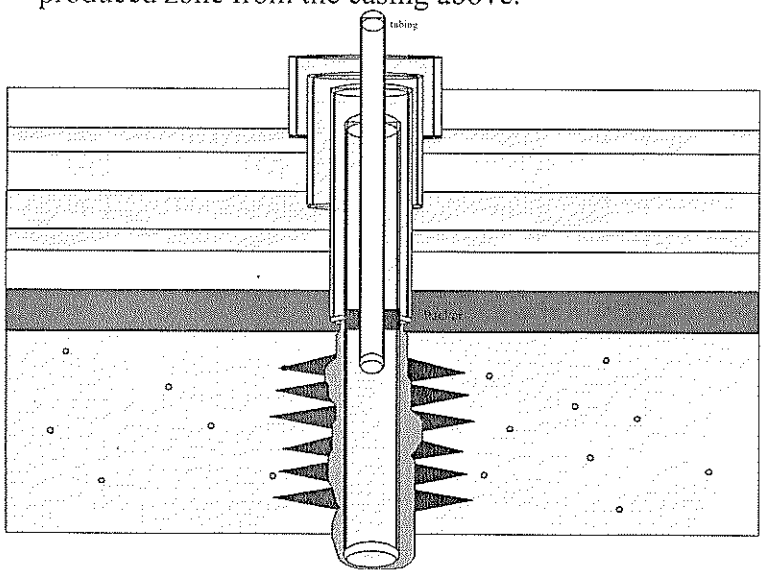
Figure 18-2 A drill stem test.

- Test the fluids in an open hole by setting packers above and below the interval of interest.
- This way a unit is isolated and the formation fluids are allowed to flow into the drill string.
- This way the formation pressure, and permeability can be measured and the formation fluids sampled.

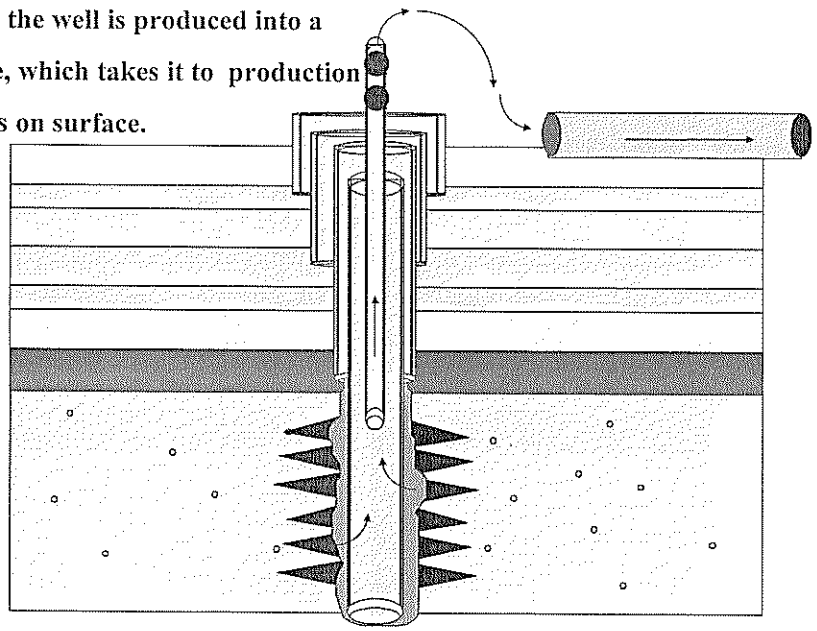
Then, we run perforating guns in the hole and perforate (shoot holes) in the casing across the productive zone.



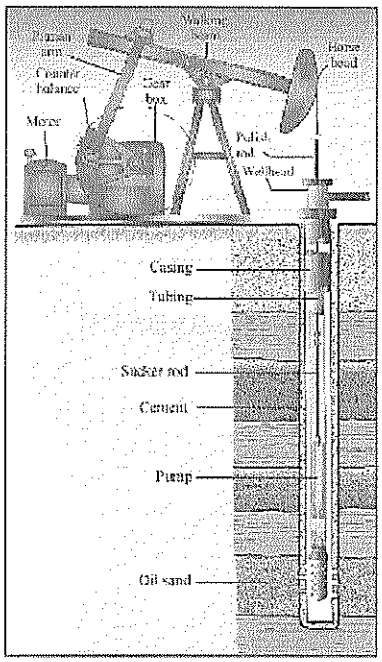
Production tubing is run, with a packer to isolate the produced zone from the casing above.



Finally, the well is produced into a pipeline, which takes it to production facilities on surface.

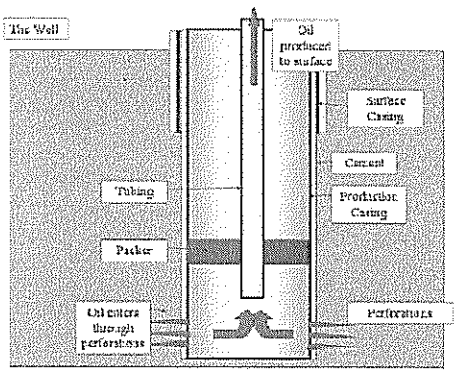


Extracting the Oil



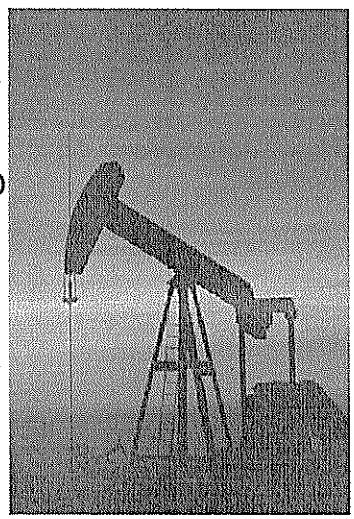
Pump on an oil well

After the rig is removed, a pump is placed on the well head.



PRODUCTION

- Production is the operation that deals with:
  - ✓bringing hydrocarbons to the surface
  - ✓maintaining production
  - ✓Purifying (Separated oil, gas and water), Measuring, testing



➢ Production begins after the well is drilled.

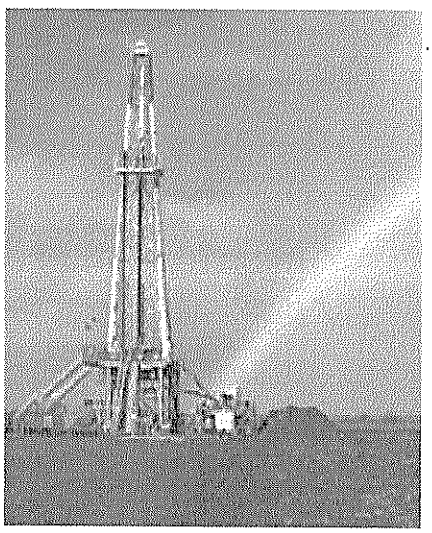
PRODUCTION- Purifying

- The mixture of oil, gas and water from the well is separated on the surface.
- The water is separated
- The oil and gas are treated, measured, and tested.

PRODUCTION

- After a well is drilled, the operating company considers all the data obtained from the various tests run on the formation of interest and a decision is made on whether:

  - to plug and abandon the well
  - to set production casing and complete the well



PRODUCTION

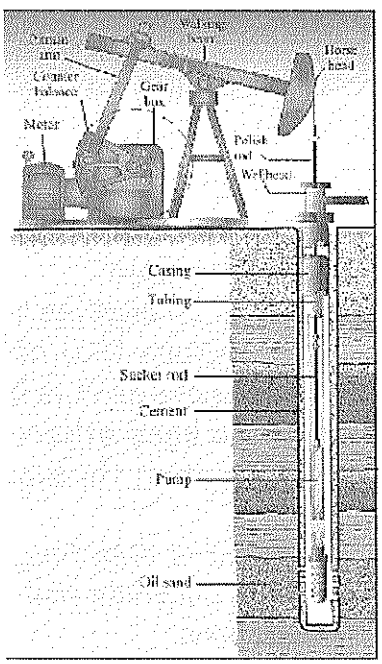
- If the decision is to abandon it, the hole is considered to be "dry" ⟹ not capable of producing oil or gas in commercial quantities, can not justify the expense of completing the well.

  Therefore, several cement plugs will be set in the well to seal it off more or less permanently.

- If the operating company decides to set production casing ⟹ Well Completion

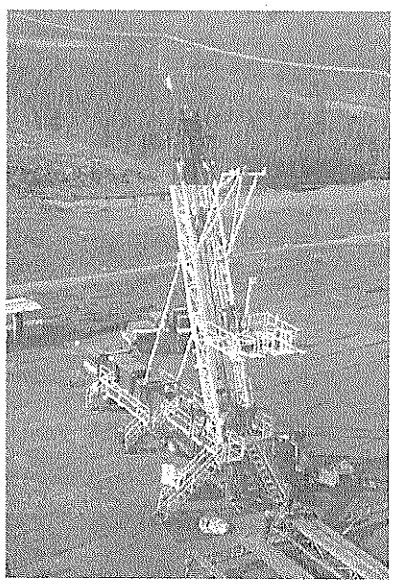
WELL COMPLETION

- Completion (well):
  All operations (tubing, installation of valves, wellhead, perforating etc.) to bring a production well into operation.

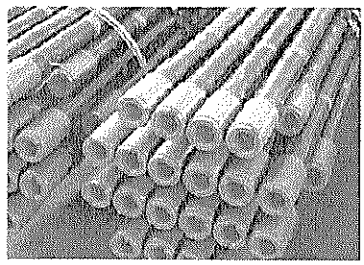


WELL COMPLETION

- Well completion allows the flow of petroleum or natural gas out of the formation and up to the surface.
- It includes;
  1. Strengthening the well hole with casing,
  2. Evaluating the pressure and temperature of the formation,
  3. Installing the proper equipment to ensure an efficient flow of oil and natural gas out of the well.



WELL COMPLETION



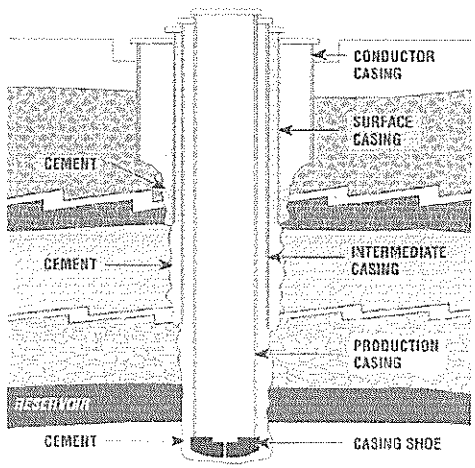
- Installing casing in the well is an important part of both the drilling and completion process.
- Casing is used;
  - ✓ to strengthen the sides of the well hole,
  - ✓ ensure that no oil or natural gas seeps out of the well hole as it is brought to the surface
  - ✓ to keep other fluids or gases from seeping into the formation through the well.

- Cement is then forced into the annulus between the casing and the borehole wall to prevent fluid movement between formations.

WELL COMPLETION

Some of the casing strings:

- Conductor Casing
- Surface Casing
- Intermediate Casing
- Production Casing
- Liner String



Function of Casing Type

Drilling

1. **Conductor pipe**: the first pipe string run on location, it set by driving or hammer down on ground. It protect the soft formation from caving in. (structural base for BOP and well Christmas Tree)
2. **Surface casing**: use for control gas and the protect freshwater zones (Rig up of BOP, required by Law)
3. **Intermediate casing**: secure the well against collapse, lost circulation, abnormal pressure and other down hazards.

Production

4. **Production casing**: set at production zones and facilitate production tubing and other well completion equipments.
5. **Liner or perforated interval**: the pipe string which not come to surface but suspended from the casing above by using hanging device.

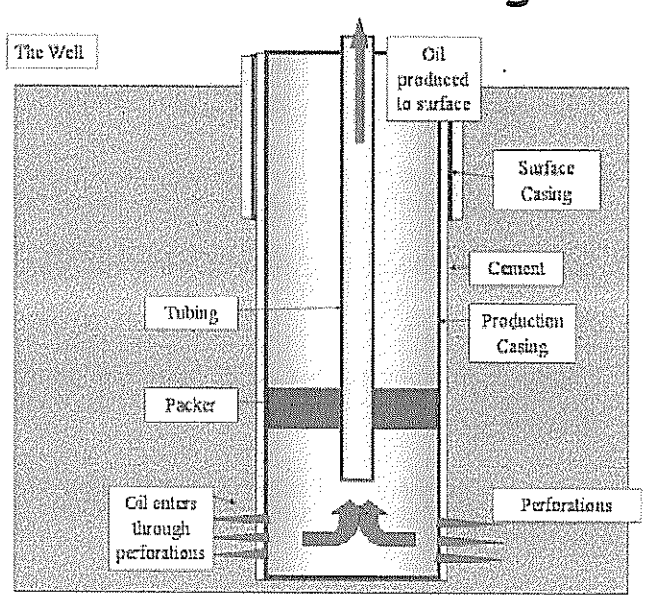
Production casing

- Production casing or oil string or long string
- The last and deepest string of casing run to the well

Size of this casing can be considering from subsurface condition:

1. Subsurface artificial lift equipment required i.e. gas valves
2. Multiple-zone completions requiring several string of tubing
3. Type of completion method to be used: open hole, perforated casing, screen open hole, or screened perforated casing
4. Prospects of deepening the well at a later date

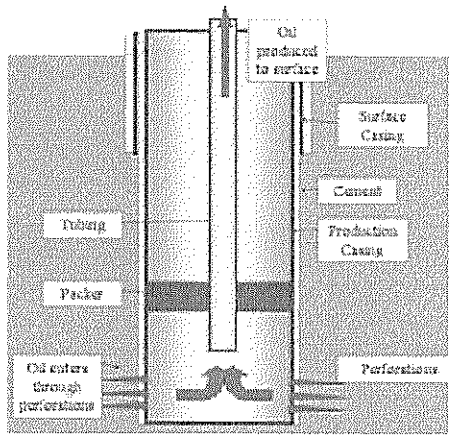
Production casing



Tubing and packer

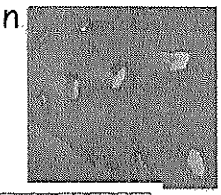
- The well is not produced through the casing. A small diameter pipe, called tubing, is used to transmit oil or gas to the surface.
- A device called packer that fits around the tubing is lowered just above the producing zone.

It expands and seals off the space between the tubing and the casing, forcing the produced fluids to enter the tubing to the surface.

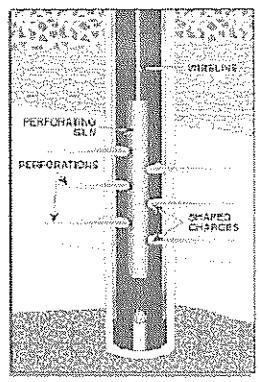


PERFORATING

- Casing must be perforated to allow liquids to flow into the well. This is a perforated completion

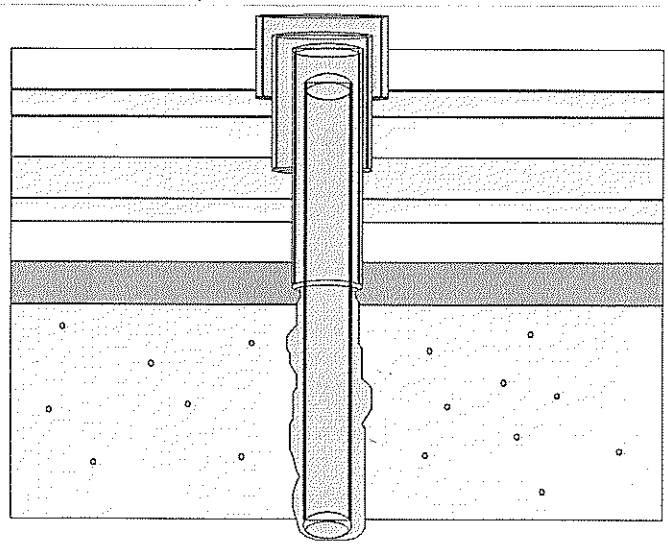


- Perforations are simply holes through the casing and cement, extending into the formation.
- The most common method of perforating is using shaped-charged explosives.
- A perforating gun is lowered into the well opposite the producing zone on a wire line & fired by electronic means from the surface.

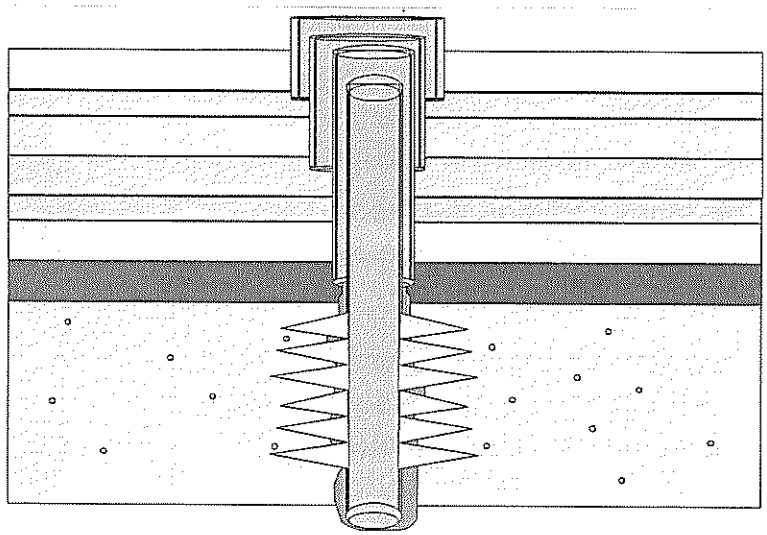


ขั้นตอนวิธีการยิงทะลุ (Perforating)

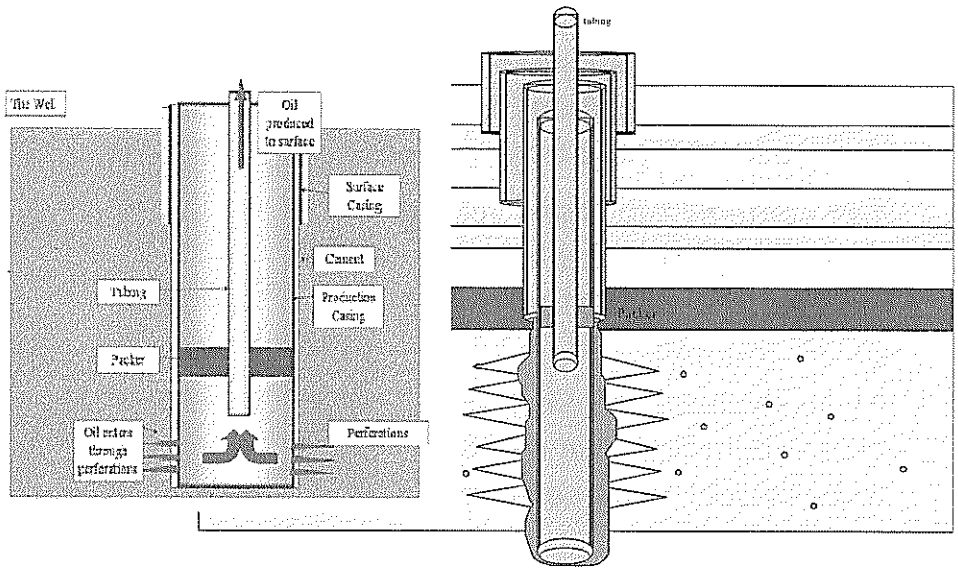
If the well looks good on the logs, we run a final string of casing across the production zone, and cement it in place.



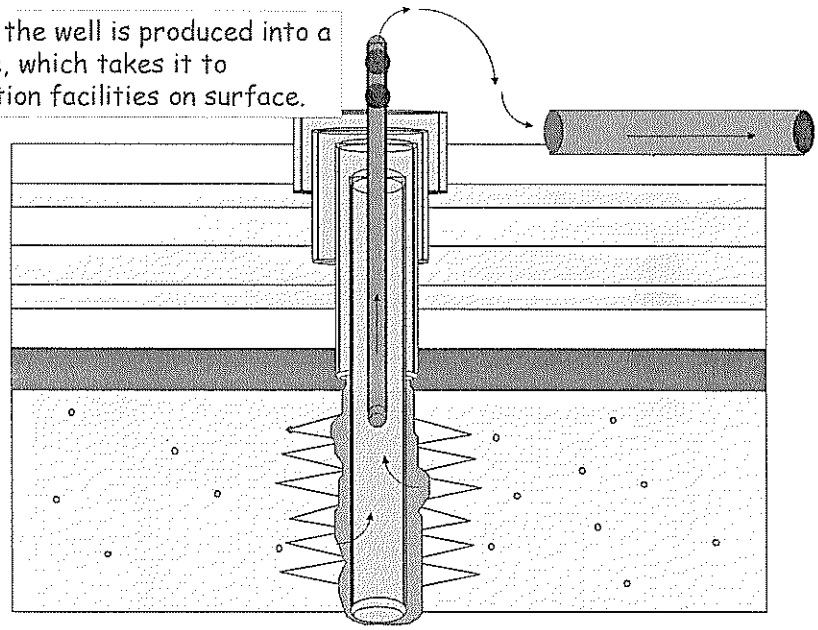
Then, we run perforating guns in the hole and perforate (shoot holes) in the casing across the productive zone.



Production tubing is run, with a packer to isolate the produced zone from the casing above.

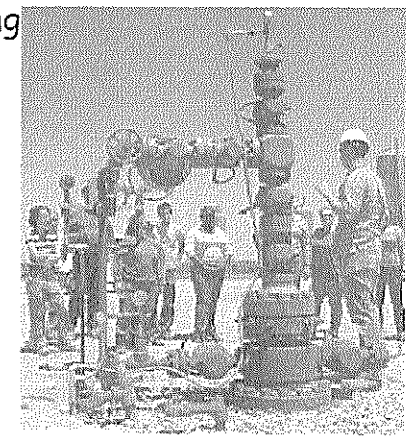


Finally, the well is produced into a pipeline, which takes it to production facilities on surface.



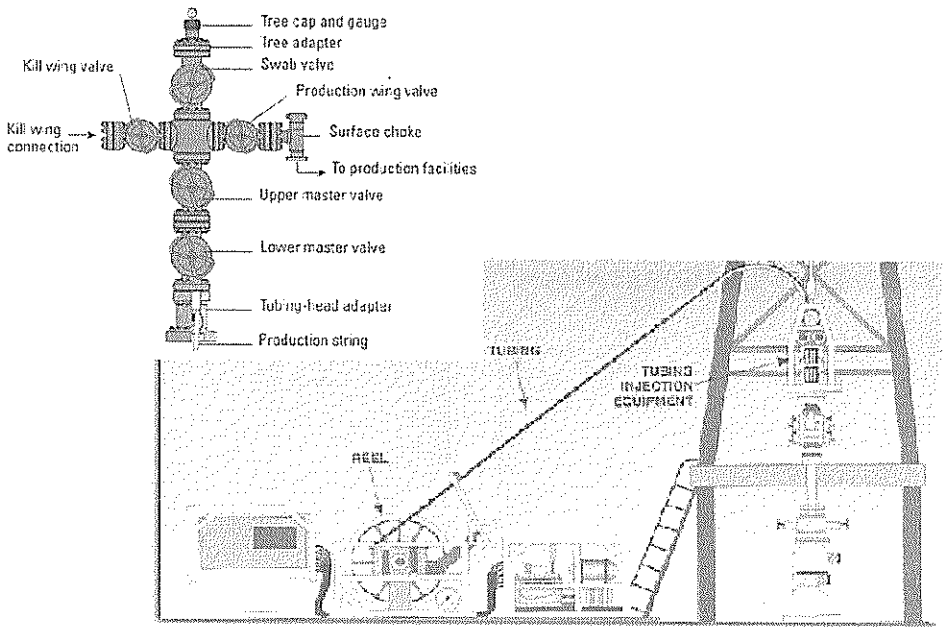
Christmas tree

- When casing is set, cemented and perforated and when the tubing string is run then a collection of valves, called Christmas tree is installed on the surface at the top of the casing



- It contains tubes and valves that control the flow of hydrocarbons and other fluids out of the well.
- Usually, once the Christmas tree is installed, the well can truly be said to be complete.

INSTALLING THE CHRISTMAS TREE



WELL TESTING

In production oil & gas more importance is being placed upon the most efficient recovery (MER) performance of the producing wells.

1. Efficient recovery take proper engineering and planning along with the right equipment
2. Controlling the production rates
3. Protects the well or formation damages

WELL TESTING

Flowing well

1. Gas wells
   : produced by pressure flowing though the formation

2. Oil wells
   : may flow naturally due to a driving force during early stages of their productive life.
   : at some point before depleting they will need an external energy source (Christmas Tree)

Classification of Well Testing

1. **Potential test:** measures the max. amount of oil and gas production rates in 24 hour period under certain fixed condition.
   - Normal test made on the each newly completed well and during its production lift
     - Production rates (flow test, pressure drop of the well, determine reserve of reservoir)
2. **Bottom-hole pressure test:** measure the reservoir pressure of the well
   - Flowing bottom-hole pressure test: measures while the well continues to flow
   - Shut-in bottom-hole pressure test: measures after the well shut in (closed) = information about the fluid levels in the well

Classification of Well Testing (cont.)

3. **Productive test:** determine the effects of different flow rates on the pressure within the producing zone
   - Test on both oil & gas well include the potential and bottom-hole pressure test
   - measure from the bottom-hole first, measure the each flow rate by estimate of the maximum flow rate (affect to risk of damage to the well)
4. **Fluid-Level Determination:** test most commonly performed on oil wells that will not flow and must be made to product by pumping or artificial lift
5. **Bottom-Hole Temperature Survey:** determines the temperature of the well at the bottom-hole or some point above the bottom
   - Determine in locating leaks in the pipe above the producing zone

WELL STIMULATION

1. Acidizing—Carbonate reservoir

2. Fracturing—Sandstone reservoir

WELL STIMULATION- Carbonate rocks

- Sometimes, petroleum exists in a formation but it is unable to flow readily into the well, because the formation has very low permeability.

1. Acidizing a well consists of injecting acid (usually hydrochloric acid, HCl) into the well.
   - In limestone or carbonate formations, the acid dissolves portions of the rock in the formation, opening up spaces to allow for the flow of petroleum.

WELL STIMULATION- Sandstone rocks

- When sandstone rock contain oil or gas in commercial quantities but the permeability is too low to permit good recovery, a process called fracturing or Frac job may be used to increase permeability to a practical level.

2. Fracturing consists of injecting a fluid down the well and into the formation under great pressure. Pumping continues until the formation literally cracks open.

In addition to the fluid being injected, 'propping agents' are also used to prop open the newly widened fissures in the formation.

- Hydraulic fracturing (water + sand + additive) involves is injected into the formation.

RESERVOIR DRIVE MECHANISMS

- After the well has been completed, the hydrocarbons flow from the reservoir to the surface. This first period in the producing life of a reservoir is called primary recovery or primary production.

- During this stage, natural energy in the reservoir often displaces the hydrocarbons from the pores of a formation and drives it toward the wells and up to the surface.

Reservoir Drive Mechanisms

- There are five important drive mechanisms (or combinations).
  1. Gas Drive:
     1.1) Solution Gas Drive
     1.2) Gas Cap Drive
  2. Water Drive
  3. Gravity Drainage
  4. Combination or Mixed Drive
- A combination or mixed drive occurs when any of the first three drives operate together or when any of the first three drives operate with the aid of gravity drainage.

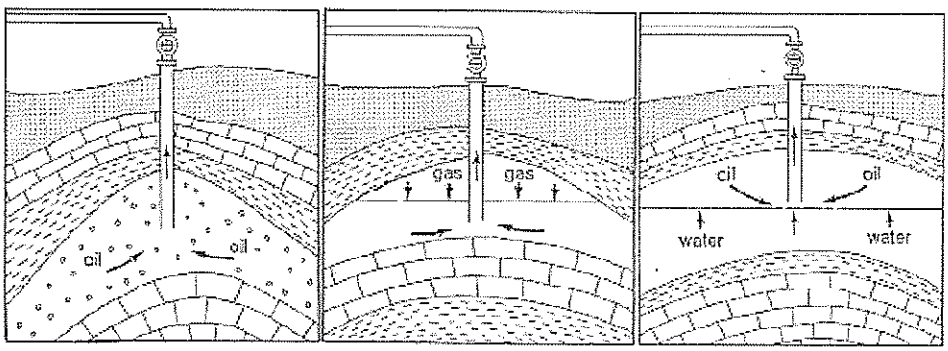
RESERVOIR DRIVE MECHANISMS

1. Water drive -when there is enough energy available from free water in the reservoir
2. Gas drive

   2.1 dissolved-gas drive (Some hydrocarbons in the oil become gaseous when the well releases pressure from the reservoir.)

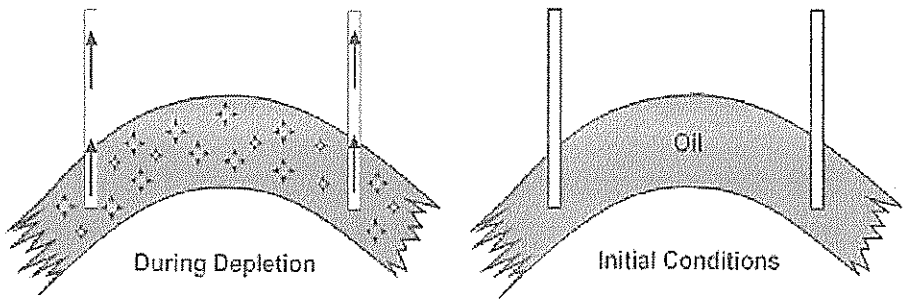
   2.2 gas-cap drive (Gas forms a cap on top of the oil. When there is an escape route for the oil in the reservoir, the pressure of the gas cap pushes the oil.)
3. Gravity drainage- (Gravity causes oil to migrate upward, because water is heavier than oil.)

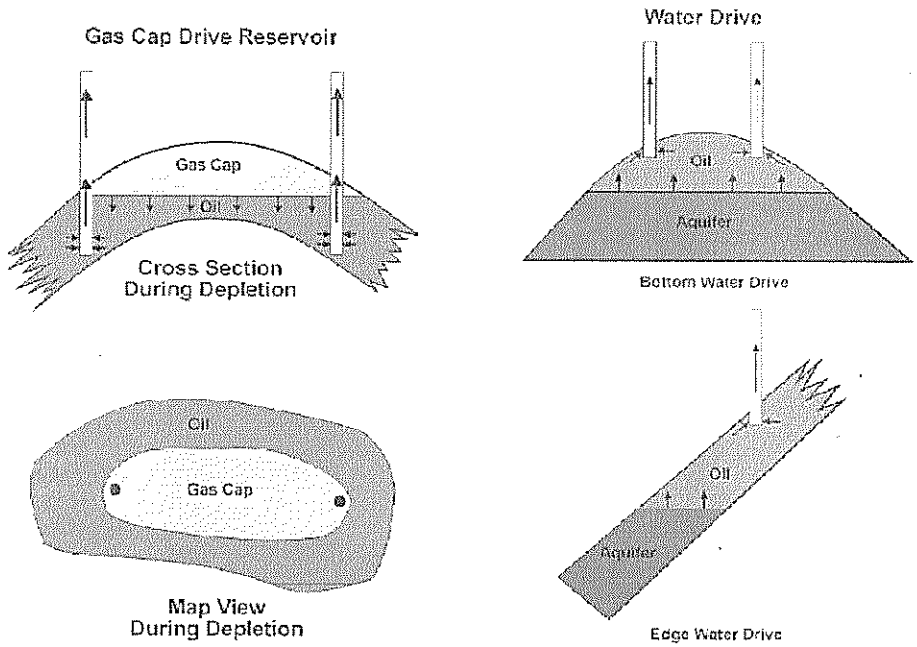
Reservoir-drive mechanisms.



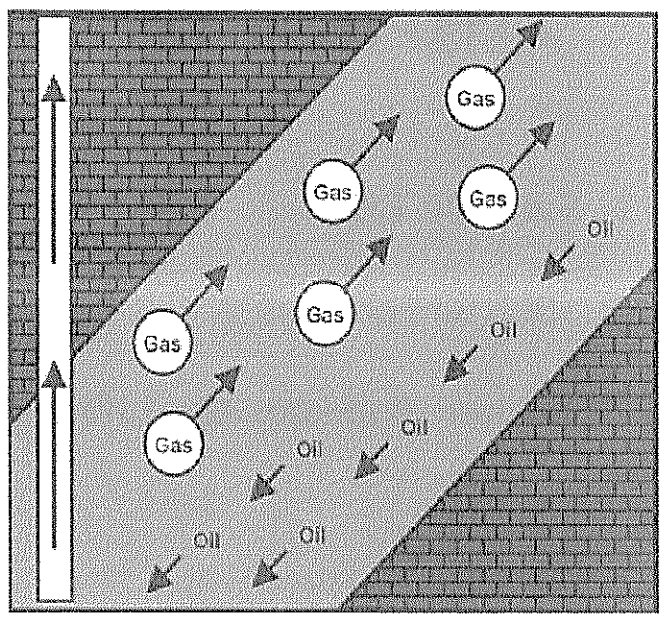
Dissolved gas drive Gas-cap drive Water drive

Solution Gas Drive Reservoir

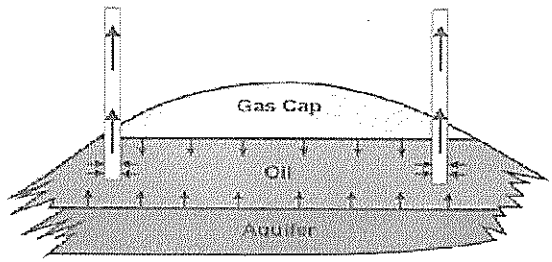


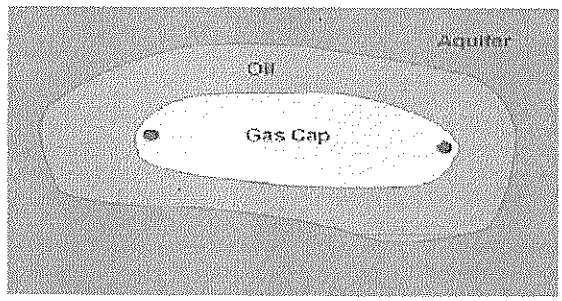


Gravity Drainage



Mixed Drive Reservoir





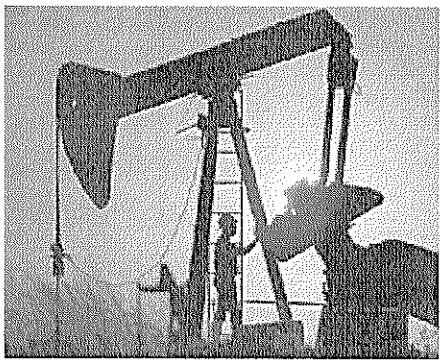
Map View During Depletion

ARTIFICIAL LIFT

1. Surface Lifts
2. Subsurface Lifts
3. Other Submersible Lift Systems

ARTIFICIAL LIFT

- When pressures in the oil reservoir have fallen to the point where a well will not be produced by natural energy, some method of artificial lift must be used.



- Artificial lift uses oil well pumps and high pressure gas to lift the oil from the reservoir.

When do we use the artificial lift

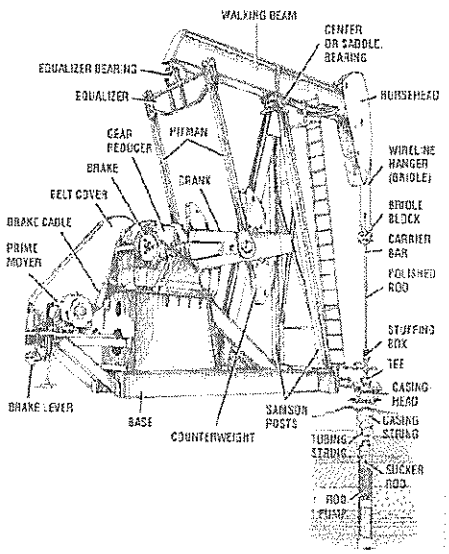
1. Producing wells that can't flow on their own
2. Initial unloading of a well that will flow later
3. Increasing the production of flowing well
4. Producing deviate and horizontal well
5. Overcoming sand and scale problems
6. Unloading a well affected adjacent drilling and fracturing
7. Back flowing a well

Classification of Artificial Lift

1. **Surface lifts** consist of:
   1. Rod pumping
   2. Stuffing Box
   3. Sucker Rods
   4. Plunger Pumps
   5. Horsehead
   6. Walking beam
   7. Counterwieght
   8. Other Rod Pumping Units

Surface lifts

- The most common method of pumping oil in land-based wells is beam pumping.
- The beam pumping creates an up-and-down motion to a string of rods called sucker rods.
- The top of the sucker rod string hangs down inside the tubing.
- A sucker rod pump is located near the bottom of the well.



2. Subsurface Lifts

1) Subsurface Hydraulic Pumping
2) Gas lift

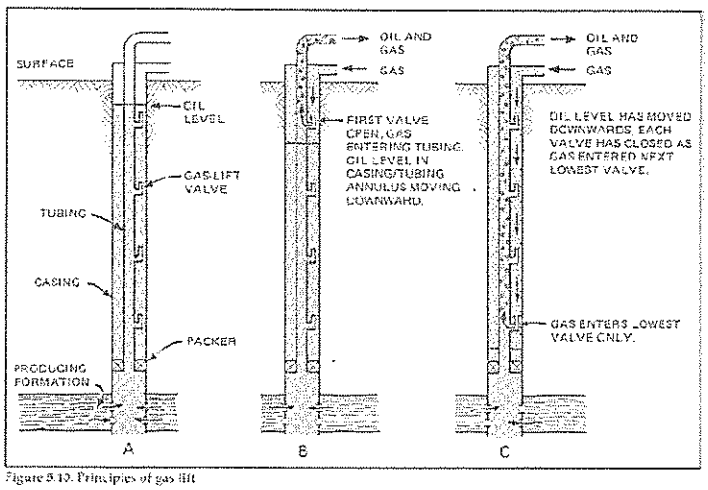
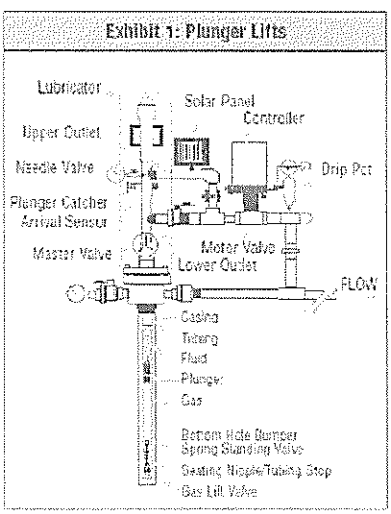
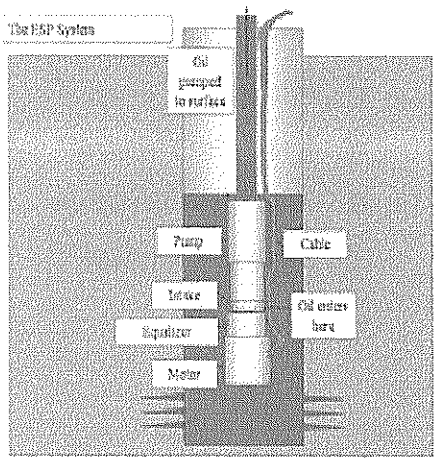


Figure 8.10. Principles of gas lift

3. Other Submersible Lift Systems

1) Sonic pump lift
2) Ball pump lift
3) Plunger pump lift
4) Electrical submersible pump (ESP)





Enhanced Oil Recovery (EOR) Techniques

- After a well has used up the reservoir's natural drives and gas lift or pumps have recovered all the hydrocarbons possible
- 25 to 95% of the original oil in the reservoir may still be there.
- These techniques are used when production from the well starts to decrease.

EOR

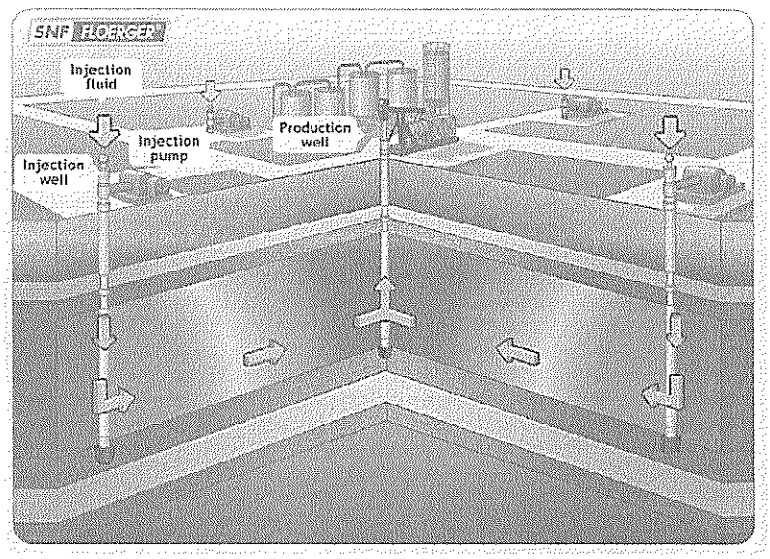
- The major methods of *improved oil recovery* are:
  1. *Water flooding*
  2. *Gas injection*
  3. *Chemical flooding*
  4. *Thermal recovery*
  5. *Steam injection*
  6. *Others*

Improved recovery techniques

1. Waterflooding: water is injected into the formation using wells. Water flooding is the least expensive and most widely used secondary recovery method.

- The injected water enters the reservoir and displaces some of the remaining oil toward producing wells in the same reservoir. The producing wells then pump up the oil and water.
- Several injection wells surround each producing well.

Waterflooding

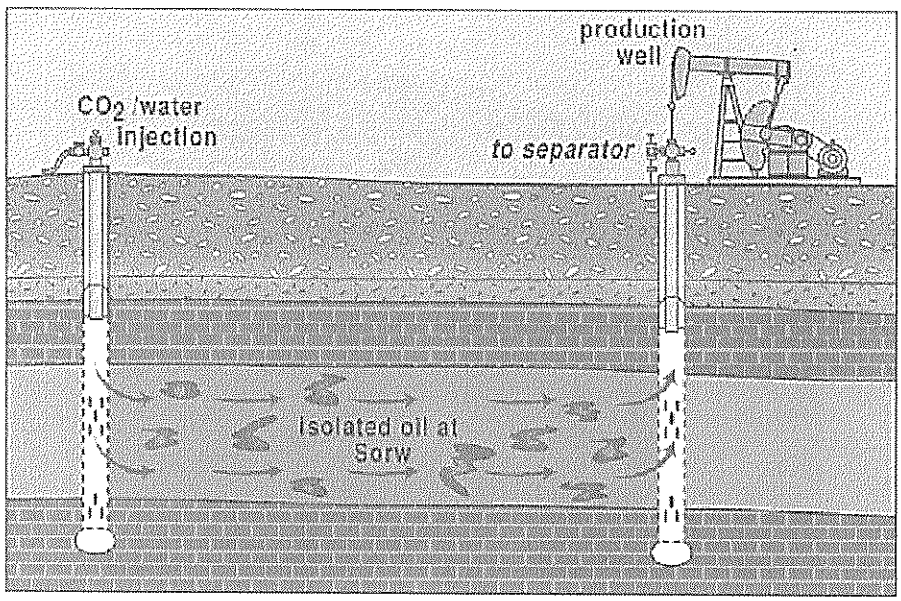


Improved recovery techniques-Con't

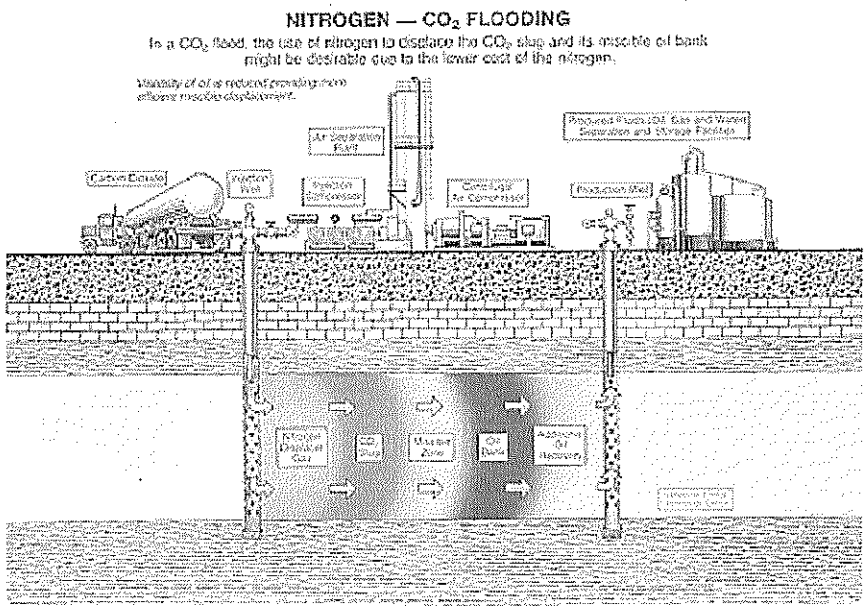
2. Gas injecting: The injected gas expands to force additional volumes of oil to the surface.

Ex. Natural gas, Nitrogen and Carbon dioxide

Gas injecting- CO_2



Gas injecting- N_2



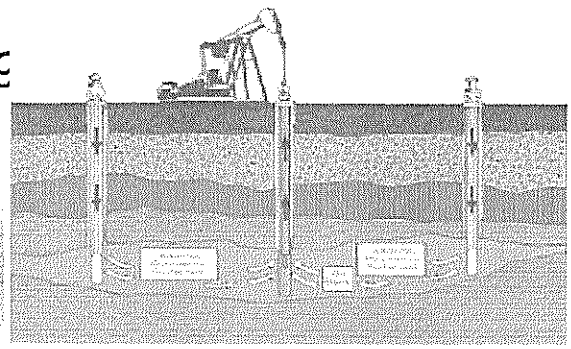
Improved recovery techniques

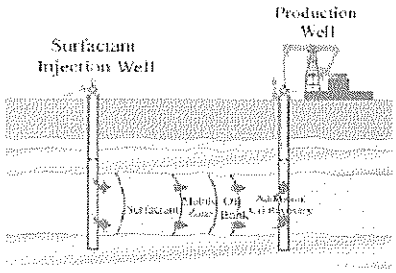
3. **Chemical flooding** uses special chemicals in water to push oil out of the formation. These chemicals act as ***surfactants*** that cause the oil and water to mix and breaks the oil into tiny droplets that can be more easily moved through the reservoir to the well.

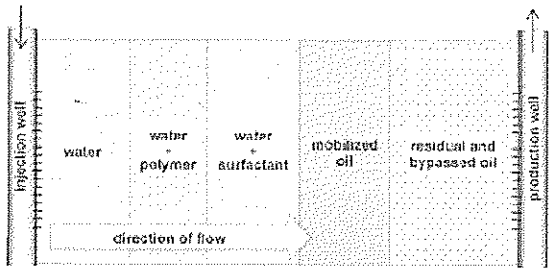
4. **Thermal recovery** is used when the oil is so viscous, or thick, that it cannot flow through the reservoir and into a well. When the oil is heated, its viscosity is decreased and the flow increases. Recovery techniques that use heat are called thermal processes or thermal recovery.

Chemical flooding

Green Surfactants for IOR



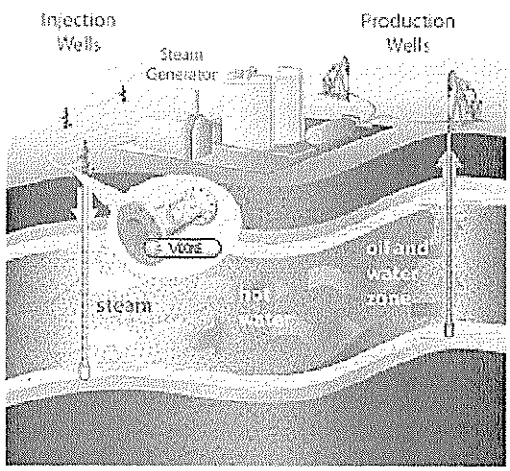


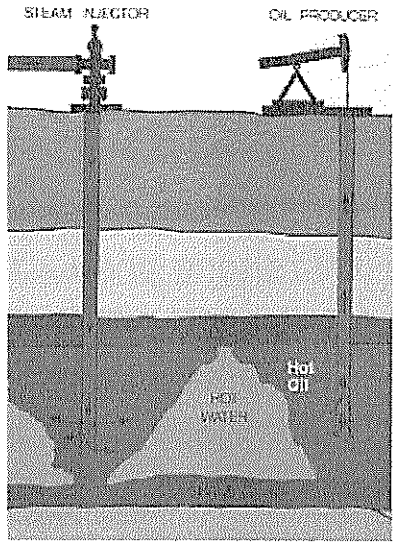


Improved recovery techniques-Con't

5. ***Steam Drive*** or ***steam injection*** involves generating steam on the surface and forcing this steam down injection wells and into the reservoir. When the steam enters the reservoir, it heats up the oil and reduces its viscosity. The heat from the steam also causes hydrocarbons to form gases which also increases flow. The gases and steam provide additional gas drive and the hot water also moves the thinned oil to production wells.

Stream drive

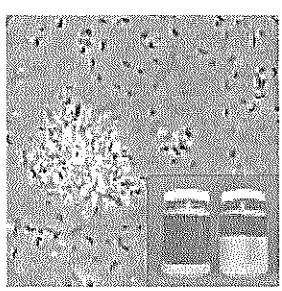


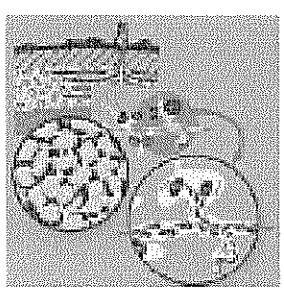


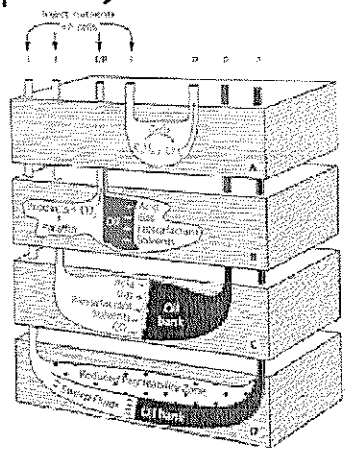
Improved recovery techniques

6. Others

- ***Fire flooding***, or ***in situ*** (in-place) combustion
- Microbial or Biosurfactant

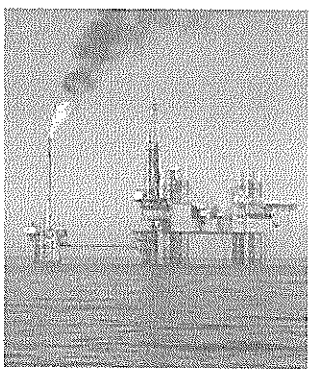


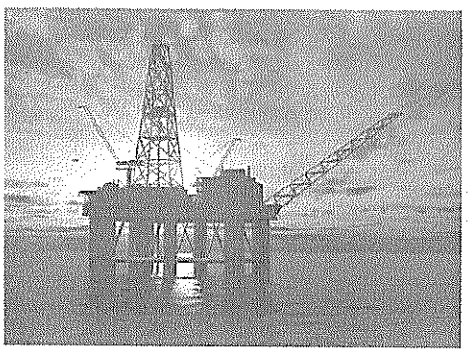




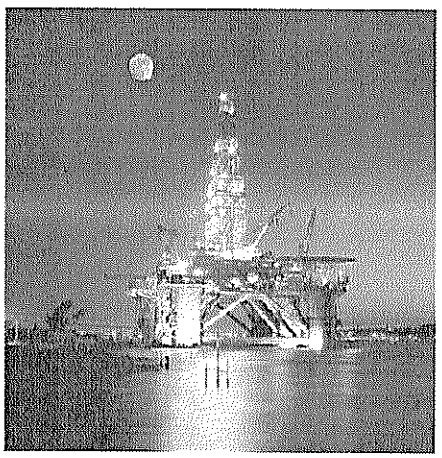
Offshore Operation

- *Offshore operations* are fundamentally the same as onshore operations with the major difference being in the complexity of the production sites and hence their costs.
- Offshore production facilities are self-contained production sites.
- The platforms are semi-permanent structures from which many wells are drilled and completed.



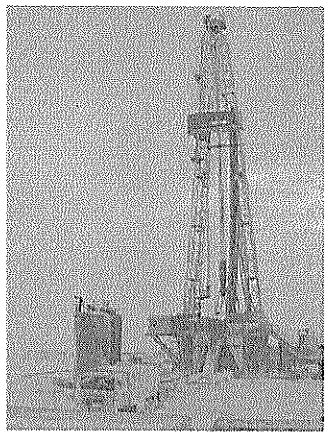


Offshore Operation

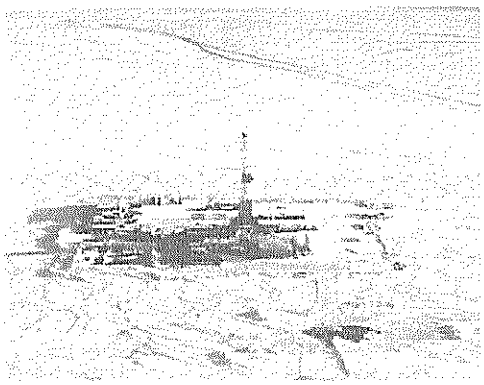


Arctic Operation

- Both onland (onshore) and at sea (offshore)
- Common problem to both are the extreme low temperature
- Steel and metal becomes as brittle as glass
- Lubricants freeze into solid
- Engines can not stop
- Hard to human



Arctic Oil Rigs

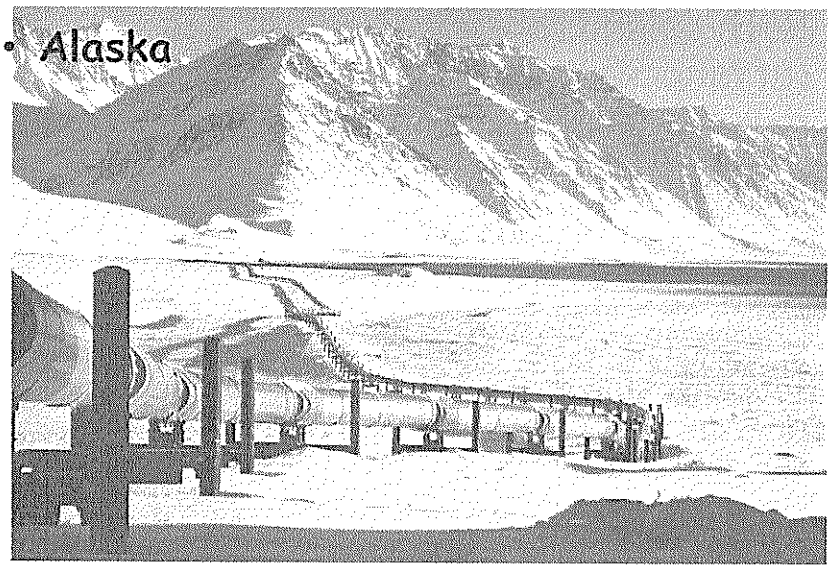


Onshore

Offshore

Arctic operation: Onland

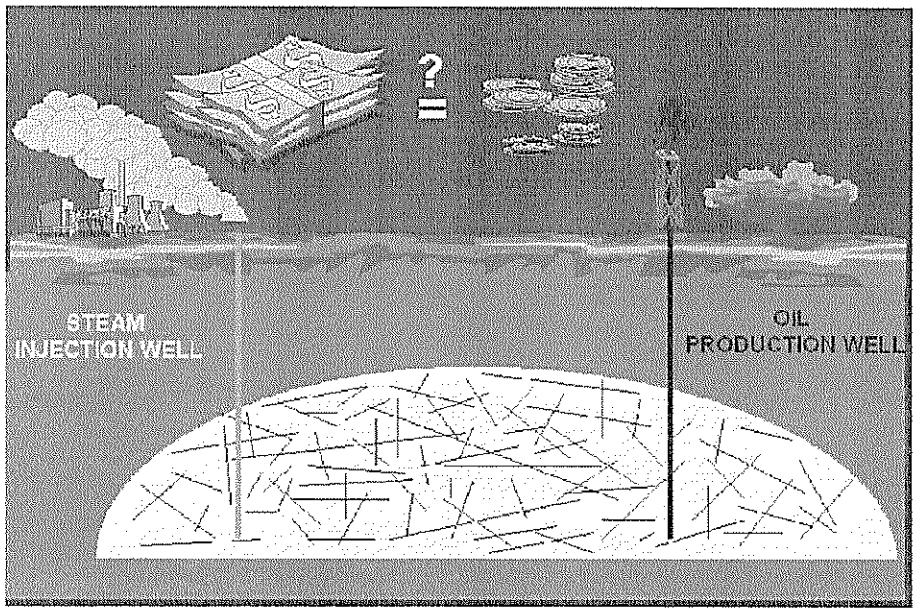
- Alaska



Production Costs

- Production or lifting costs are the expenses associated with bringing oil and gas from the reservoir to the surface, separating the oil from any associated gas, and treating the produced oil and gas to remove impurities such as water and hydrogen sulfide.
- Worldwide lifting costs have been increasing since 2001
  - U.S. costs have been higher than foreign cost since 2004. In 2007, U.S. production costs were $11.25/barrel of oil equivalent (BOE)
  - foreign costs averaged $8.88/BOE.

Cost of EOR

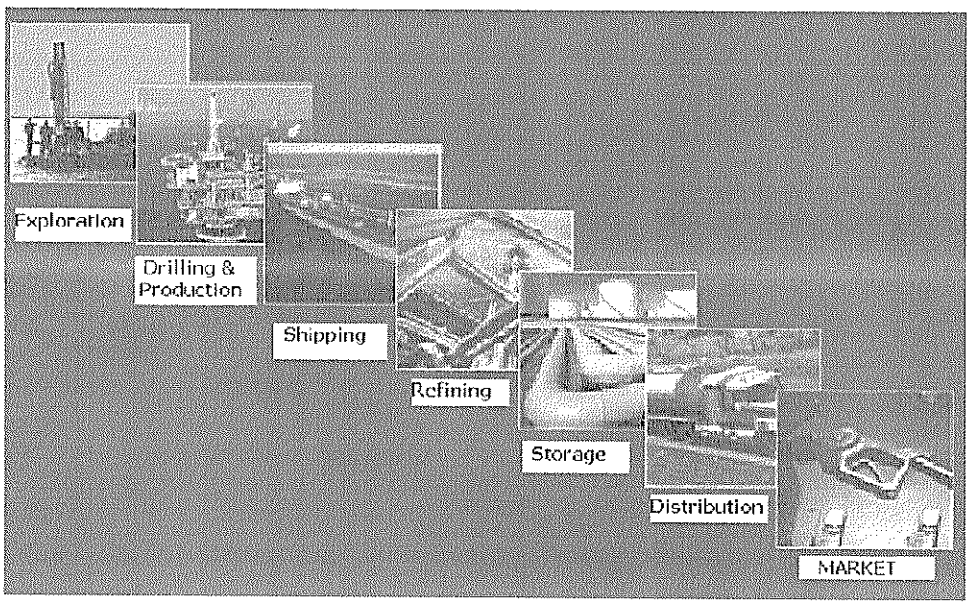


Chapter 6
Storage & Transportation

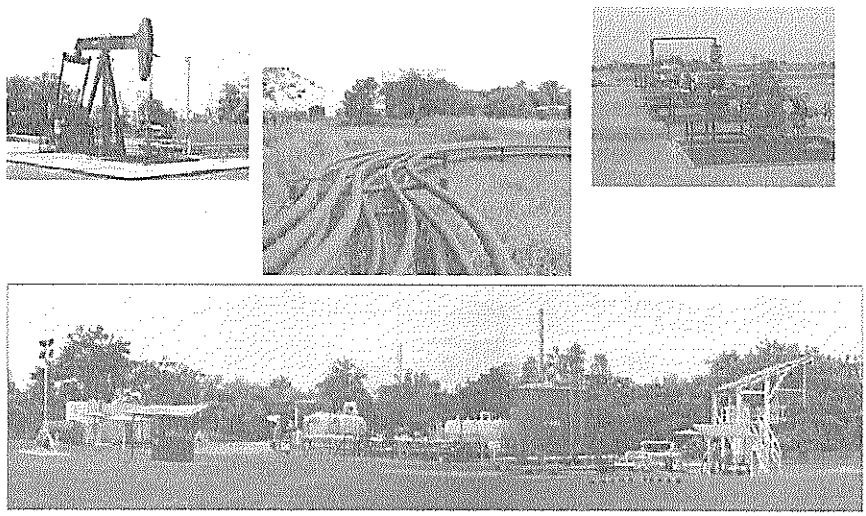
Course Contents

- Storage
- Transportation
  - Onshore
  - Offshore
  - Pipeline
    - Production pipeline
    - Natural gas pipeline
    - Pipeline construction

The Oil and Natural Gas Value Chain



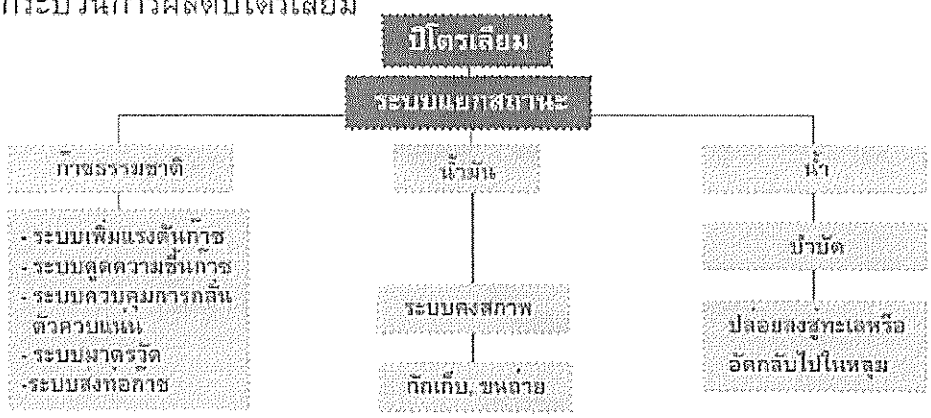
Petroleum Storage



กรมเชื้อเพลิงธรรมชาติ
กระทรวงพลังงาน

กระบวนการผลิตปิโตรเลียม

กระบวนการผลิตปิโตรเลียม



กระบวนการผลิตปิโตรเลียม

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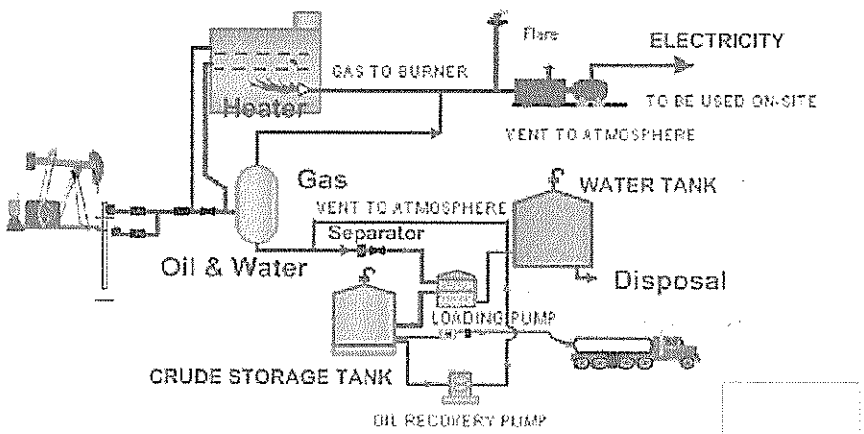

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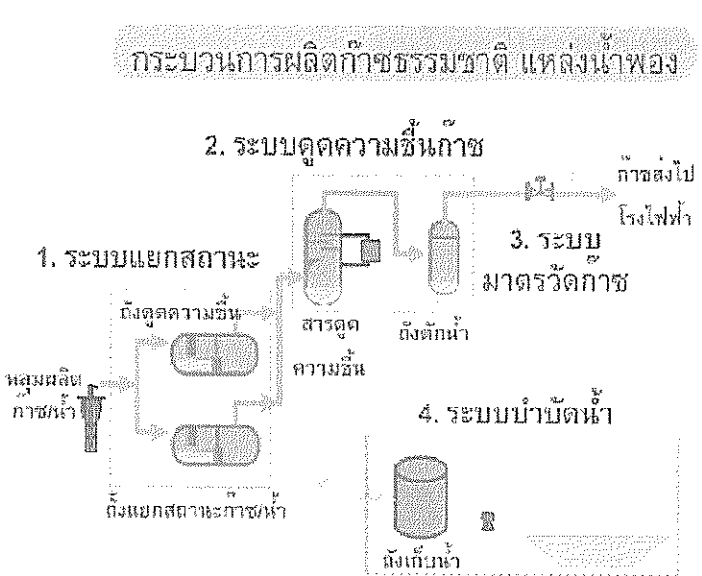


Petroleum Tanker

⊙ An **oil tanker** or **petroleum tanker**, is a ship designed for the bulk transport of oil and gas.

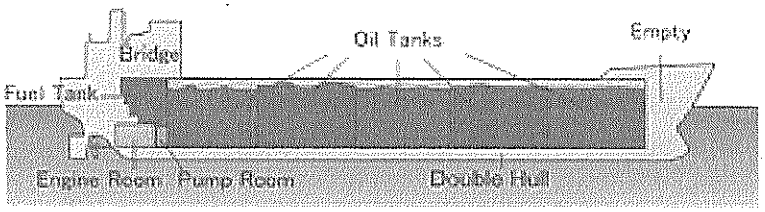
There are 3 basic types of oil tankers:

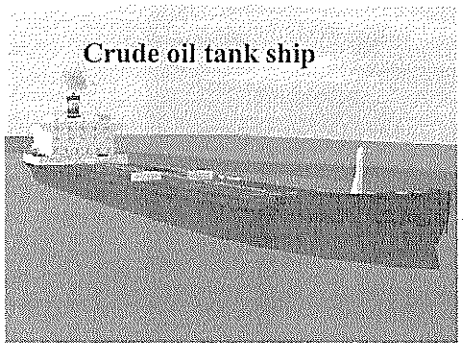
1. **Crude tankers:** large size, move crude oil from its point of extraction to refineries.

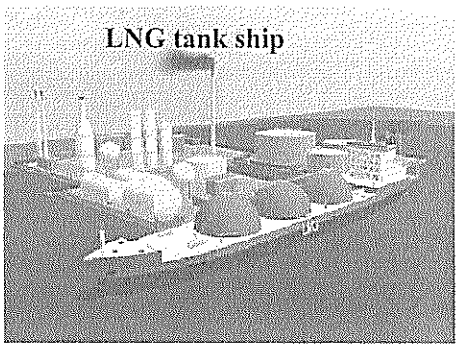
2. **LNG tankers:** spherical tank, move LNG (Liquefied Natural Gas) from offshore to terminal.

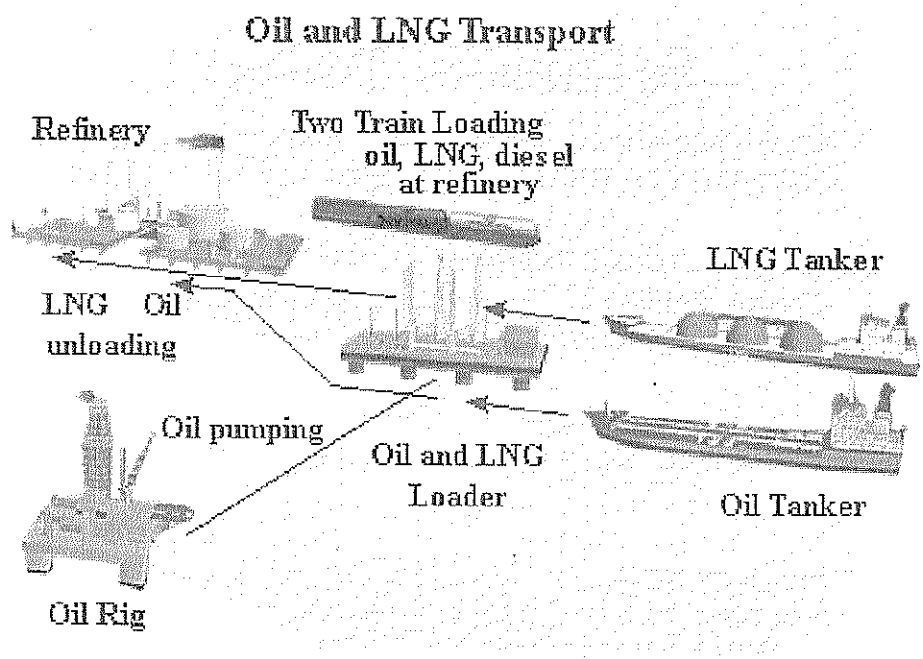
3. **Product tankers,** generally much smaller, are designed to move petrochemicals from refineries to points near consuming markets.

Oil tanker (side view)



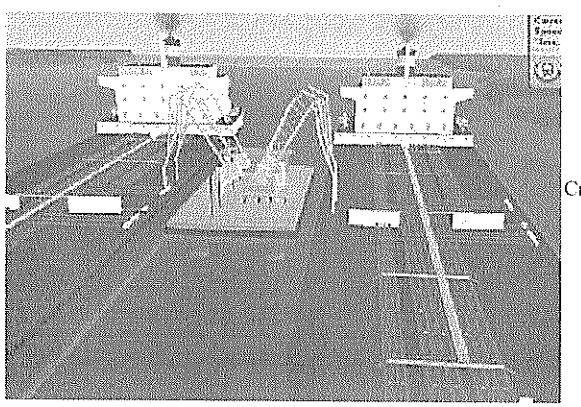






Oil Loading Platform and Tankers

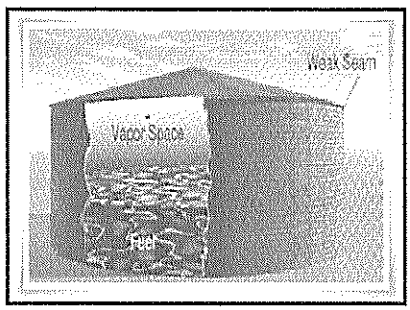
- The Tankers are loading oil and LNG at the offshore loading platform in a stopped load process. The loading tubes on the platform are animated.
- In the picture, crude oil is loaded from the right side of the platform and LNG on the left side.

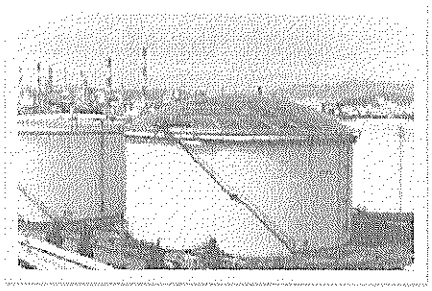
LNG  Crude oil

Type of Storage Tanks

1. **Vertical tank: Oil & Water tanks**
   - 1.1 **Dome roof tank:** Fertilizer and chemical solvents
   - 1.2 **Floating roof tank:** flammable/ combustible liquids
2. **Horizontal tank: Gas & Oil tank**
   - 2.1 **Pressurized horizontal tank:** Butane, propane, anhydrous ammonia, chlorine, sulfur dioxide and hydrogen chloride
   - 2.2 **Non-pressurized horizontal tank:** Flammable/combustible liquids, corrosives, poison, solvents

Dome roof tank

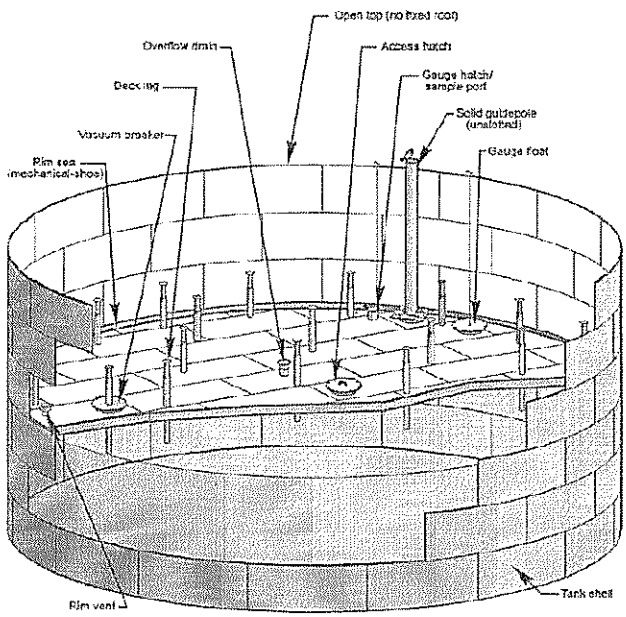




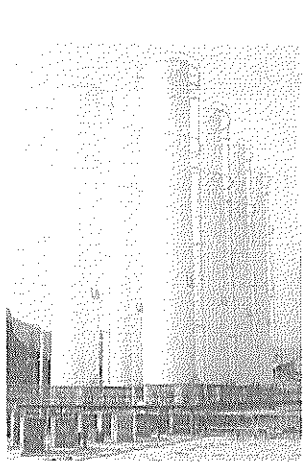
Floating roof tank

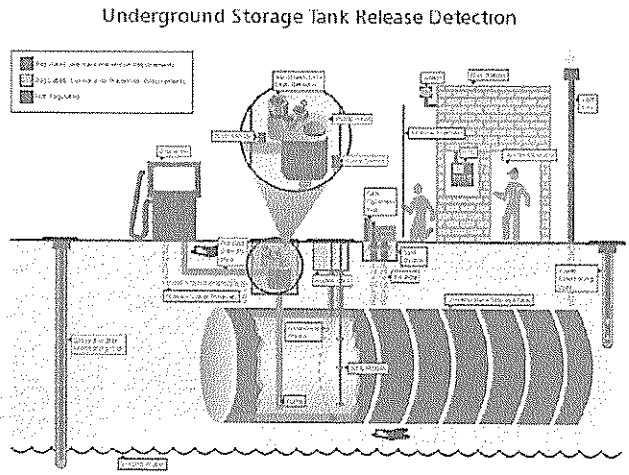
Horizontal tank

External floating roof tank

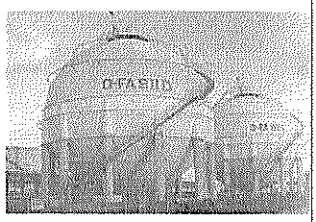


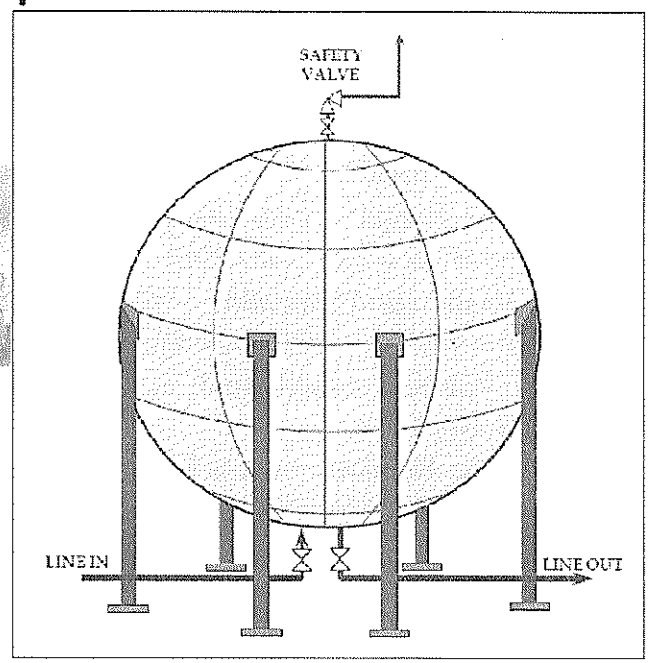
3. **Spherical tank:** methane, propane, LPG
4. **Cryogenic liquid tank:** oxygen, nitrogen liquids
5. **Underground storage tank:** LPG, gasoline, fuel oil



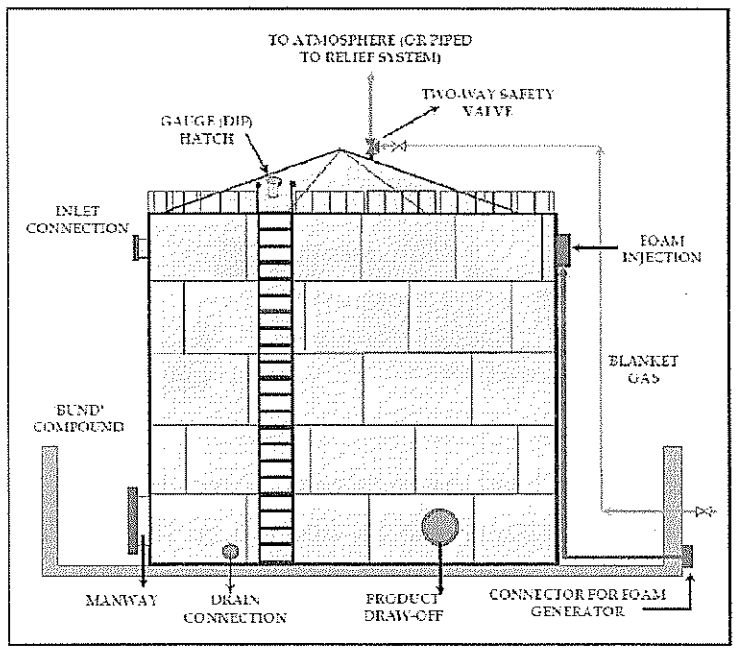


Spherical tank





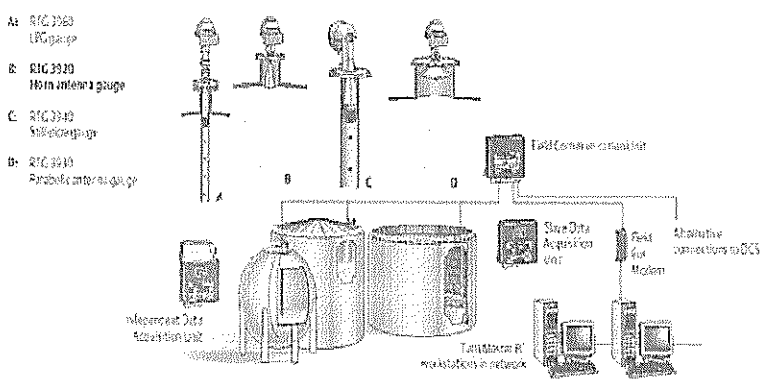
Typical Storage Tank



Composition of Storage Tank

- Roof Access Ladder – บันได
- Access Manholes –ช่องให้คนผ่านเข้าไปด้านใน เพื่อทำความสะอาดหรือซ่อมแซม tank
- Water Drain –แยกน้ำออกจาก tank ที่น้ำมีการแยกตัวออกจากปิโตรเลียม หรือเอาน้ำออกเมื่อทำความสะอาด tank
- Transfer Pumps – ปั๊มเพื่อขนถ่าย product ลงสู่ เรือ รถบรรทุก รถไฟ หรือท่อส่ง หรือเป็นการกวนให้ product ที่อยู่ใน tank มันรวมตัวกัน
- Bund Walls (or Firewalls) – ใช้ในการป้องกันการเกิดการรั่วไหล เป็นกำแพงกั้น เพื่อแยกบริเวณของ tank ออกจากพื้นที่โดยรอบเหมือนรั้วกั้น
- Relief Valves –ติดตั้งเมื่อใน tank ประกอบด้วยความดันสูง ต้องลดความดันใน tank เพื่อป้องกันไม่ให้เกิดอันตราย
- Inert Gas Blanket –ติดตั้งเมื่อ tank ประกอบด้วย volatile liquid ที่จะติดไฟและระเบิดได้ง่ายเมื่อสัมผัสกับอากาศ ส่วนใหญ่ก๊าซเฉื่อยที่ใช้ในการอัดเข้าไปคือ Nitrogen
- Foam Injection –ในกรณีฉุกเฉิน Foam จะถูกฉีดเข้าไปข้างในและข้างบนของ tank และฉีดไปบนพื้นผิวของ liquid
- Vapour Vent – (บางครั้งเรียกว่า 'Breather Valve') –ช่องระบายอากาศ

Tank Gauging System (Onshore/ Offshore)



An overview of the RTG 3920 gauge integrated in the TankRadar Rex system.

- Storage Tank level measurement based on radar gauges
- The Tank gauging should be integral to the Automation system
- Facility wise inventory calculation and reporting

Transportation

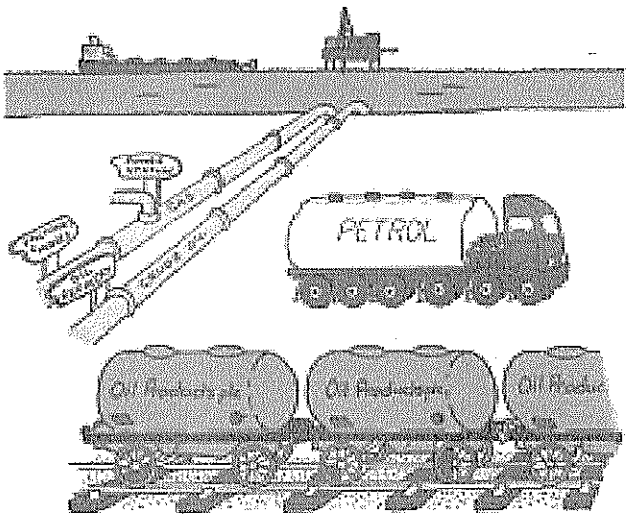
Transporting petroleum fluids from the producing field to the customer requires

It includes:

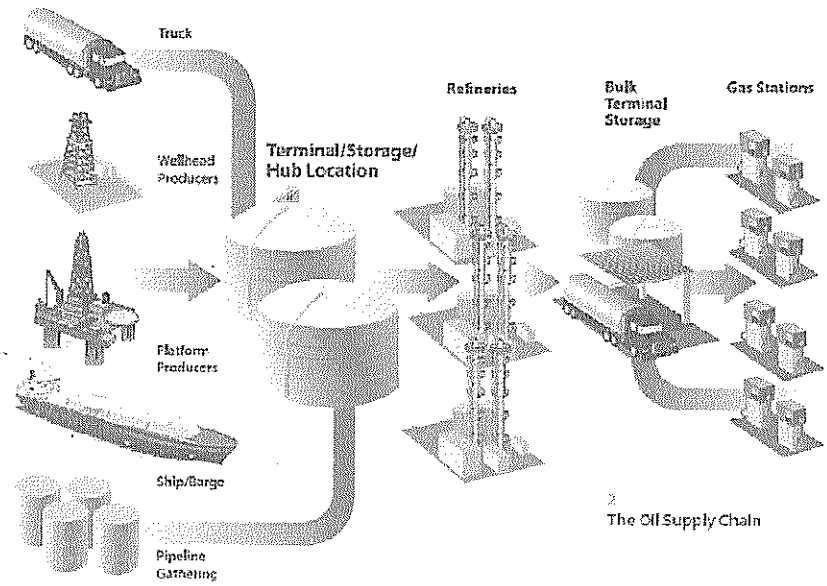
1. Pipeline
2. Transport trucks
3. Railway tank cars
4. Inland water way barges
5. Ocean-going tankers: FSO, FPSO

Oil/Gas/Condensate Transportation

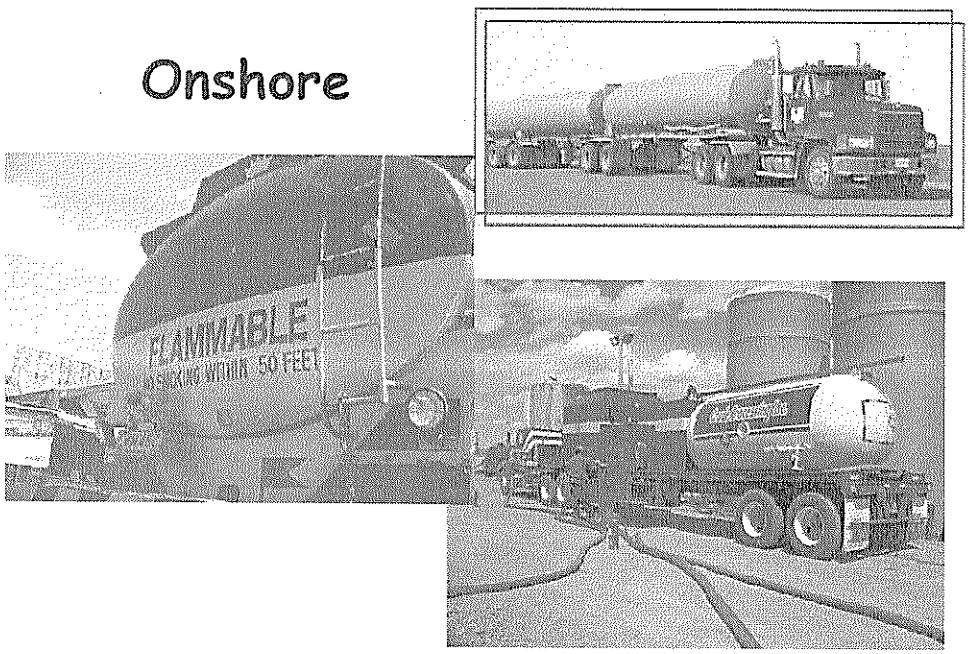
1. Onshore: Truck, Rail and Pipeline
2. Offshore: Ship and pipeline



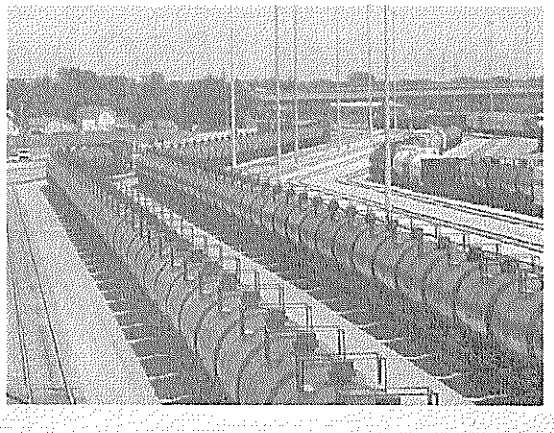
Onshore and Offshore Transportation

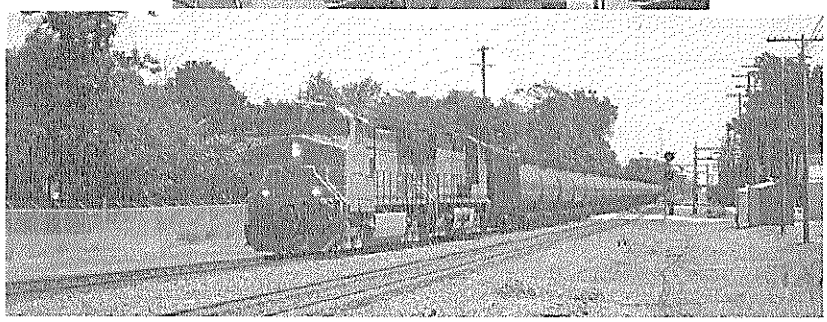


Onshore

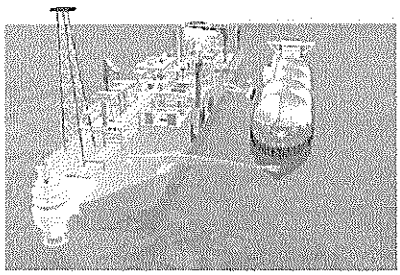


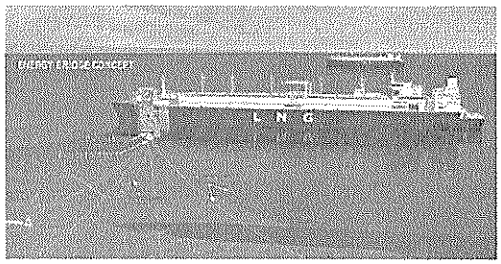
Onshore



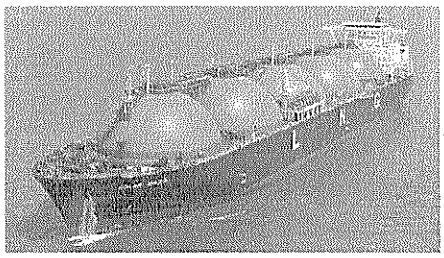


Offshore



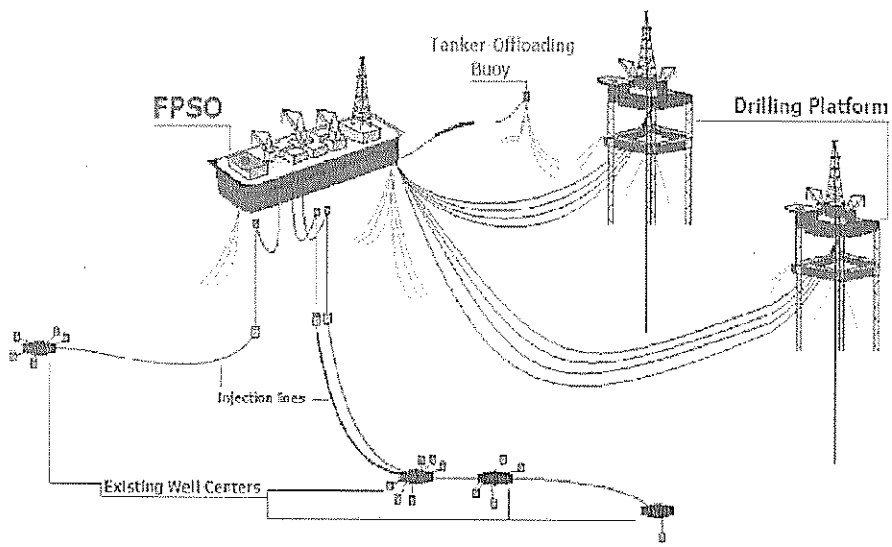


Floating Production Storage and Offloading (FPSO)



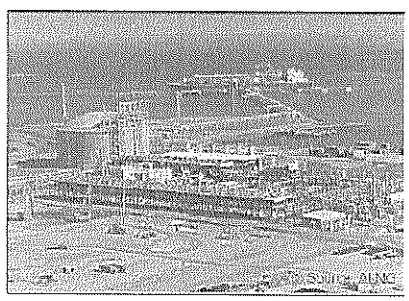
Floating Storage and Offloading (FSO)

How does FPSO work?



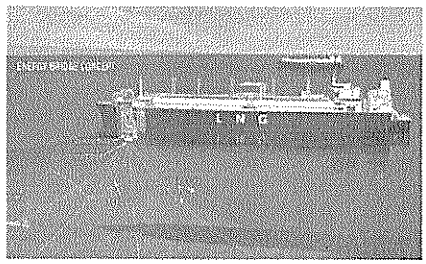
LNG-Liquefaction

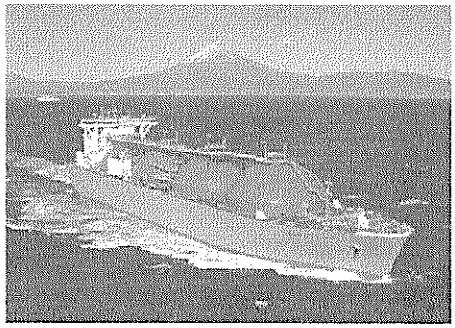
- Contaminants are removed to avoid damaging equipments
- Purify Natural Gas
- Cooling to -260°F



LNG-Transportation

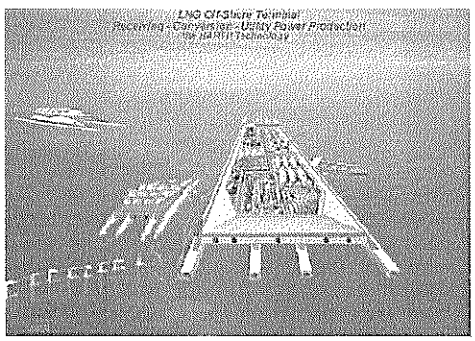
- Special Purpose Vessels
- Spherical, Membrane, and Structural Prismatic Design
- Pipeline vs. Ship
- 2000+ Miles





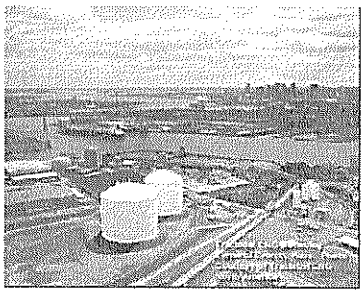
Offshore Regasification

- US to build two Offshore plants, one already under construction
- Floating Storage and Regasification Unit (FSRU)



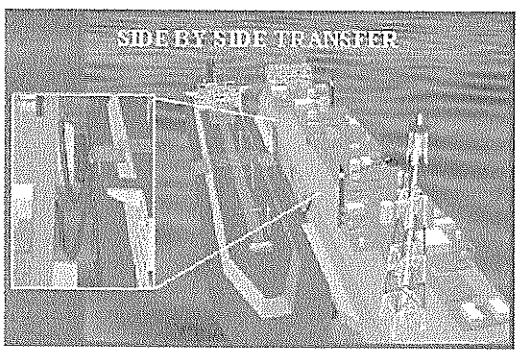
Regasification and Storage

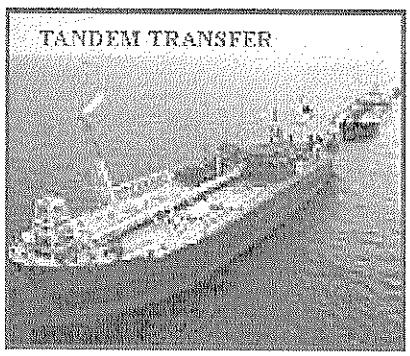
- Specially Insulated Tanks
- LNG is converted back to its gaseous phase
- Transferred by Pipeline



Ship-to-Ship Transfer (STS)

- Emergence of Offshore regasification and liquefaction
- New vessels may now have capability to transfer or receive loads





Pipeline

- Use both onshore and offshore
- There are both oil and natural gas pipeline
- Easy for transport
- High construction cost
- Harm environment and animal
- Danger when got accident

Pipeline Types by transport function

pipelines can be classified in three categories depending on purpose:

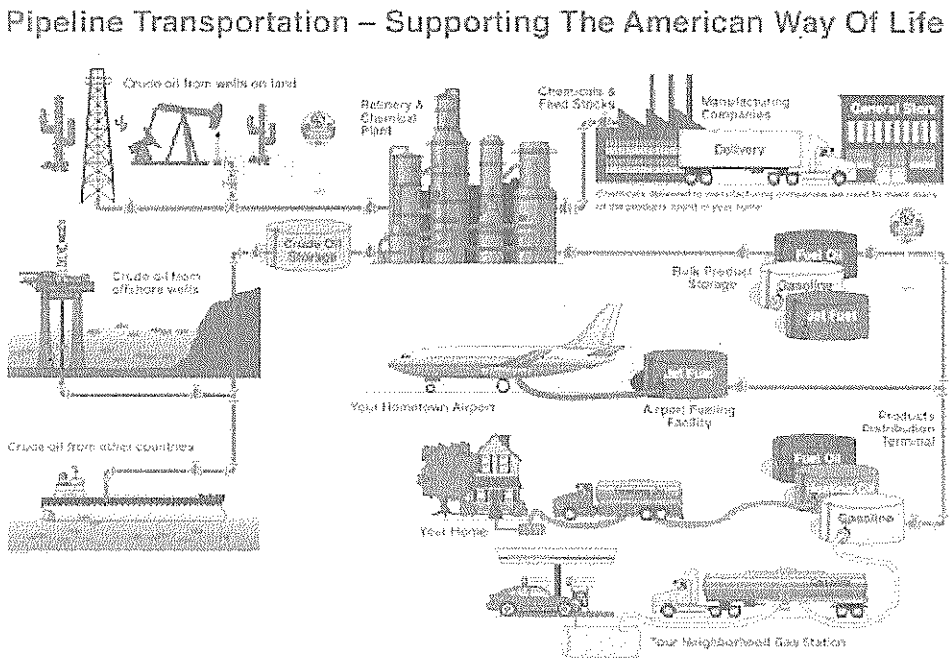
1. **Gathering pipelines:**
   - Group of smaller interconnected pipelines forming complex networks,
   - the purpose of bringing crude oil or natural gas from several nearby wells to a treatment plant or processing facility.
   - Short pipeline and small diameters.
   - Sub-sea pipelines for collecting product from deep water production platforms are considered gathering systems.

Pipeline Types by transport function- Con't

2. **Transportation pipelines:**
   - Mainly long pipes with large diameters
   - Moving products (oil, gas, refined products) between cities, countries and even continents.
   - Transportation networks include several compressor stations in gas lines or pump stations for crude and multiproducts pipelines.

Pipeline Types by transport function- Con't

3. **Distribution pipelines:**
- Composed of several interconnected pipelines with small diameters
- Used to take the products to the final consumer
- Feeder lines to distribute gas to homes and businesses downstream.
- Pipelines at terminals for distributing products to tanks and storage facilities are included in this group.



Petroleum Pipelines

- Pipelines are generally the most economical way to transport large quantities of oil, refined oil products or natural gas over land.

- Multi-product pipelines are used to transport two or more different products in sequence in the same pipeline.

Type of Pipeline define by product

Type of Pipeline can be defined into

1. Oil Pipeline
2. Natural Gas Pipeline

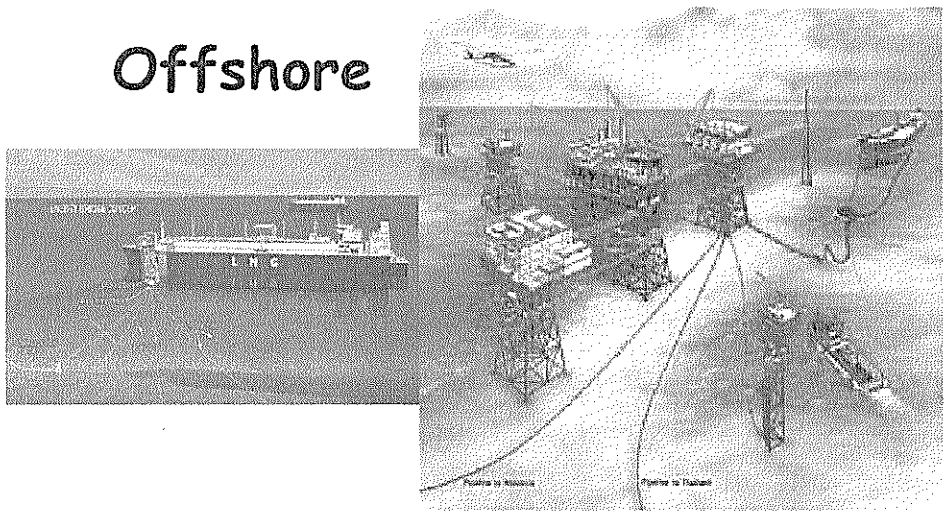
1. Oil Pipelines

- Oil pipelines are made from steel or plastic tubes (diameter 4 to 48 inches or100 to 1,200 mm).
- Most pipelines are buried at a typical depth of about 3 to 6 feet (0.91 to 1.8 m).
- The oil is kept in motion by pump stations along the pipeline,
- Flows at speed about 1 to 6 m/s (3.3 to 20 ft/s).

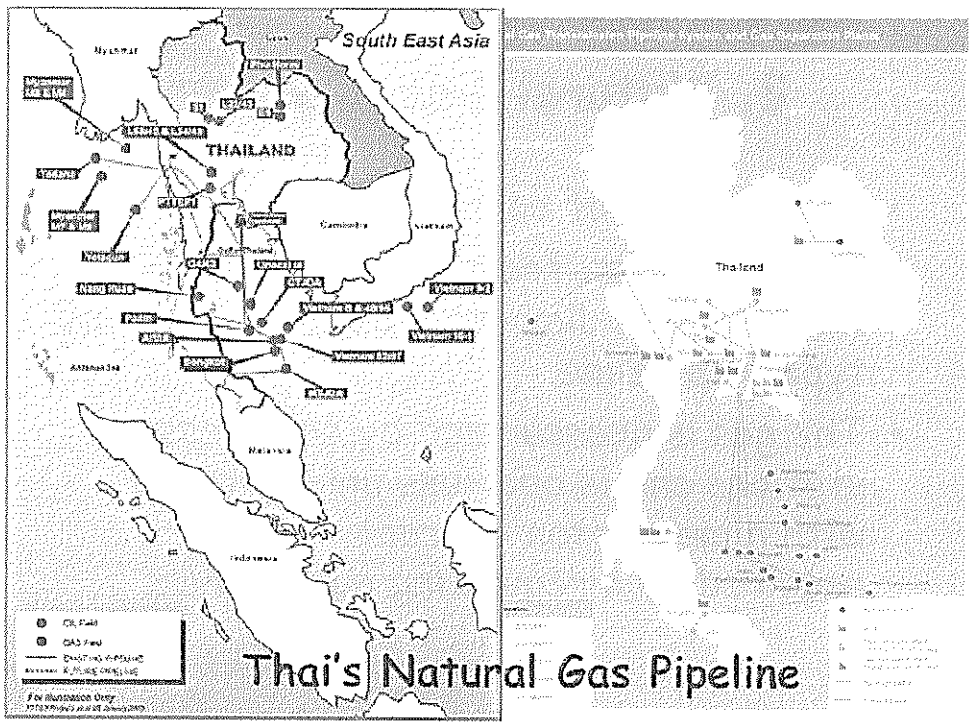
2. Natural Gas Pipelines

- Constructed of carbon steel
- Varying in size from 2 - 60 inches (51 - 1,500 mm) in diameter, depending on the type of pipeline.
- The gas is pressurized by compressor stations and is odorless unless mixed with a mercaptan odorant where required by a regulating authority.

Offshore



- Gas will be shipped via **pipeline**, and condensate will be stored in the FSO ...

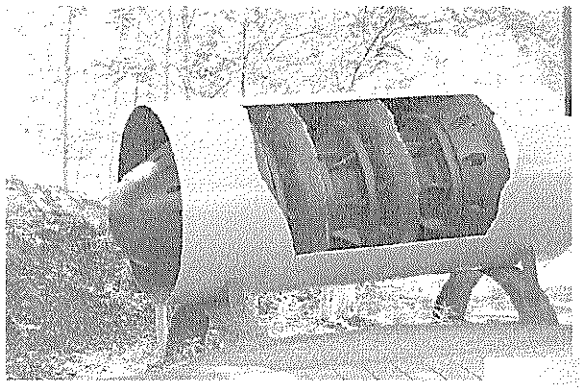


Pipeline Inspection Gauge

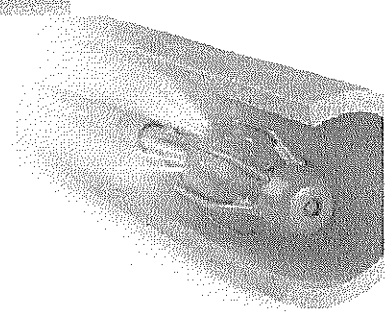
- Pipelines are inspected and cleaned using pipeline inspection gauges *Pigs* (*Scrapers* or *Go-devils*).
- Smart pigs (intelligent pigs) are used to detect anomalies in the pipe such as dents, metal loss caused by corrosion, cracking or other mechanical damage.
- These devices are launched from pig-launcher stations and travel through the pipeline to be received at any other station down-stream, either cleaning wax deposits and material that may have accumulated inside the line or inspecting and recording the condition of the line.

There are 4 main uses for pigs:

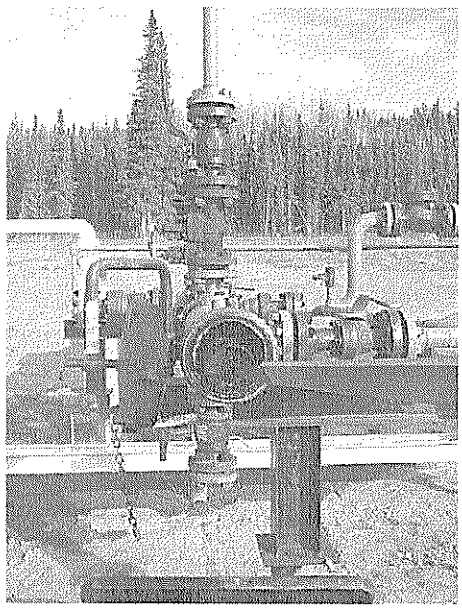
1. Physical separation between different liquids being transported in pipelines
2. Internal cleaning of pipelines
3. Inspection of the condition of pipeline walls (also known as an Inline Inspection (ILI) tool)
4. Capturing and recording geometric information relating to pipelines (e.g. size, position)



Pigs



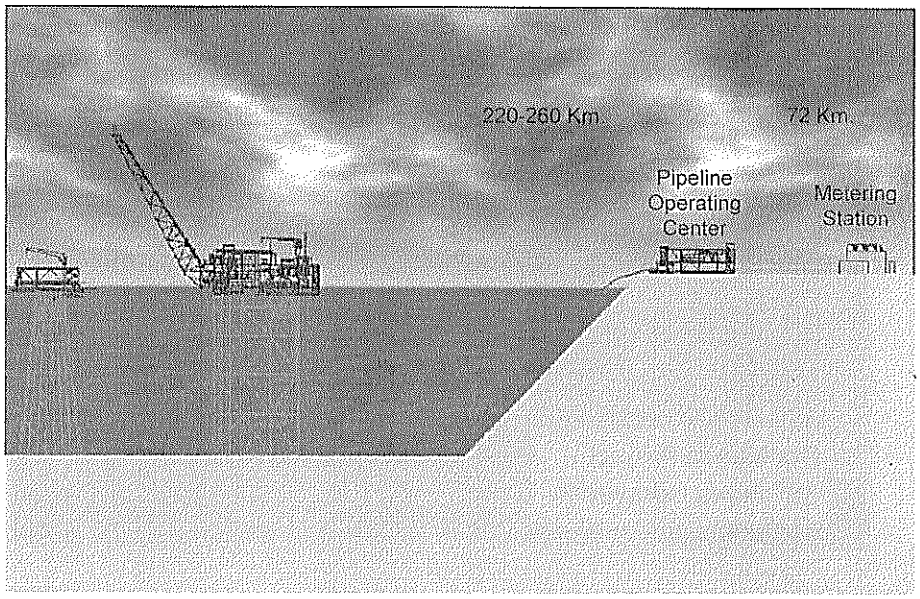
How the Pigs work?

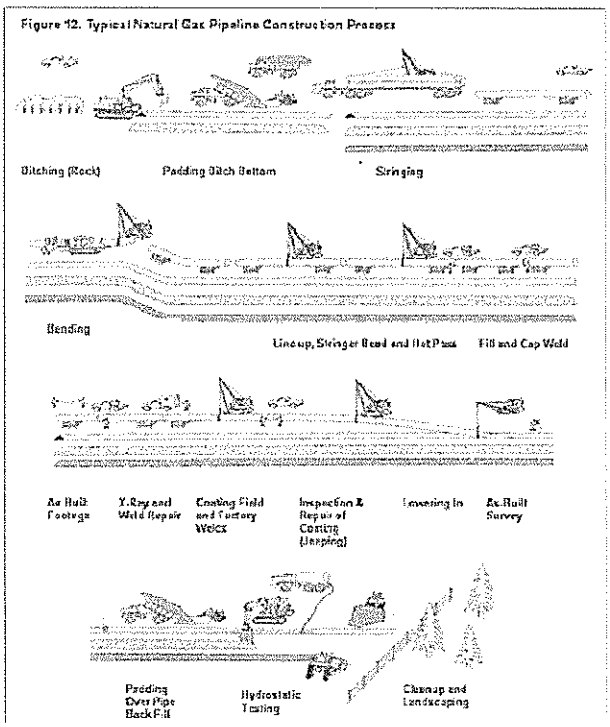


- inserting a pipeline inspection gauge ("pig") into a natural gas line
- The pigging here was done to shunt any water that may have precipitated out of the natural gas.

Pipeline construction

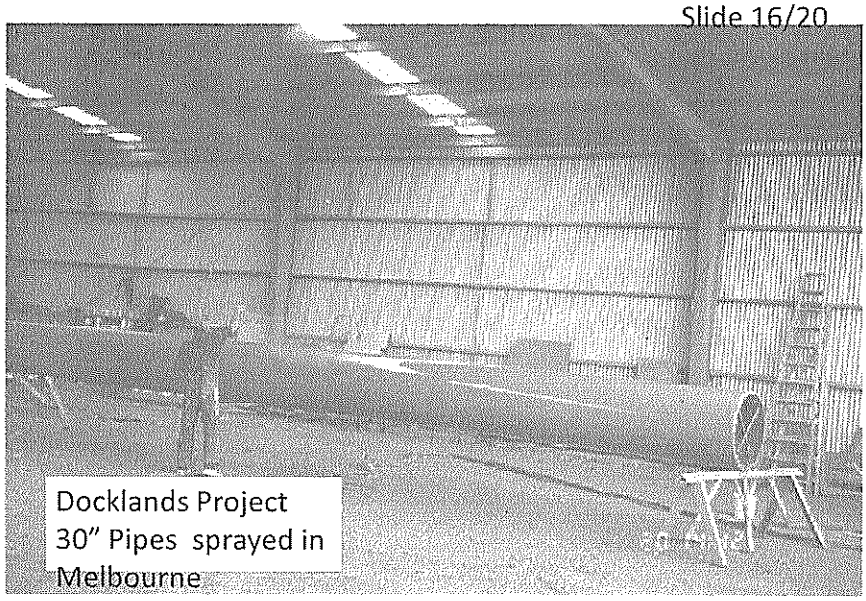
Offshore Pipeline Construction



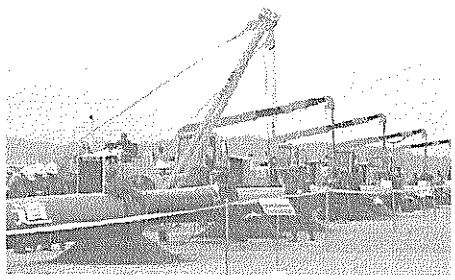


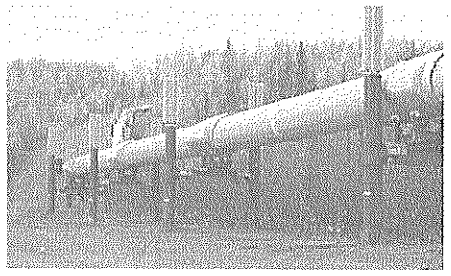
Typical Natural gas Pipeline Construction

Slide 16/20

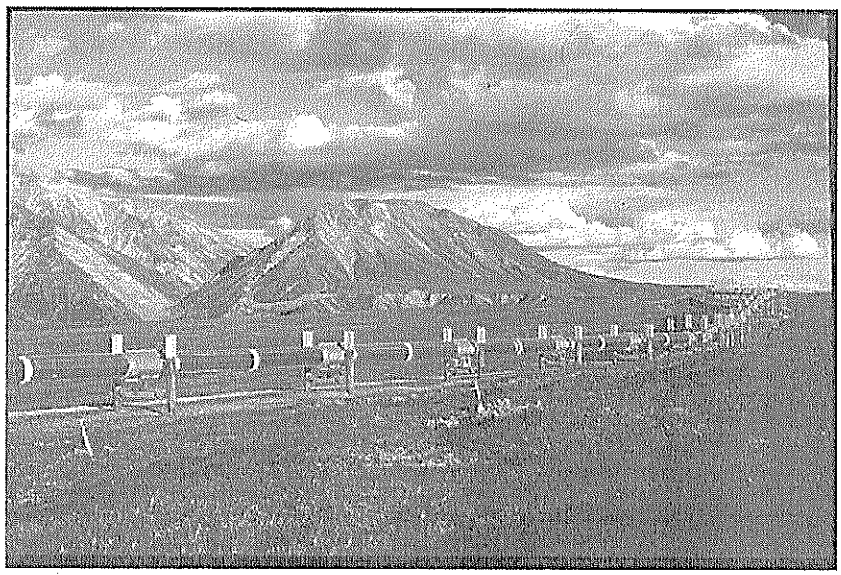


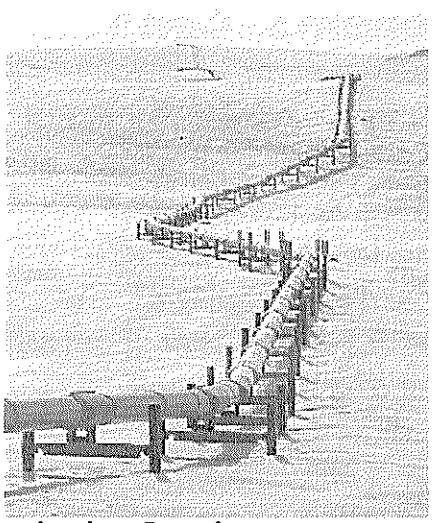
Onshore Pipeline Construction

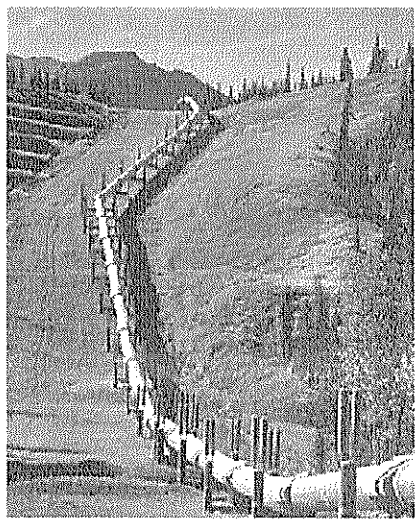




Pipeline through AK range







Alaska Pipeline ประเทศ **United States** ราคา 8,000 ล้านเหรียญ เสร็จใน 1977 เป็นท่อส่งน้ำมันที่ยาวที่สุดในโลก ส่งจากรัฐอลาสก้ามายังคลังเก็บน้ำมันในสหรัฐ เป็นมาตรการความมั่นคงของชาติ แต่กลับไปเอาของประเทศอื่นมาใช้ แล้วสุดท้ายประเทศที่เหลือน้ำมันเป็นประเทศสุดท้ายก็คือ สหรัฐอเมริกา

Pipeline Components

Pipeline networks are composed of several pieces of equipment that operate together to move products from location to location.

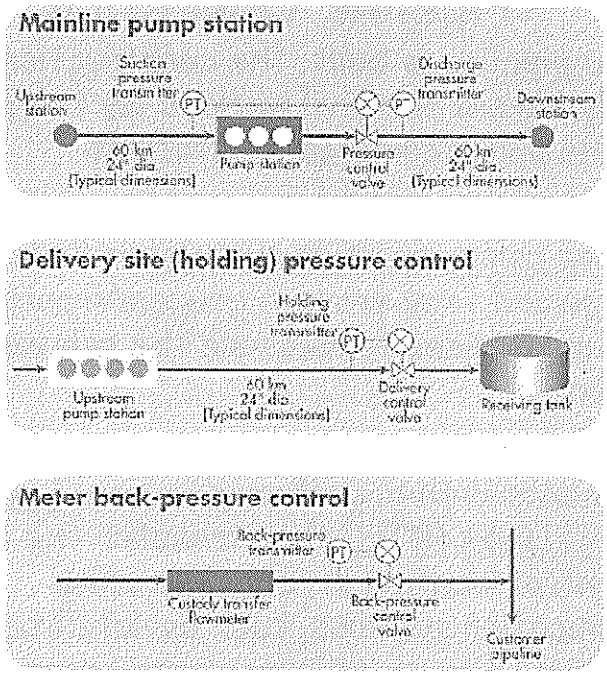
The main elements of a pipeline system are:

1. **Initial injection station (***supply* or *inlet* station): is the beginning of the system, where the product is injected into the line. Storage facilities, pumps or compressors are usually located at these locations.

Pipeline Components-Con't

2. **Compressor/pump stations:** Pumps for liquid pipelines and Compressors for gas pipelines, are located along the line to move the product through the pipeline. The location of these stations is defined by the topography of the terrain, the type of product being transported, or operational conditions of the network.

3. **Partial delivery station** (*intermediate* stations): these facilities allow the pipeline operator to deliver part of the product being transported.

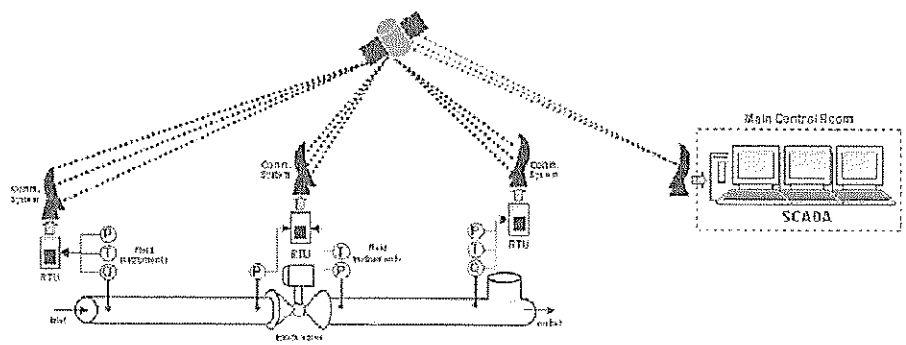


Pipeline Components-Con't

4. **Block valve station:** First line of protection for pipelines. These valves the operator can isolate any segment of the line for maintenance work or isolate a rupture or leak. Block valve stations are usually located every 20 to 30 miles (48 km), depending on the type of pipeline.
5. **Regulator station:** Special type of valve station, where the operator can release some of the pressure from the line. Regulators are usually located at the downhill side of a peak.
6. **Final delivery station** (**Outlet** stations or terminals): this is where the product will be distributed to the consumer. It could be a tank terminal for liquid pipelines or a connection to a distribution network for gas pipelines

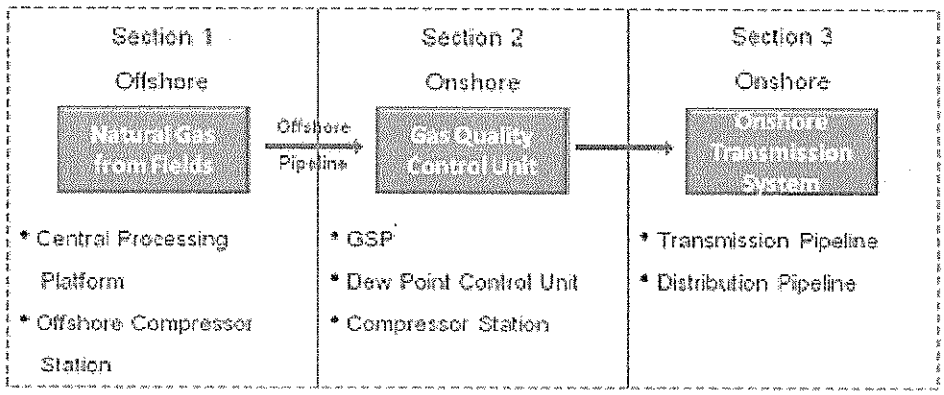
Pipeline Operation

- When a pipeline is built, the construction project not only covers the civil work to lay the pipeline and build the pump/compressor stations
- Field devices are instrumentation, data gathering units and communication systems includes flow, pressure and temperature gauges/transmitters, and other devices to measure the relevant data required.
- The information measured by these field instruments is then gathered in local Remote Terminal Units (RTU) that transfer the field data to a central location in real time using communication systems, such as satellite channels, microwave links, or cellular phone connections.



• *Remote Terminal Units* (RTU): information measured by local field instruments then send the data to main control
• Pipelines are controlled and operated remotely, from *The Main Control Room*

The natural gas transmission pipeline system is composed of three major sections



Natural Gas Transmission Pipeline Operation in Thailand

The head quarter is located in Chonburi (Chonburi Operations Center)

Offshore Pipeline Operations Department is responsible for offshore gas transmission, Erawan Riser Platform (ERP) and PTT Riser Platform (PRP) covering the area of Pattanee, Songkhla, Nakhon Si Thammarat, Surajthani, Chumporn, Prachuabkirikhan and Rayong.

1. Region I Gas Operations Division is responsible for gas transmission in Rayong, Chonburi, Chachoengsao, Samutprakarn and Bangkok

Natural Gas Transmission Pipeline Operation in Thailand-Con't

2. Region II Gas Operations Division is responsible for gas transmission in Bangkok, Pathumthani, Pha Nakhon Sri Ayutthaya and Saraburi
3. **Region III Gas Operations Division** is responsible for gas transmission in Rayong
4. **Region IV Gas Operations Division** is responsible for gas transmission in Khon Khaen.
5. **Region V Gas Operations Division** is responsible for Thai-Burma border gas transmission from Baan E-Tong, Thongphaphum District, Kanchanaburi to Ratchaburi power plant, Ratchaburi.

Natural Gas Transmission Pipeline Operation in Thailand-Con't

6. **Region VI Gas Operations Division** is responsible for gas transmission in Bangkok, Nonthaburi, Samutprakarn, Pathumthani and Nakhonpathom.
7. **Region VII Gas Operations Division** is responsible for gas transmission in Songkhla.
8. **Region VIII Gas Operations Division** is responsible for gas transmission in Kanchanaburi.

Main Duties of Gas Operations Division

1. Operation controlling and planning
2. Gas transmission pipeline engineering support
3. Gas transmission pipeline maintenance
4. Gas transmission pipeline's safety and environment control
5. Block valve station control
6. Preventing and handling gas transmission's emergency by using Supervisory Control And Data Acquisition system (SCADA) via communication systems e.g. microwave, optic fiber cable and satellite communication

Gas Transmission Control System of Pipeline in Thailand

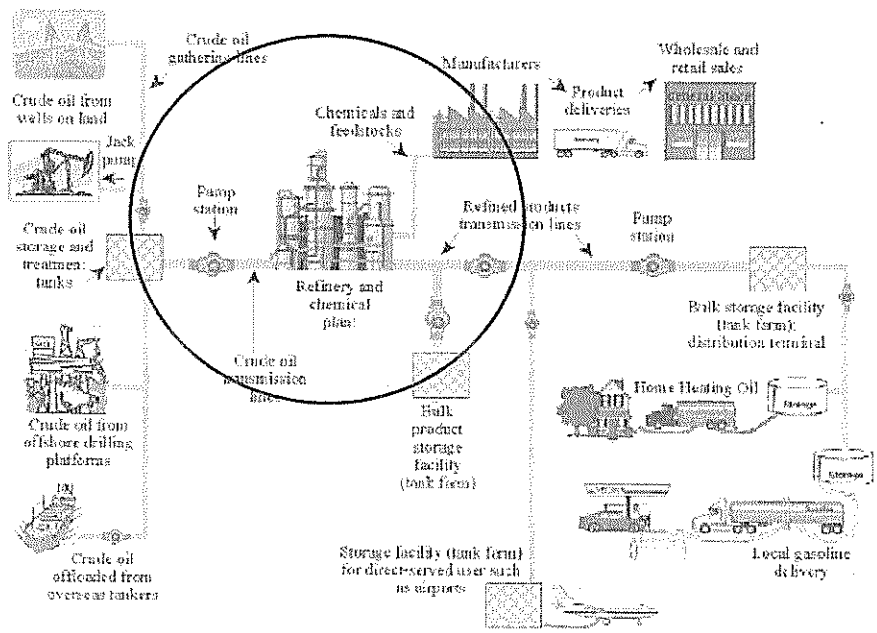
The gas transmission system consists two major parts as follows

1. **Block Valve Station** Each block valve station is installed with gas transmission controlling system.

2. The system is directly operated by Chonburi Operations Center and other gas operations division via the SCADA system.

- Chonburi Operations Center is the main controlling centre and staffed 24 hours.

Chapter 7
Petroleum Refinery



Crude Oil Refining

- Method by which crude oil converted to petroleum products

1. Fractional Distillation: การกลั่นลำดับส่วน
   - At high temperature the lightest fractions rise to the top of a tower, heavier fractions condense at bottom
2. Oil Cracking: การกลั่นแบบ Cracking
   1) Thermal Cracking
   2) Catalytic Cracking
   3) Steam Cracking
   4) Hydro Cracking

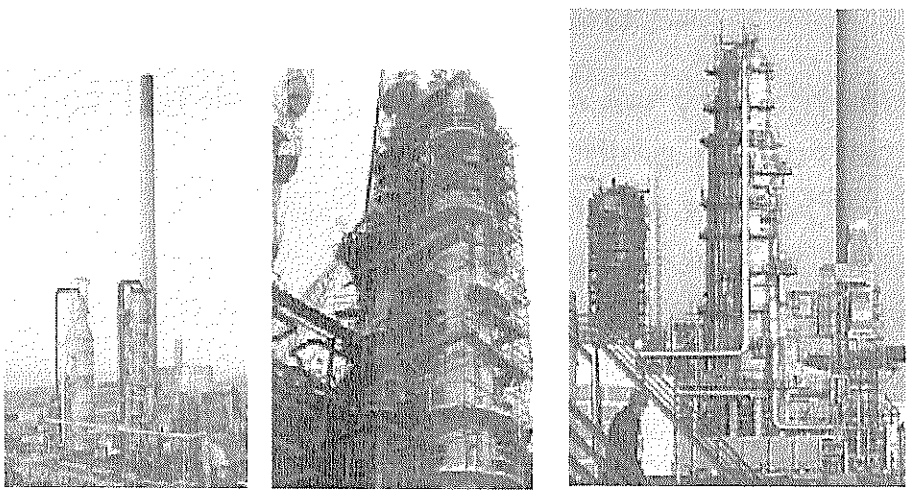
การกลั่นลำดับส่วนน้ำมันดิบ

(Crude Oil Fractional Distillation)

• การกลั่นลำดับส่วน เป็นกระบวนการที่ทำให้น้ำมันดิบได้รับความร้อนสูงประมาณ 500 องศาเซลเซียส ทำให้สารทุกชนิดเปลี่ยนสถานะเป็นแก๊สพร้อมกัน ผ่านขึ้นไปบนหอกลั่นแล้วควบแน่นแยกออกเป็นส่วนๆ

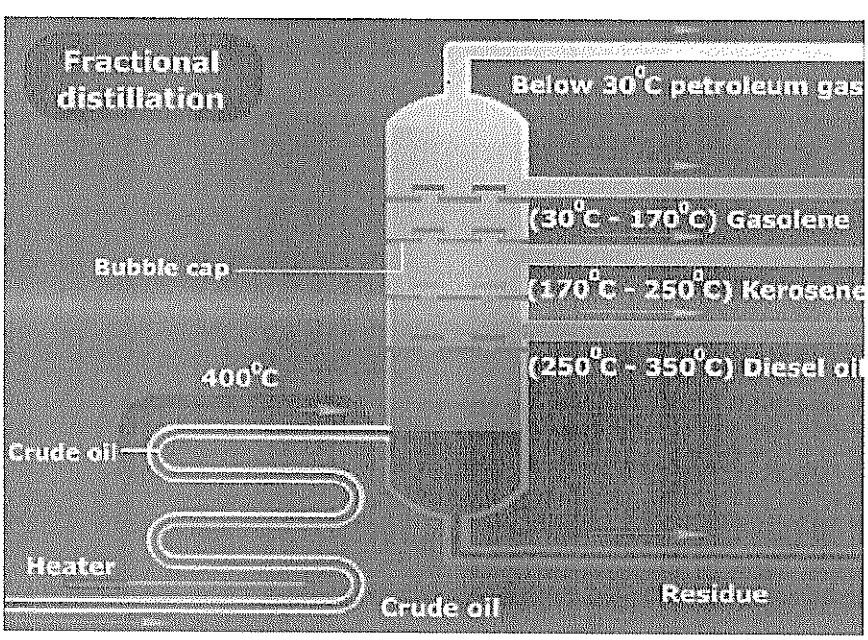
• โดยสารที่มีจุดเดือดสูง แรงยึดเหนี่ยวระหว่างโมเลกุลมาก จึงควบแน่นเป็นของเหลวก่อน และอยู่ที่ด้านล่างของหอกลั่น

• ส่วนสารที่มีจุดเดือดต่ำ แรงยึดเหนี่ยวระหว่างโมเลกุลน้อย จึงเคลื่อนที่ขึ้นไปควบแน่นที่ชั้นบนสุดของหอกลั่น

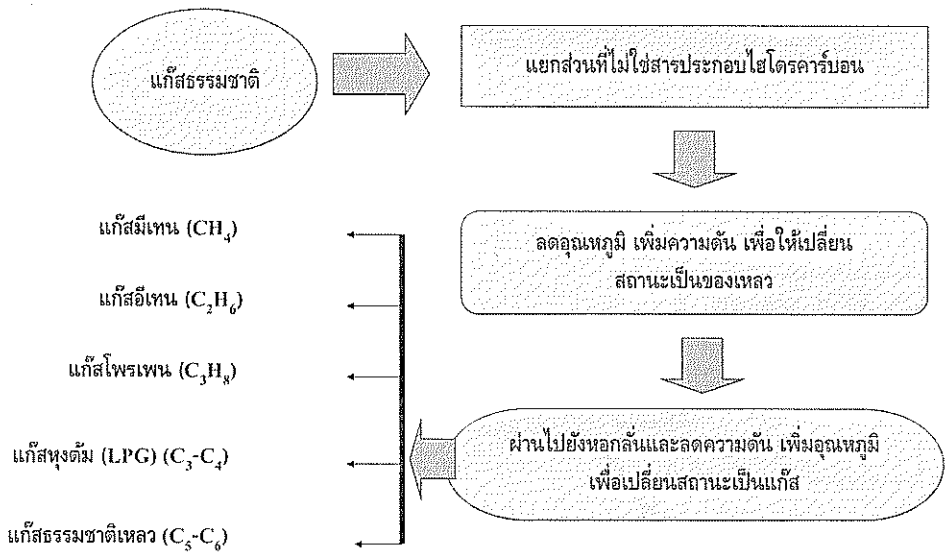


รูปแสดงหอกลั่นน้ำมันดิบ

Fractional Distillation การกลั่นลำดับส่วน

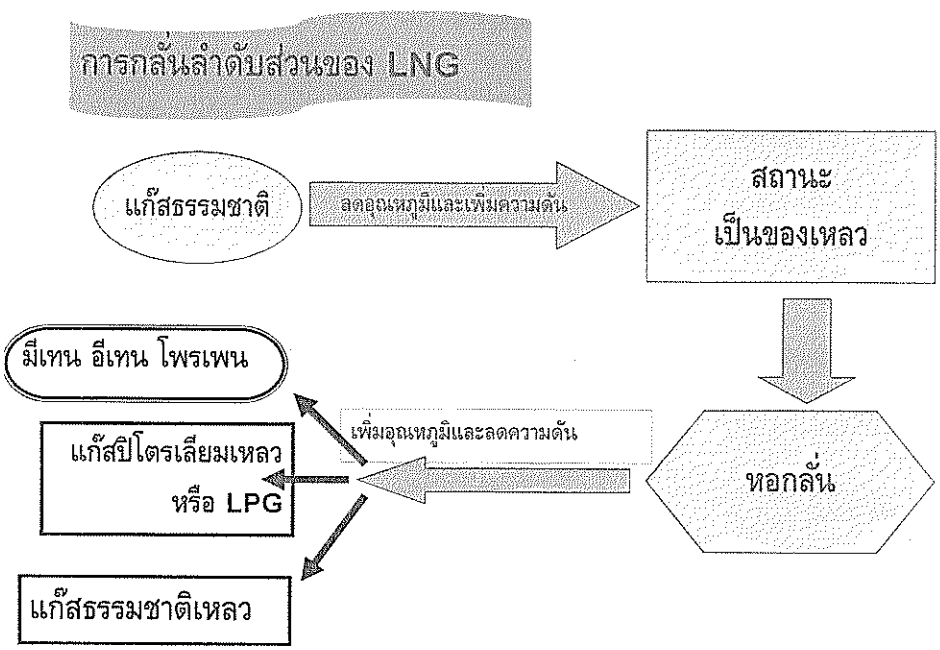


หลักการแยกแก๊สธรรมชาติ



การแยกส่วนที่ไม่ใช่สารประกอบไฮโดรคาร์บอน

- แยกส่วนที่ไม่ใช่สารประกอบไฮโดรคาร์บอน โดยใช้วัสดุที่มีรูพรุนดูดซับ และแยกแก๊สคาร์บอนไดออกไซด์ออกโดยใช้โพแทสเซียมคาร์บอเนต (K_2CO_3) ดูดซับ
- เนื่องจากถ้าไม่แยกออกเมื่อลดอุณหภูมิต่ำกว่า 0 องศาเซลเซียส น้ำจะแข็งอุดตันท่อแก๊ส แล้วจึงนำส่วนที่เป็นสารประกอบไฮโดรคาร์บอนไปแยกโดยใช้หลักการ กลั่นลำดับส่วนต่อไป

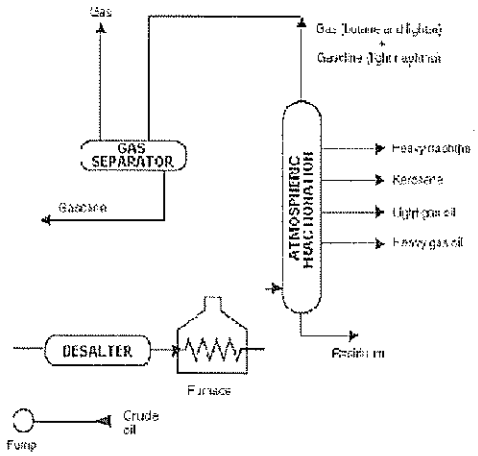


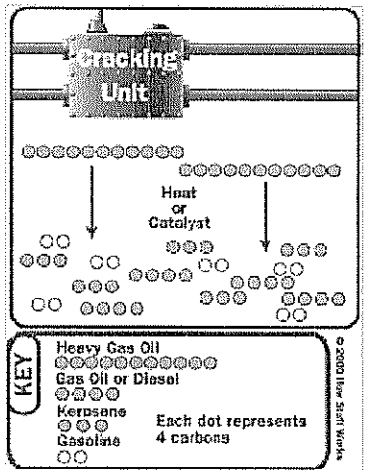
2. Oil Cracking: การกลั่นแบบ Cracking

1. Thermal Cracking
2. Catalytic Cracking
3. Steam Cracking
4. Hydro Cracking

1. Thermal Cracking

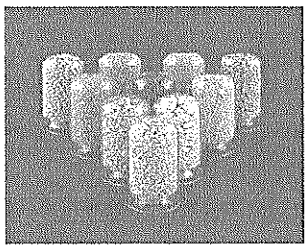
Thermal - heat large hydrocarbons at high temperatures (750-900 °C) (sometimes high pressures as well) until they break apart.
: Products: light gases, diesel fuel and medium naphtha.



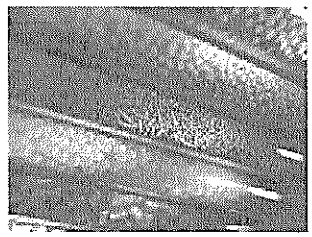


2. Catalytic Cracking

- **Catalytic (or Cat cracking)** - uses a catalyst to speed up the cracking reaction.
- Catalysts include zeolite, aluminum hydrosilicate, bauxite and silica-alumina.
  - **Fluid catalytic cracking** - a hot, fluid catalyst (1000 °F/538 °C) cracks heavy gas oil into diesel oils and gasoline.

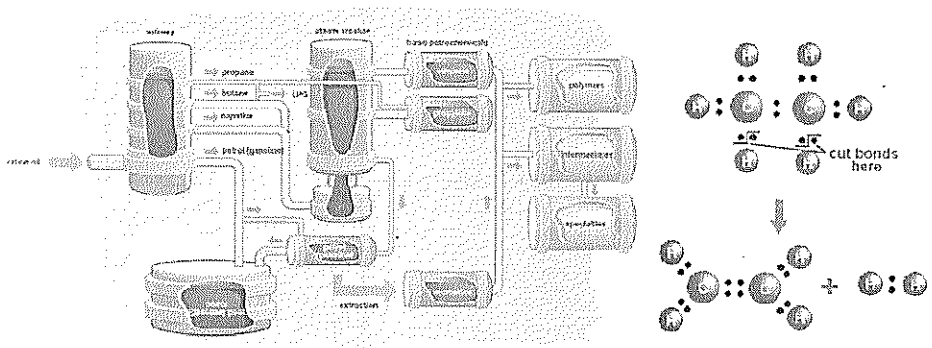


Catalysts used in catalytic cracking or reforming



3. Steam Cracking

- **Steam**: high temperature steam (1500 °F /816 °C: No oxygen) is used to break ethane, butane and naptha into ethylene and benzene, which are used to manufacture chemicals.



4. Hydro Cracking

4.1 **Hydrocracking** - similar to fluid catalytic cracking, but uses a different catalyst, lower temperatures, higher pressure (5000 kPa), and hydrogen gas.

– Heavy oil cracks into gasoline and kerosene (jet fuel).

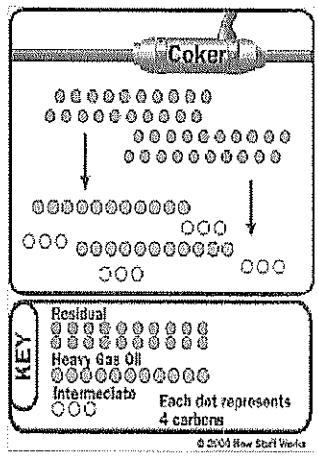
- Large, thick-walled chambers are required to contain the reactions and pressure.

Propane&butane	<0°C
Light gasoline	0-70°C
Bezene	70-140°C
Naphtha	140-180°C
Kerosene	180-250°C
Gas / oil	250-350°C

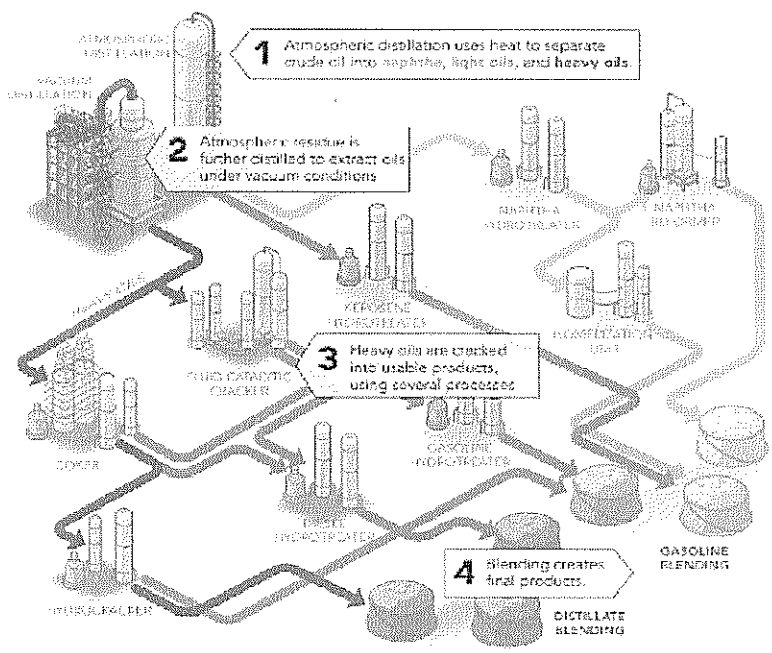
4. Hydro Cracking

4.2 **Visbreaking**: residual from the distillation tower is heated (900 °F/482 °C), cooled with gas oil and rapidly burned (flashed) in a distillation tower. This process reduces the viscosity of heavy weight oils and produces tar.

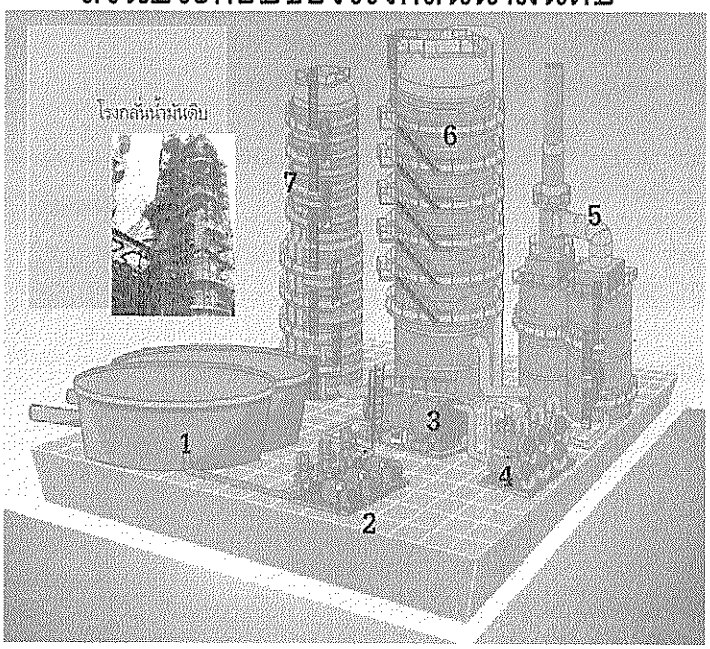
4.3 **Coking**: residual from the distillation tower is heated to temperatures above 900 °F/482 °C until it cracks into heavy oil, gasoline and naphtha. When the process is done, a heavy, almost pure carbon residue is left (**coke**); the coke is cleaned from the cokers and sold.

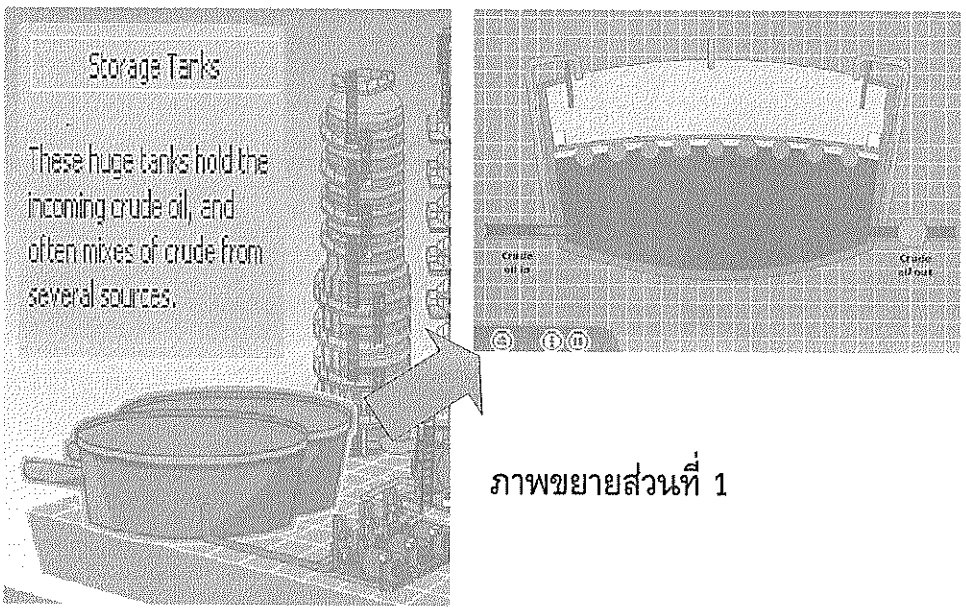


Crude Oil Refining

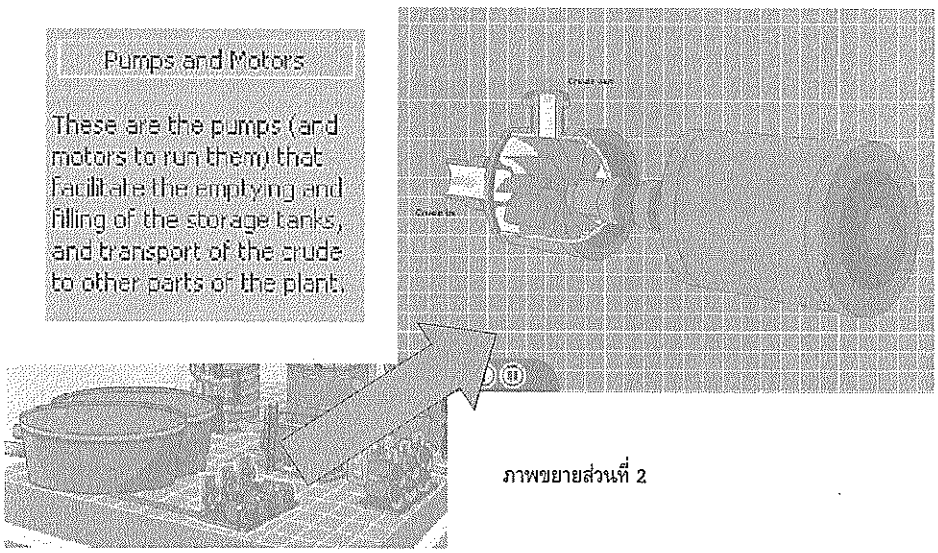


ส่วนประกอบของโรงกลั่นน้ำมันดิบ

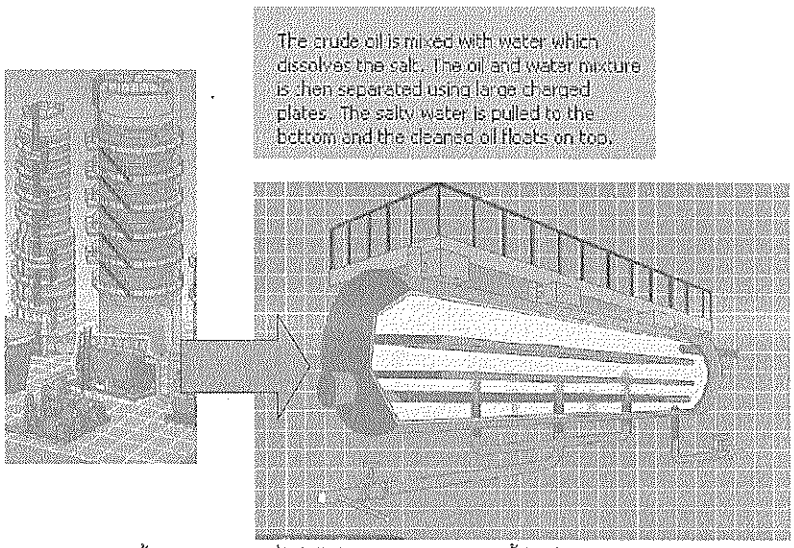




ภาพขยายส่วนที่ 1

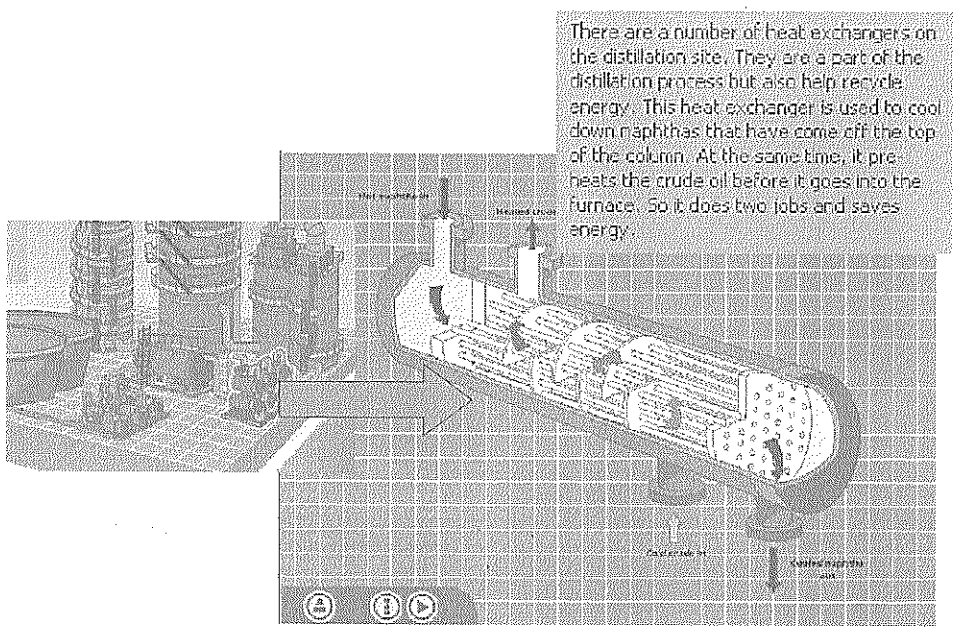


ภาพขยายส่วนที่ 2

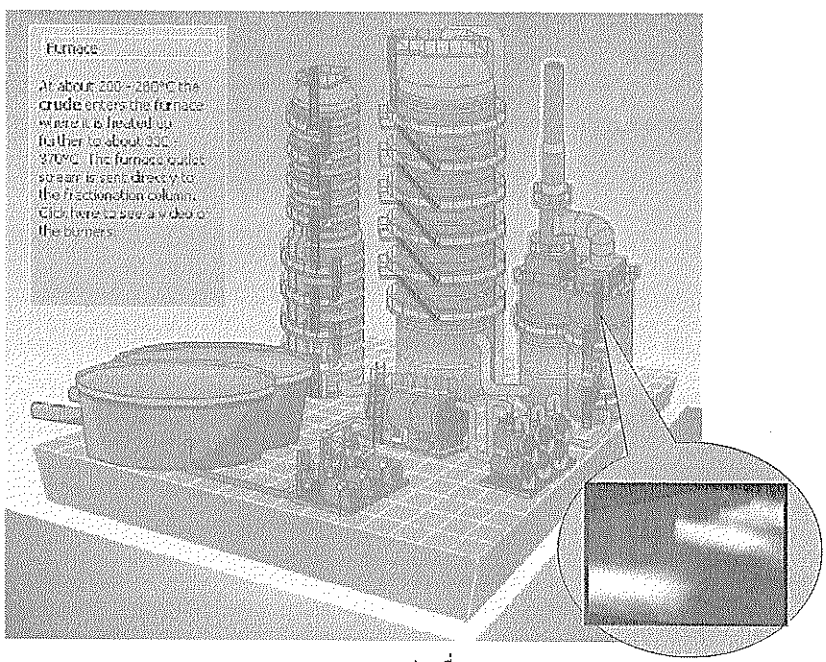


ส่วนนี้ทำหน้าแยกสารที่ไม่ใช่ไฮโดรคาร์บอนออกเช่น น้ำโดยใช้ตัวดูดซับ

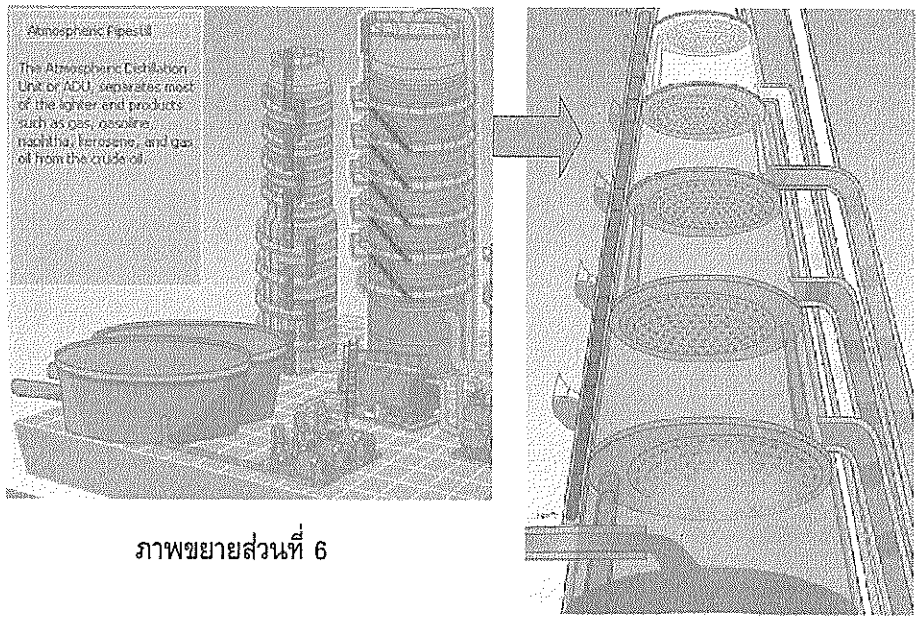
ภาพขยายส่วนที่ 3



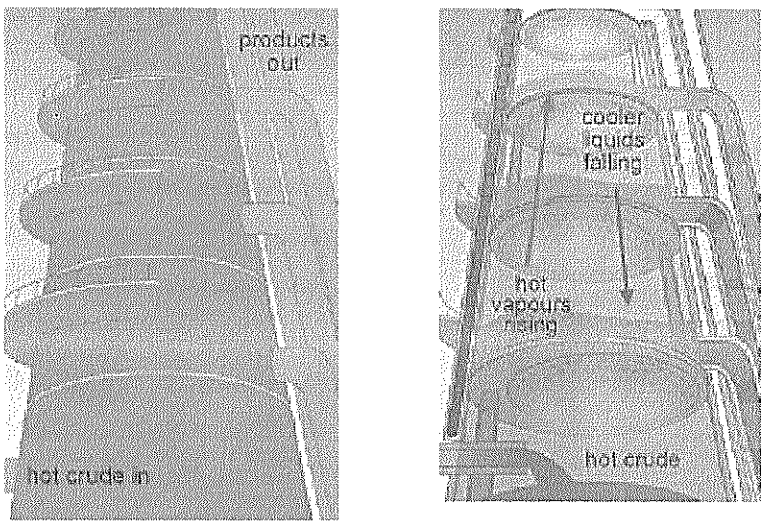
ภาพขยายส่วนที่ 4



ภาพขยายส่วนที่ 5

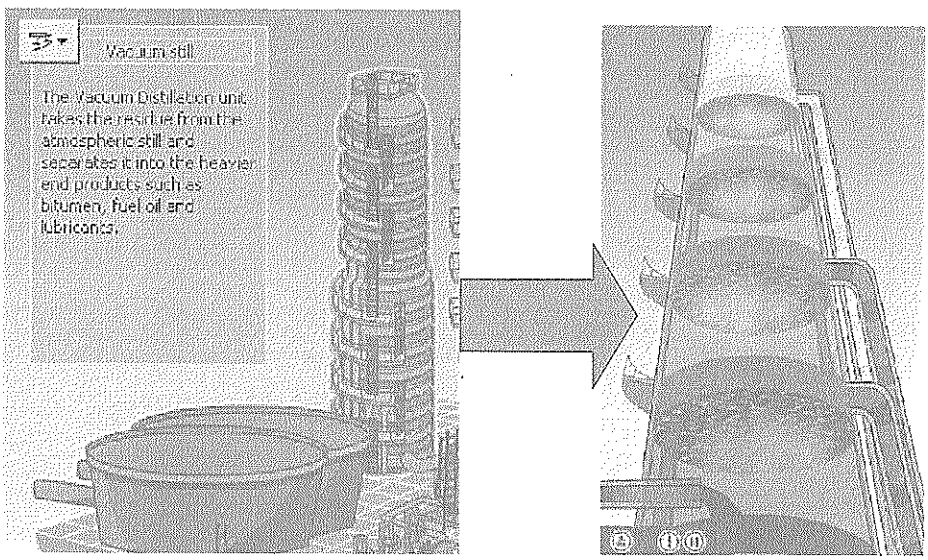


ภาพขยายส่วนที่ 6



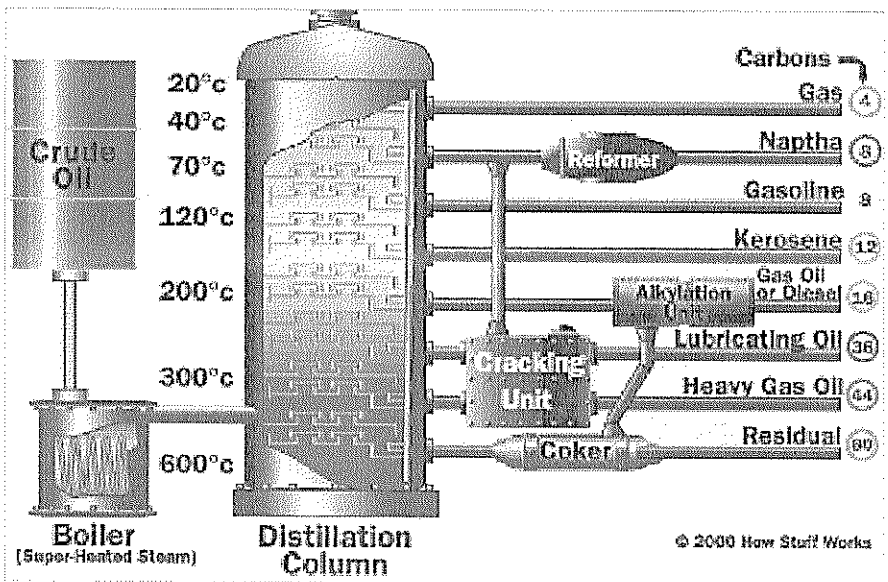
แบบจำลองภายนอก แบบจำลองภายใน

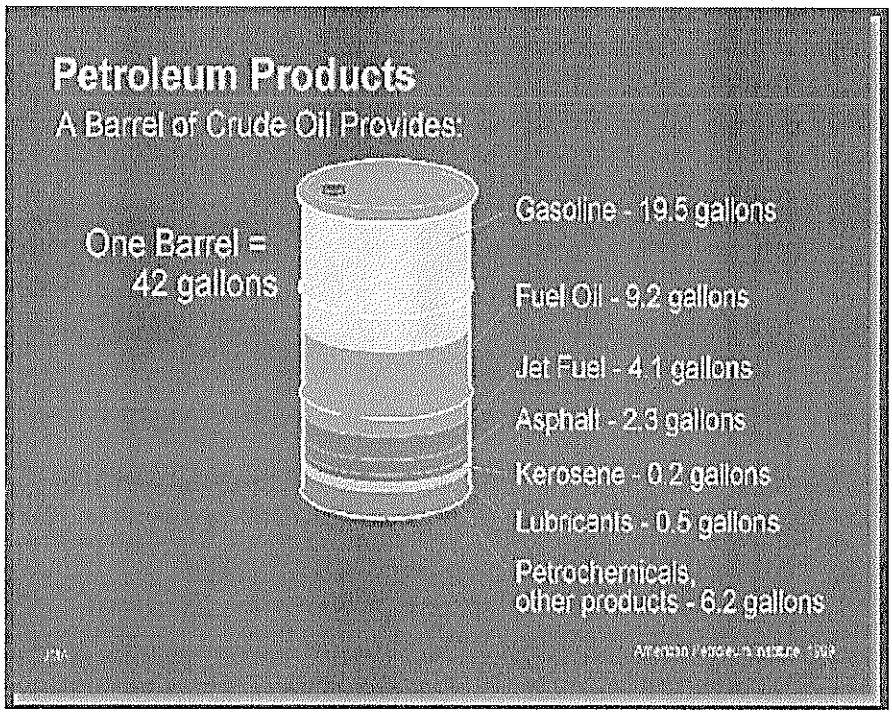
ภาพขยายส่วนที่ 6 รูปแสดงหอกลั่นน้ำมันดิบ



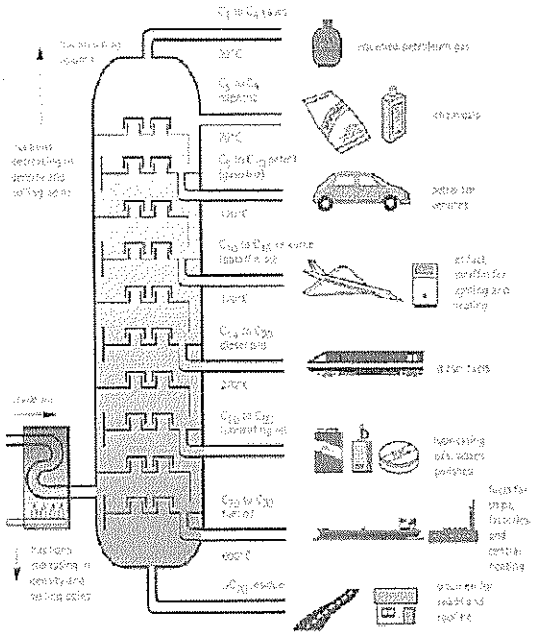
ภาพขยายส่วนที่ 7 แสดงหอกลั่นส่วนที่ 2 กลั่น **bitumen fuel oil** และ **lubricants**

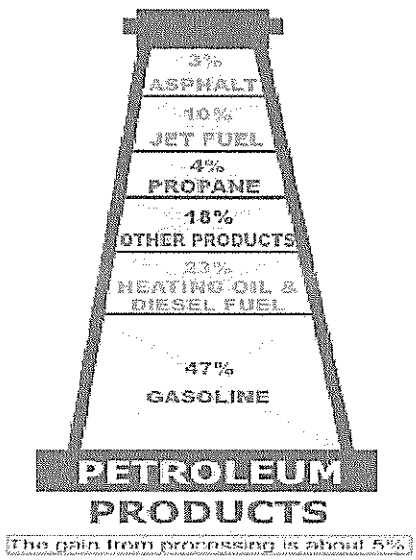
Petroleum Products from Distillation Column



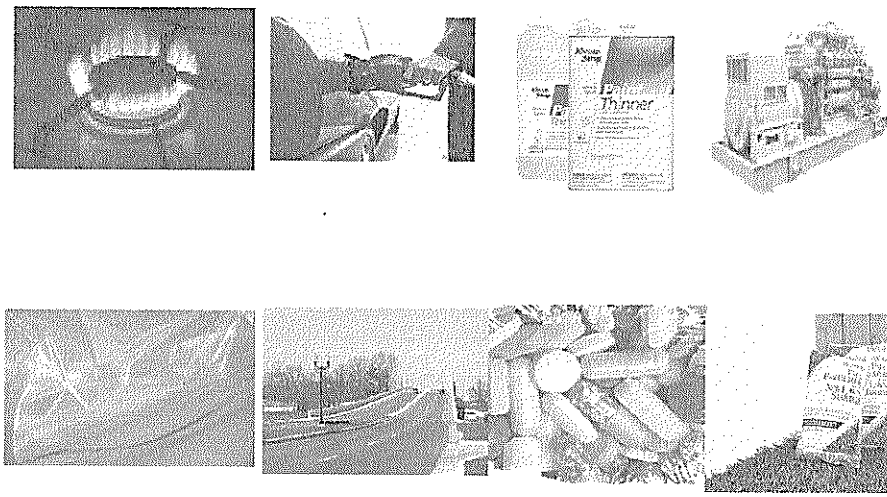


Products Consumed from Petroleum





Petroleum products



WHAT HAPPENS TO THE BAD STUFF IN THE CRUDE?

1. Sulfur
   - converted to elemental sulfurin high sulfur fuel oil in coke
2. Heavy Metals (nickel, vanadium)
   - in high sulfur fuel oil and coke
3. Nitrogen (organic nitrogen)
   - most is converted to ammonia and neutralized in high sulfur fuel oil and coke

ประโยชน์ของผลิตภัณฑ์จากการกลั่นน้ำมันดิบ

สารที่ได้จากการกลั่น	จำนวน C	จุดเดือด °C	การนำไปใช้ประโยชน์
แก๊สปิโตรเลียม	1-4	< 40	• ทำเชื้อเพลิง สารเคมี •สารตั้งต้นของวัสดุสังเคราะห์
แนฟทาเบา-หนัก	5 -10	25 – 175	• น้ำมันเบนซิน • สารเคมี
น้ำมันก๊าด	10 -16	150 – 260	• เชื้อเพลิงเครื่องบินไอพ่น
น้ำมันดีเซล	14 -50	235 – 360	• เชื้อเพลิงใช้กับเครื่องยนต์ดีเซล
น้ำมันหล่อลื่น	20 -70	330 – 380	•น้ำมันหล่อลื่น
ไข	19-35	340- 500	• ทำเทียนไข • ทำเครื่องสำอาง •วัตถุดิบในการผลิตผงซักฟอก
น้ำมันเตา	> 35	> 500	•เชื้อเพลิงเครื่องจักร
Bitumen	>35	>500	• ทำวัสดุกันรั่วซึม ยางมะตอย

Composition and Application of Natural Gas

Compound	Molecular	% by volume	Application
มีเทน	CH_4	80-90	ใช้เป็นเชื้อเพลิง
อีเทน	C_2H_6	4-10	ผลิตพลาสติก ผลิตแอลกอฮอล์ ผลิต LPG
โพรเพน	C_3H_8	3-5	เชื้อเพลิงแก๊สหุงต้ม ในรถยนต์ เชื้อเพลิงในอุตสาหกรรม

Composition and Application of Natural Gas

Compound	Molecular	% by volume	Application
มีเทน	C_1H_4	1-3	ใช้เป็นวัตถุดิบในอุตสาหกรรมผลิตสารเคมีเป็นเชื้อเพลิง
อีเทน	C_2H_6	3-5	ใช้เป็นวัตถุดิบในอุตสาหกรรมผลิตสารเคมี
โพรเพน	C_3H_8	0.1-1	ใช้เป็นเชื้อเพลิงหุงต้ม

Composition and Application of Natural Gas

Compound	Molecular	% by volume	Application
คาร์บอนไดออกไซด์	CO_2	15-25	ผลิตน้ำแข็งแห้งดับเพลิง
ไนโตรเจน	N_2	ไม่เกิน 3	ใช้ทำปุ๋ยไนโตรเจน
ฮีเลียม ไฮโดรเจน ไฮโดรเจนซัลไฟด์		น้อยมาก	

Classification of Natural Gas

- **Dry Gas:** Natural gas consisting principally of methane (>90%) and devoid of readily condensable constituents such as gasoline.
- **Wet gas:** Natural gas consisting of methane (<90%) and heavier hydrocarbon (C2-C5)
- **Condensate:** A hydrocarbon mixture that is gas phase in its reservoir but condenses into liquid when produced. Its gravity usually ranges from 55 API upward. (C6-C7)
- **Sweet Gas:** Gas that contains with low or no sulfur is priced higher than sour gas.
- **Sour Gas:** Gas that contains significant amounts of sulfur or hydrogen sulfide.
- **Bacteria Gas:** Methane formed by bacteria (methanogens) utilizing carbon dioxide and hydrogen.

โรงกลั่นน้ำมันในประเทศไทย

1. โรงกลั่นน้ำมันไทยออยล์(Thai Oil Refinery)

โรงกลั่นน้ำมัน ปตท. อะโรเมติกส์และการกลั่น (PTTAR Refinery)

โรงกลั่นน้ำมันระยองเพียวริฟายเออร์(Rayong Purifier Refinery)

โรงกลั่นน้ำมันไออาร์พีซี(IRPC Refinery)

โรงกลั่นน้ำมันบางจาก (Bangchak Refinery)

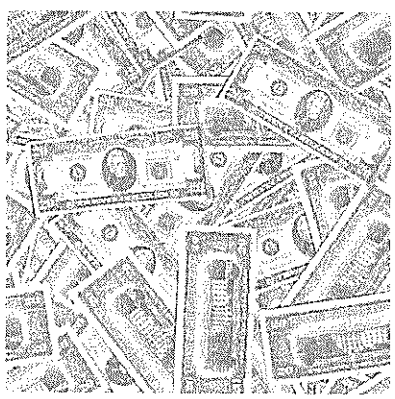
โรงกลั่นน้ำมันเอสโซ่(Esso Refinery)

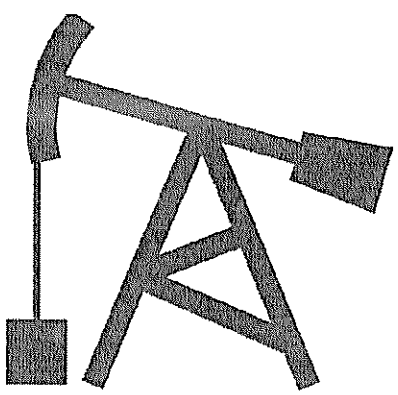
โรงกลั่นน้ำมันสตาร์ปิโตรเลียม รีไฟน์นิ่ง(SPRC Refinery)

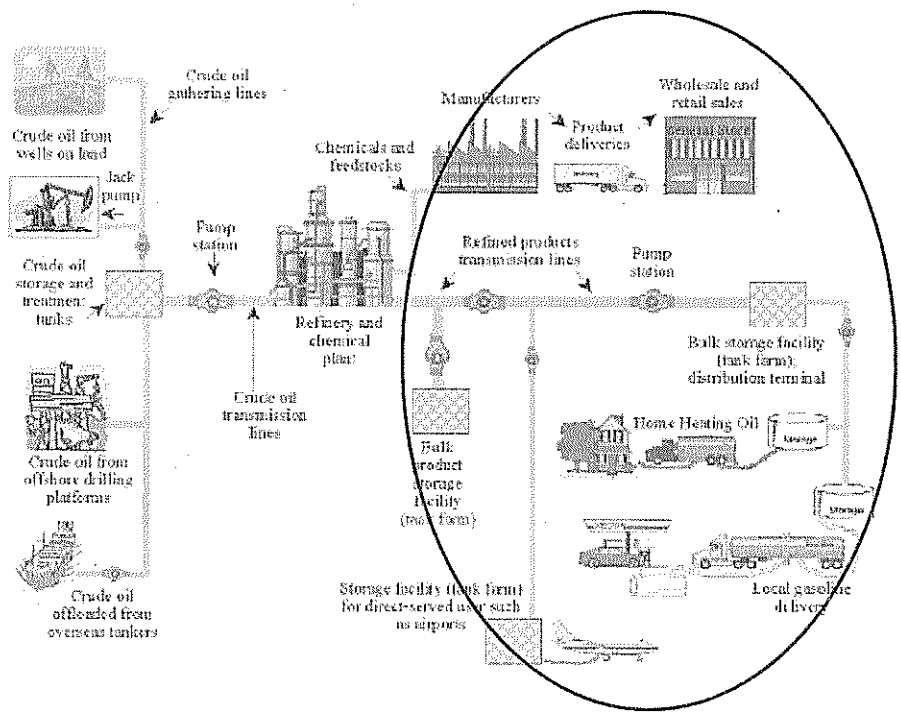
โรงกลั่นน้ำมันในประเทศไทย

อันดับที่	โรงกลั่น	กำลังกลั่นน้ำมันดิบ 2008	
		บาเรลล์ต่อวัน	ล้านลิตรต่อวัน
1	ไทย ออยล์ (TOP)	275,000	43.7
2	ไออาร์พีซี (IRPC)	215,000	34.2
3	เอสโซ่ (ESSO)	170,000	27.0
4	สตาร์ปิโตรเลียม รีไฟน์นิ่ง(SPRC)	150,000	23.8
5	ปตท อะโรมาติกส์และการกลั่น (PTTAR)	145,000	23.1
6	บางจากปิโตรเลียม (BCP)	120,000	19.1
7	ระยองเพียวริฟายเออร์ (RPC)	17,000	2.7
	รวม	1,092,000	173.6

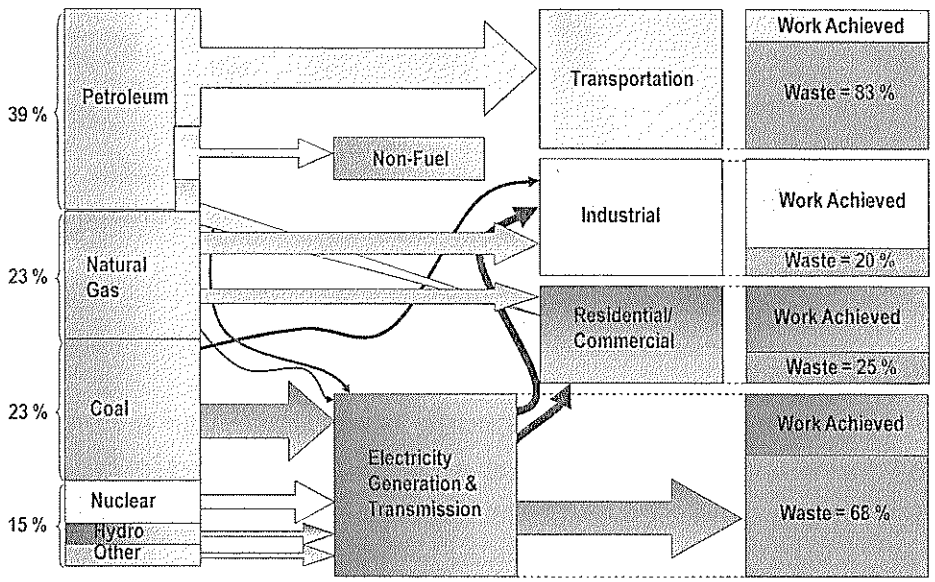
Chapter 8
Petroleum Marketing







How much petroleum goes into market?

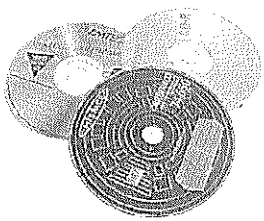


Fuel source

- 84% of crude oil is refined into fuel, principally for cars and planes

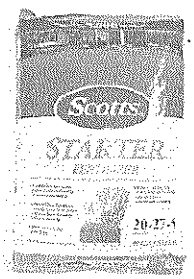
- Demand is ever increasing, especially due to growth of Chinese economy

Other uses



CDs and DVDs

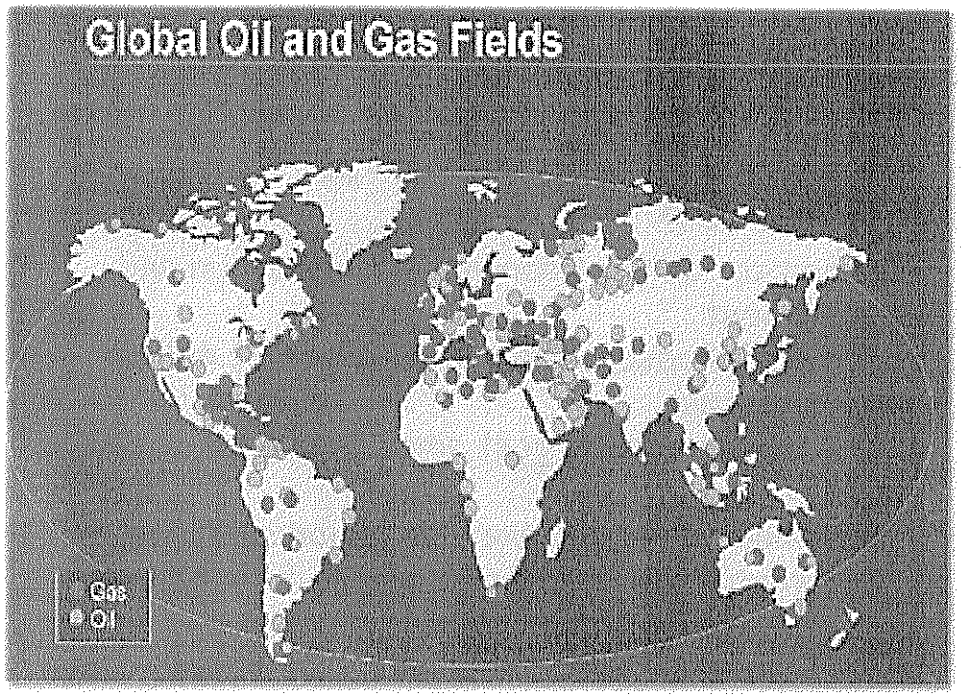
Plastic



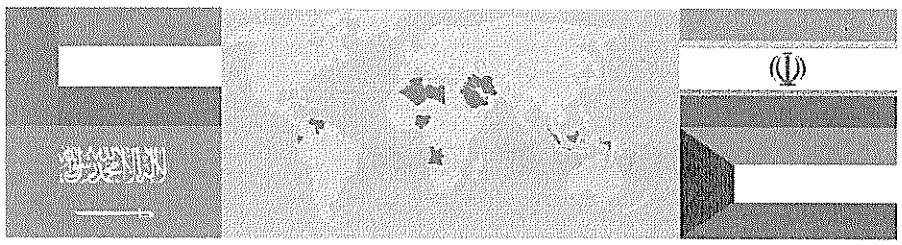
Fertilizers and Pesticides

Food additives

- The remaining 16% of crude oil is used for a range of purposes shown above as well as synthetic fibers, fertilizer and detergents and so on.

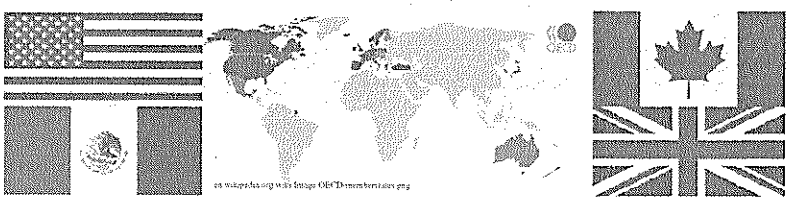


Main Producers - OPEC



- Organization of the Petroleum Exporting Countries (OPEC) is a group of 13 countries that produce 36% of the world's oil, or 32 million barrels of oil per day.
- The biggest producer is Saudi Arabia, but Iran, United Arab Emirates, Kuwait and Venezuela are also major suppliers

Other Producers



- Organization for Economic Co-operation and Development
- (OECD) produces 24% of all oil, or 21 million barrels per day.
- The USA is the biggest single producer in OECD but Mexico,
- Canada and the UK are also major suppliers
- Outside OECD, the states of the former Soviet Union are also major producers supplying a further 15% of global output

Today's Super-Majors Oil Companies

1. Exxon-Mobil
2. Shell
3. BP (formerly BP-Amoco)
4. Total
   - Merged with Petrofina (Belgium) 1999
   - Merged with Elf Aquitaine (France) 2000
5. Chevron (formerly Chevron-Texaco)
6. Conoco-Phillips

หน่วยงานรัฐและบริษัทสำรวจและผลิตน้ำมันในไทย

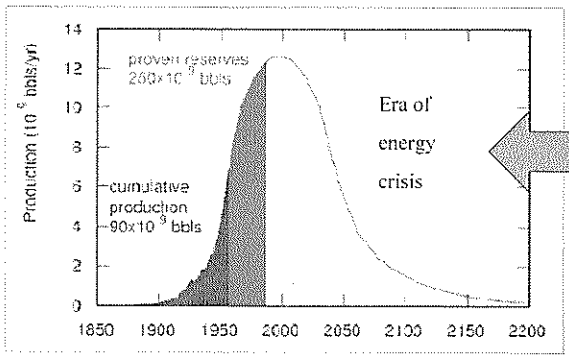
Supply and Demand

USA uses 24% of global supply but China shows the biggest year-to-year increase in usage

Oil consumption per person
(darker reds indicate higher usage)

- In 2007, global consumption grew by 1.2 million barrels per day.
- OPEC and OECD nations can only raise production by a further 2.5 million barrels per day so a squeeze is on the cards

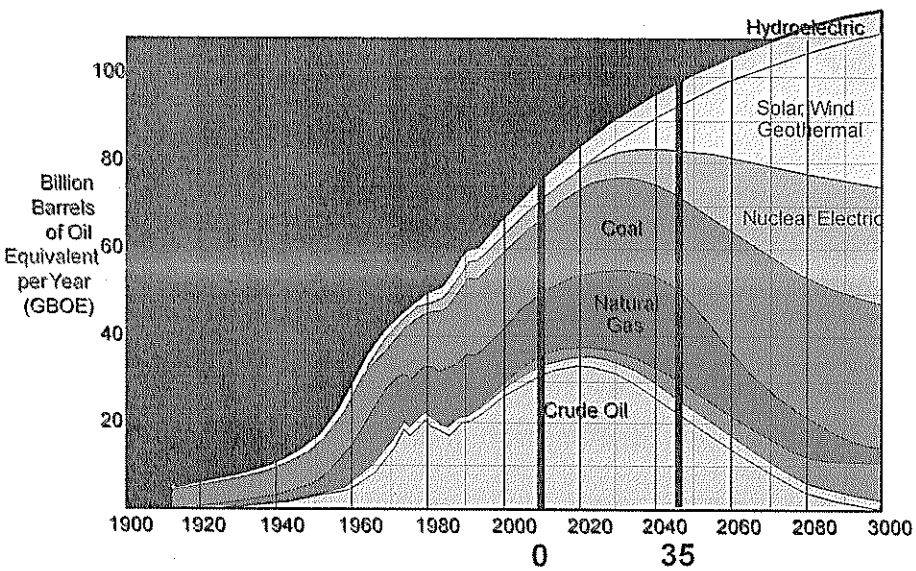
Peak Oil



Hubbert (1903-1989)

- In 1956, Hubbert predicted that global oil production would peak around the Year 2000 and trigger an Energy Crisis with power blackouts and rising costs of energy and fuel

Projected World Energy Demand



Fossil Fuel Prices

- NATURAL GAS:

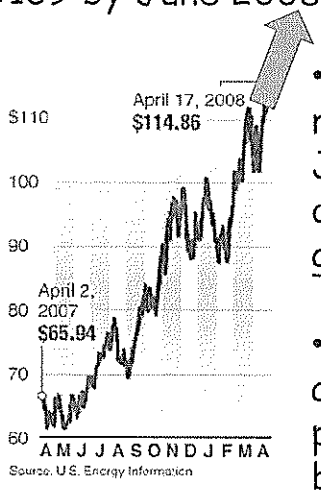
$$\left(\frac{\$3.00}{1000\ \text{ft}^3}\right)\left(\frac{1\ \text{ft}^3}{1000\ \text{BTU}}\right) = \$3.00/10^6\ \text{BTU}$$

$$\left(\frac{\$50}{\text{ton}}\right)\left(\frac{1\ \text{ton}}{2000\ \text{lb}}\right)\left(\frac{1\ \text{lb}}{1.3\text{x}10^4\ \text{BTU}}\right)\left(\frac{10^6\ \text{BTU}}{10^6\ \text{BTU}}\right) = \$1.92/10^6\ \text{BTU}$$

$$\left(\frac{\$20}{\text{barrel}}\right)\left(\frac{1\ \text{barrel}}{5.8\text{x}10^6\ \text{BTU}}\right)\left(\frac{10^6\ \text{BTU}}{10^6\ \text{BTU}}\right) = \$3.45/10^6\ \text{BTU}$$

Rising Oil Prices

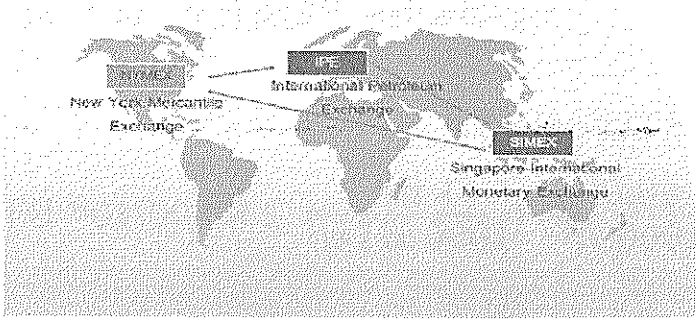
$139 by June 2008



- Oil prices have been steadily rising for several years and in June 2008 stand at a record high of $139 per barrel. (1bbl=42 US gallon or 158.9873 liters).

- Is the rise due to a squeeze in availability (peak oil) or are other political or economic factors to blame?

ตลาดซื้อขายน้ำมันของโลก



1. ตลาดนิวยอร์ค (NYMEX) เป็นตลาดกลางซื้อขายขายน้ำมันในอเมริกา
2. ตลาดลอนดอน (IPE) เป็นตลาดกลางซื้อขายขายน้ำมันในยุโรป
3. ตลาดสิงคโปร์ (SIMEX) เป็นตลาดกลางซื้อขายขายน้ำมันในเอเชียแปซิฟิก

- เนื่องจาก ไทยอยู่ใกล้สิงคโปร์ อีกทั้งราคาสิงคโปร์จะสะท้อน Demand and Supply ของน้ำมันในภูมิภาคนี้
- เวลาขึ้นราคาน้ำมันขยับขึ้นครั้งละ 20 สตางค์ต่อลิตร เหตุผลเพราะราคาที่สิงค์โปร์ส่วนใหญ่จะขึ้นทีละ 1 $/bbl เมื่อคำนวณคร่าวๆ เลขจึงออกมาเป็น 20 สตางค์ต่อลิตรนั่นเอง

OIL PRICE DETERMINATION BEFORE DEREGULATION

RETAIL PRICE = EX-REFINERY/IMPORT PRICE + OIL FUND + TAXES + MARKETING MARGIN when

: Ex-refinery & import prices ตั้งโดยรัฐบาล โดยใช้ราคาตลาดกลางที่ Singapore เป็นพื้นฐาน

- Marketing margin ตั้งโดยรัฐบาลและมีการเปลี่ยนแปลงน้อยมาก (rarely changed)
- Excise and municipal taxes ภาษีท้องที่

OIL MARKET BEFORE DEREGULATION

Retail trade controlled by 4 major oil companies:
PTT, Shell, Esso, and Caltex

1. Oil imports were controlled with quota system
2. No new entrants into oil business due to government policy (no license issued for Article 6 oil trader)
3. **Domestic refining** capacity approx. 50% of demand
4. Many remote areas did not have petrol stations. Consumers bought oil from "DRUM PUMPS" whose prices were not controlled and were 1-3 baht/liter higher than service station prices.