

## Producing a well

There are many steps in the life of a well.

So far we saw how the well location was determined, it was drilled, logged, cased and cemented.

To bring this well to production it first needs to be perforated i.e. the casing has to be perforated to allow the petroleum to flow inside.

To stimulate the flow of oil acid might be injected to further clean out perforation debris and the microscopic cementation of the sand grains.

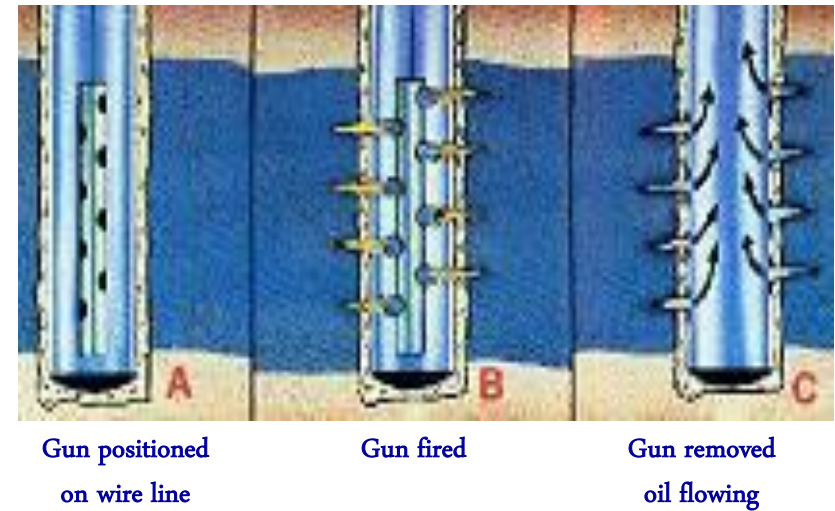
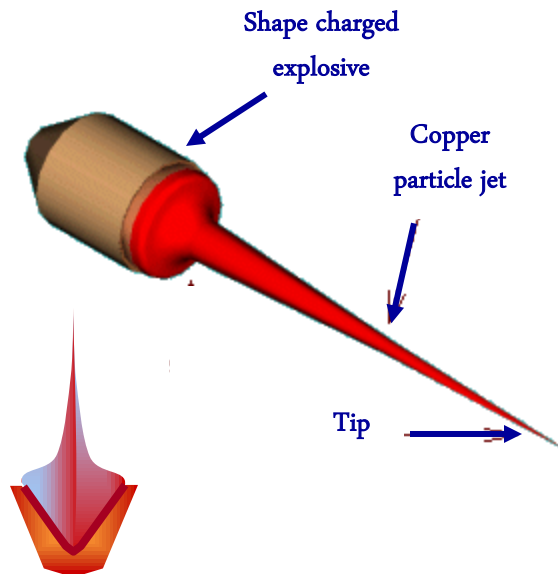


If this does not produce the expected flow rates the reservoir can be fractured by applying pressure of over 1,000 bar at surface to physically crack the rock to increase permeability.

We segment between primary and secondary or tertiary recovery or production.

While the primary production works by the well's own pressure, secondary recovery requires various techniques to exploit as much oil as possible.

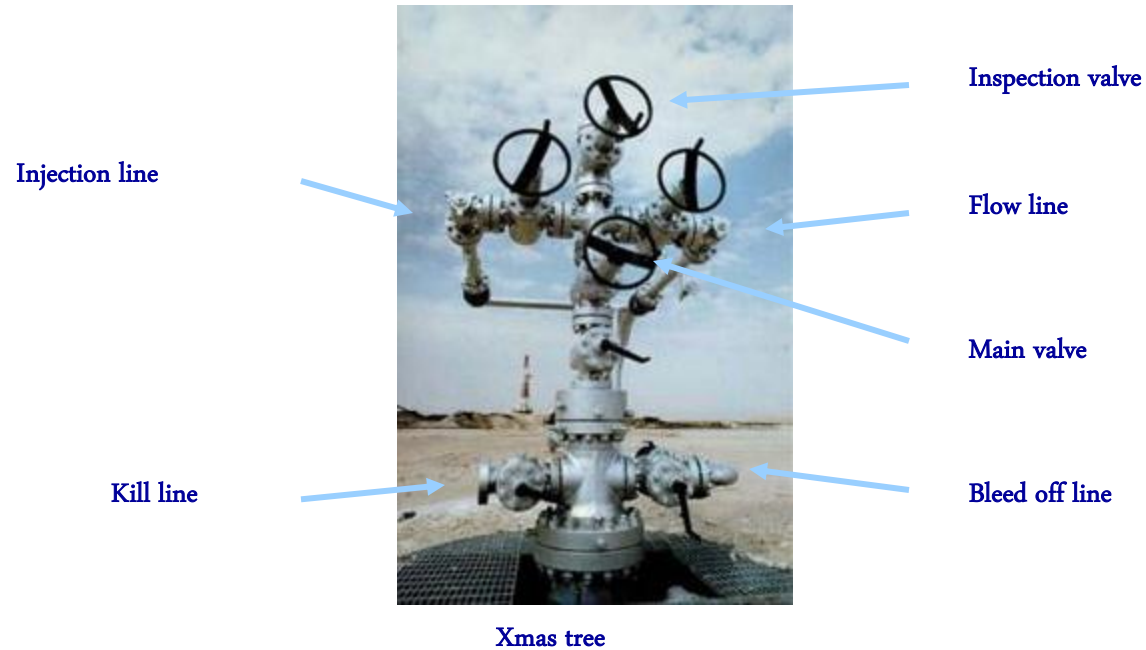
# Perforation



After the well was drilled, logged, cased and cemented it is sealed off against the reservoir and no petroleum can flow. With perforation guns, holes are fired into the casing and rock for the oil and gas to flow.

Shape charged explosives are precisely positioned at the reservoir layers and fired. The charges, up to 12 shots per foot, create a pressure jet of over 15,000,000 psi - 1,000,000 bar and a velocity of over 10,000 m/s at its tip. All material in front is atomised and holes up to 1 m long and over 1" (2.5 cm) in diameter are created for the oil to flow into the well.

# Wellhead



Before the drilling rig has been removed, production tubing was installed and the heavy and high pressure rated BOP is replaced by the Xmas tree. Through the inspection valve logging and perforation operations can be carried out without the presence of a rig.

Offshore this valve assembly is implemented into a subsea manifold to be operated from a remote control room.

## Production methods

From the total available petroleum of a reservoir only a small portion can be recovered and produced. We differentiate three different production methods to enhance recovery rates.

### Primary production method

Eruptive production

Down hole pumps

Surface pumps, horse heads

Gas lifts



10 - 20% recovery

### Secondary production methods

Water injection



30 - 40% recovery

### Tertiary production methods

Steam injection

Polymer flooding, increase viscosity of injection water

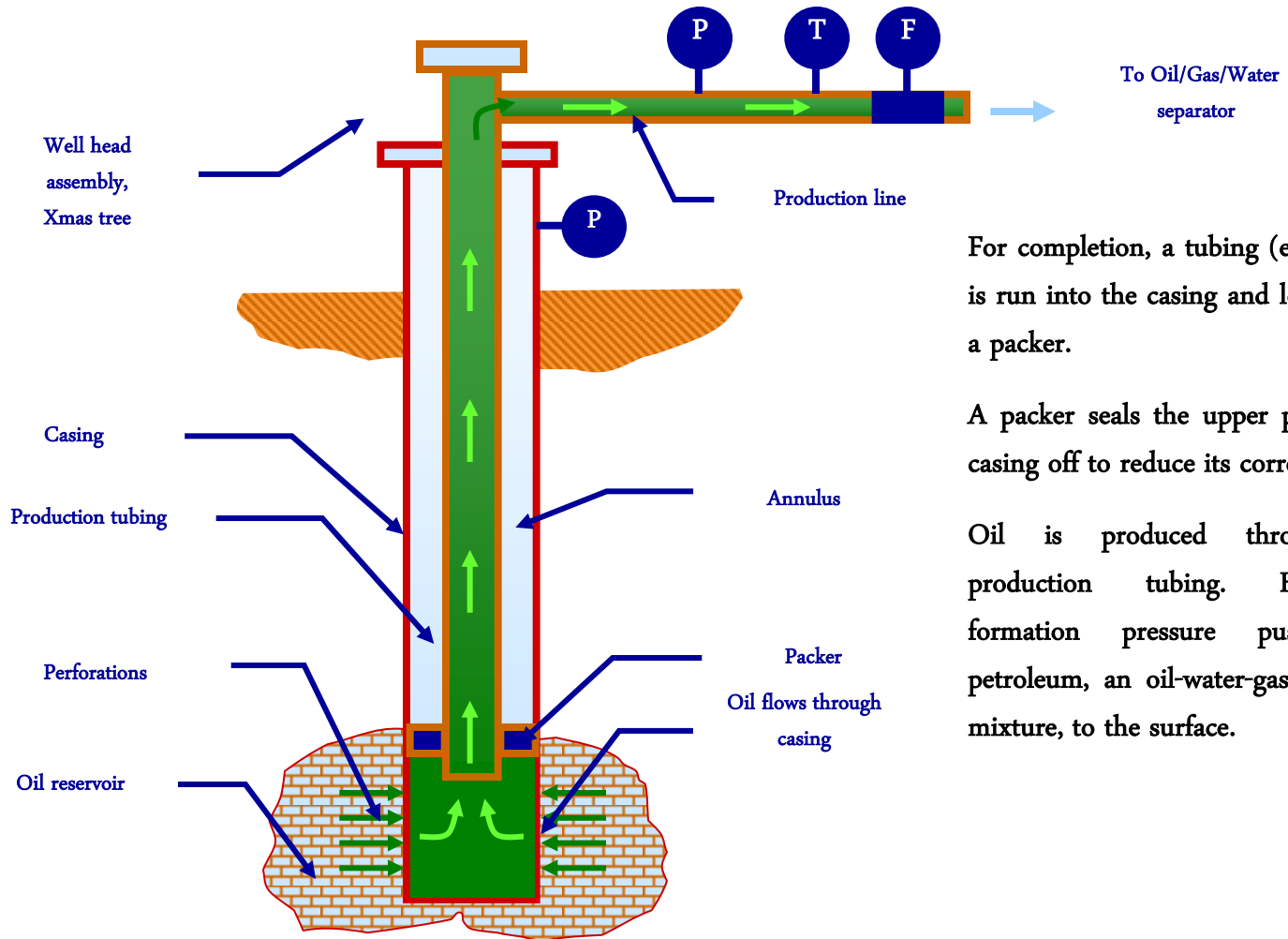
CO<sub>2</sub> flooding



→

> 40% recovery

# Artesian oil production

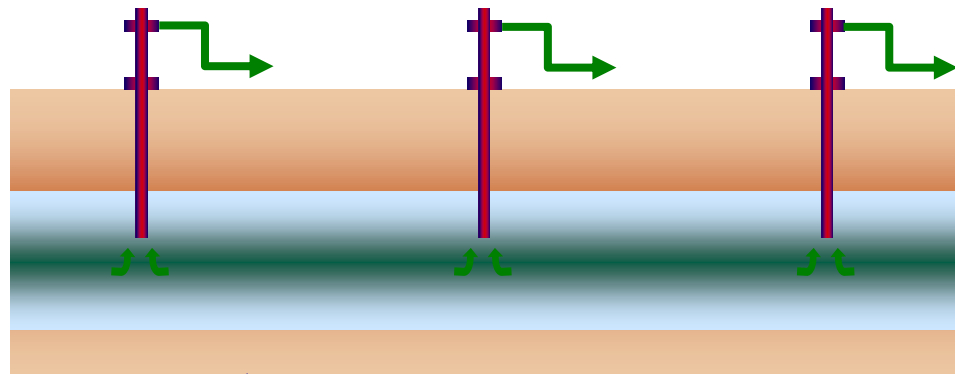


For completion, a tubing (e.g. 3 3/8") is run into the casing and locked it in a packer.

A packer seals the upper part of the casing off to reduce its corrosion.

Oil is produced through the production tubing. Hydrostatic formation pressure pushes the petroleum, an oil-water-gas and sand mixture, to the surface.

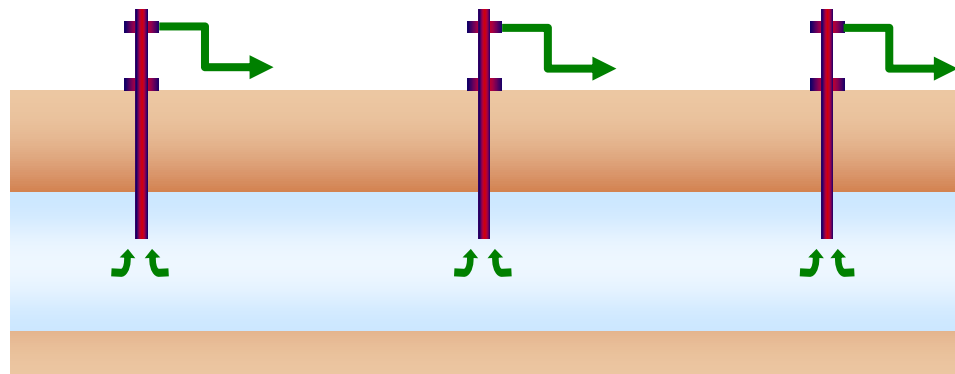
## Reservoir depletion



High pressure reservoir

When reservoir pressure is high and the oil thin enough petroleum flows by natural force to surface.

With time and depletion the reservoir pressure will constantly decrease.

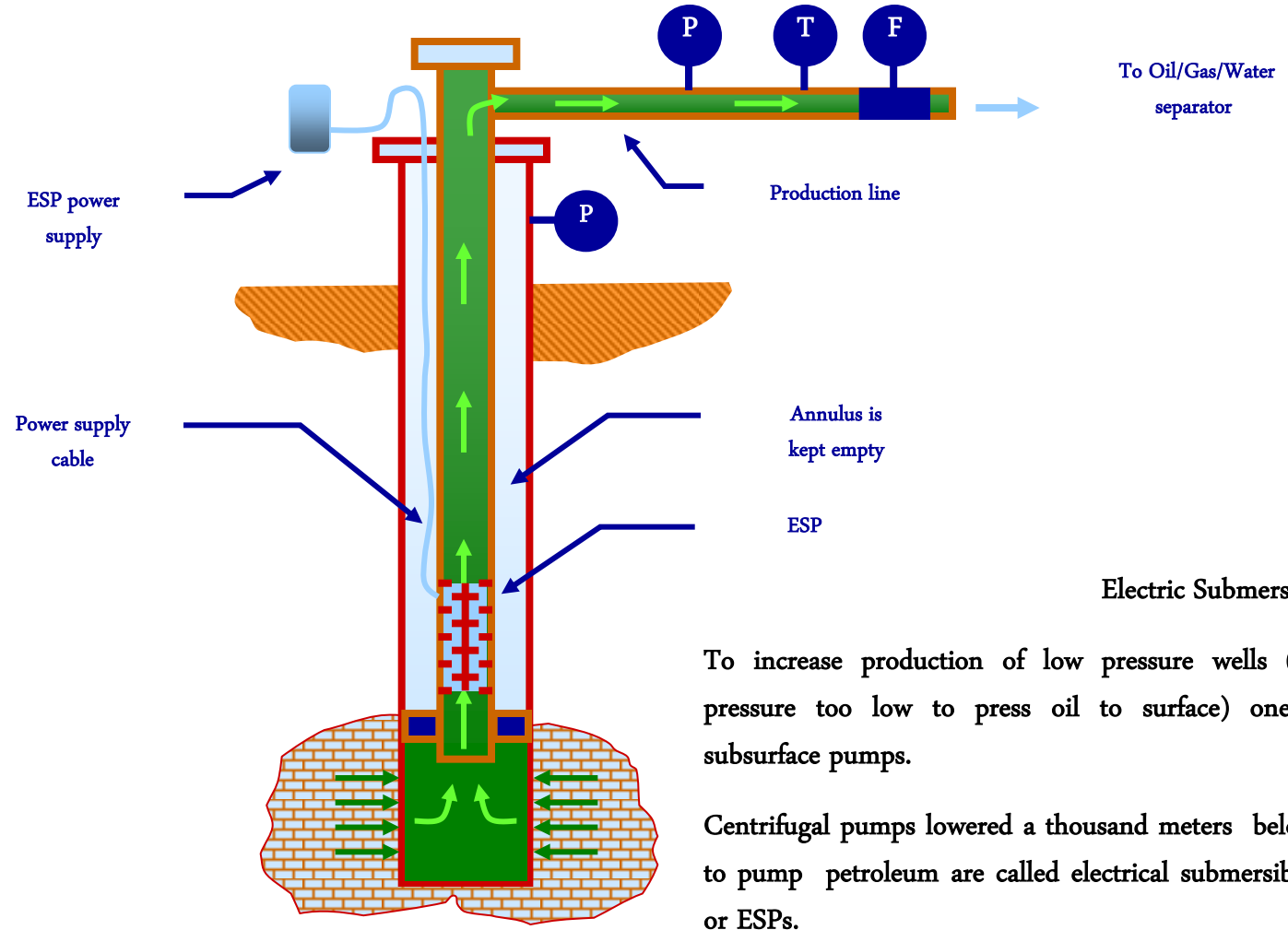


Depleted low pressure reservoir

At one time well pressure is too low to keep the well flowing.

Now a pump or other methods need to be implemented to keep the wells and the \$ flowing.

# ESP production

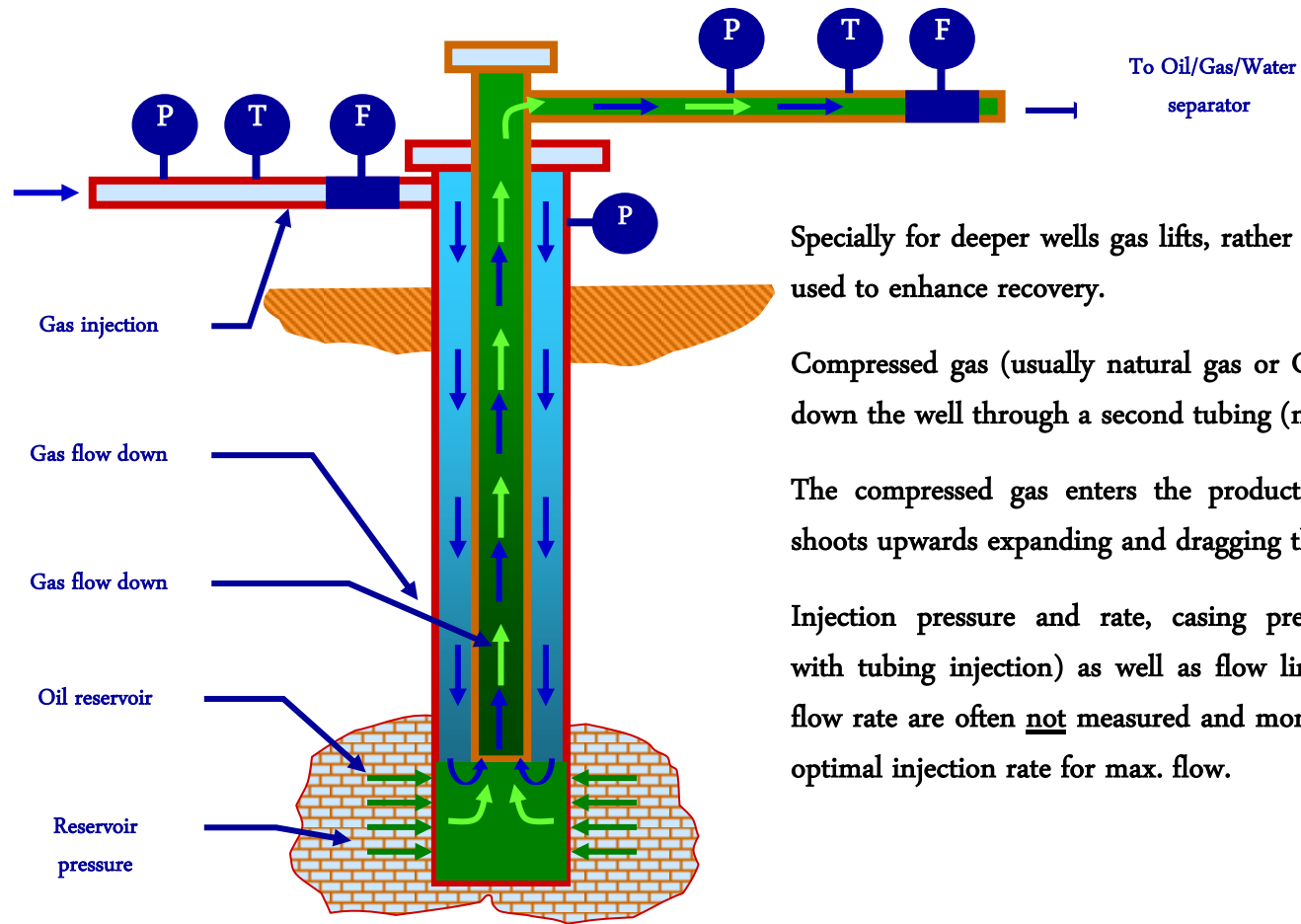


## Electric Submersible Pump

To increase production of low pressure wells (formation pressure too low to press oil to surface) one can use subsurface pumps.

Centrifugal pumps lowered a thousand meters below surface to pump petroleum are called electrical submersible pumps, or ESPs.

# Gas lift



Specially for deeper wells gas lifts, rather than pumps are used to enhance recovery.

Compressed gas (usually natural gas or  $\text{CO}_2$ ) is pumped down the well through a second tubing (not shown).

The compressed gas enters the production tubing and shoots upwards expanding and dragging the oil with it.

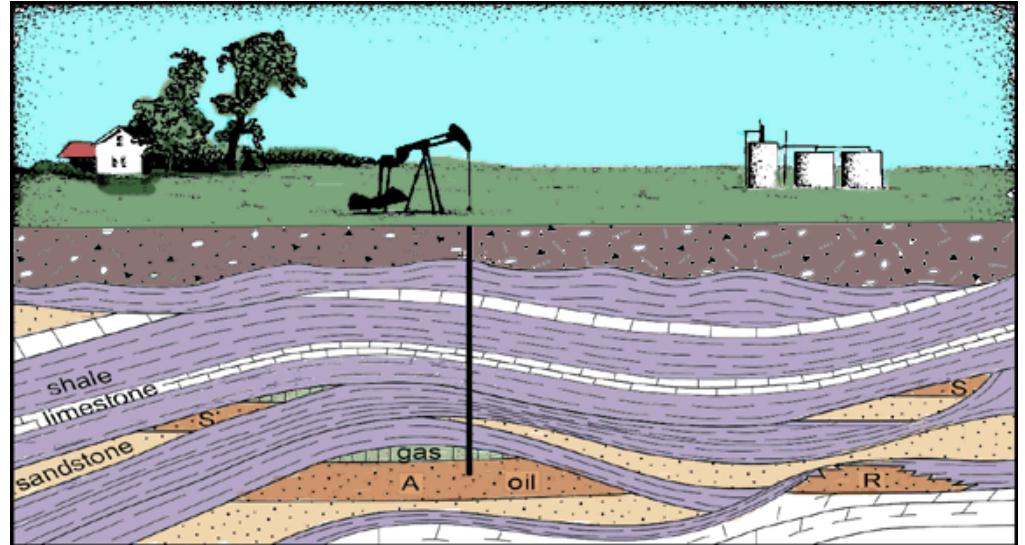
Injection pressure and rate, casing pressure (specially with tubing injection) as well as flow line pressure and flow rate are often not measured and monitored to adjust optimal injection rate for max. flow.



## Walking beam, “horse head”



OMV wellhead and pump



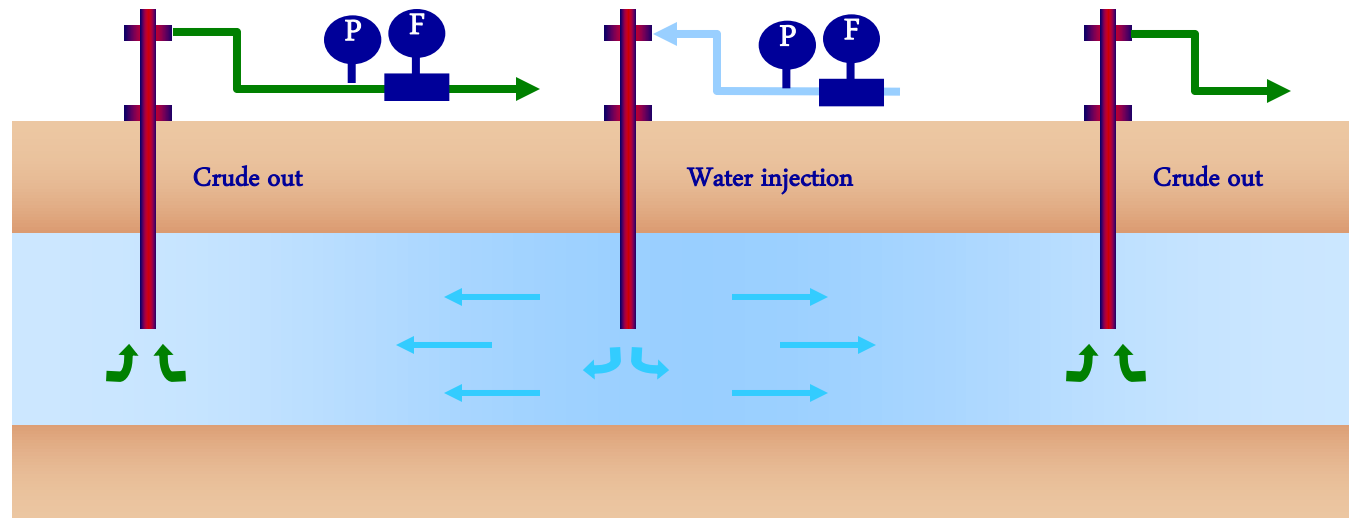
Most commonly used are walking beam pumps usually called “horse head pumps”.

In the US over 95% of all wells are pumped with such pumps. They are simple and reliable and last for ever.

At the end of the sucker rod just above the reservoir is a piston pump lifting the oil to the surface.

In many regions of the world these pumps became a common view in the landscape and a symbol of wealth.

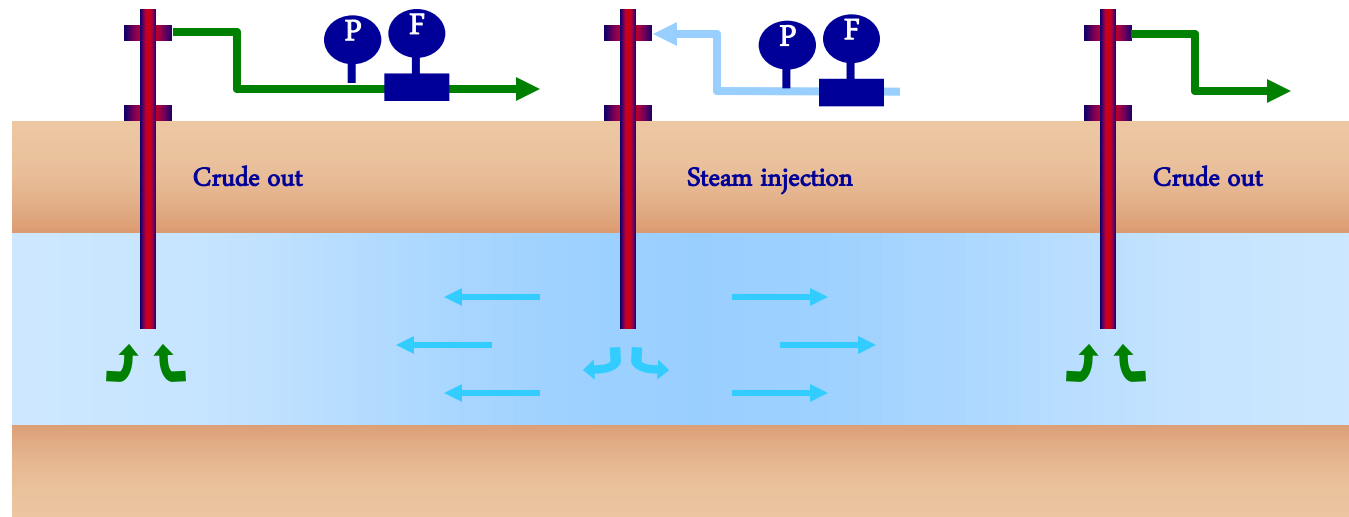
## Water injection



In order to maintain the pressure of a reservoir some appropriate wells are converted to water injection wells. The injected water front penetrates the formation. With time the water will slowly travel through the reservoir and push the oil towards the producing wells. Production will rise. However, after some time the wells will produce more water than oil. The so called watercut can be 90% water by only 10% oil.

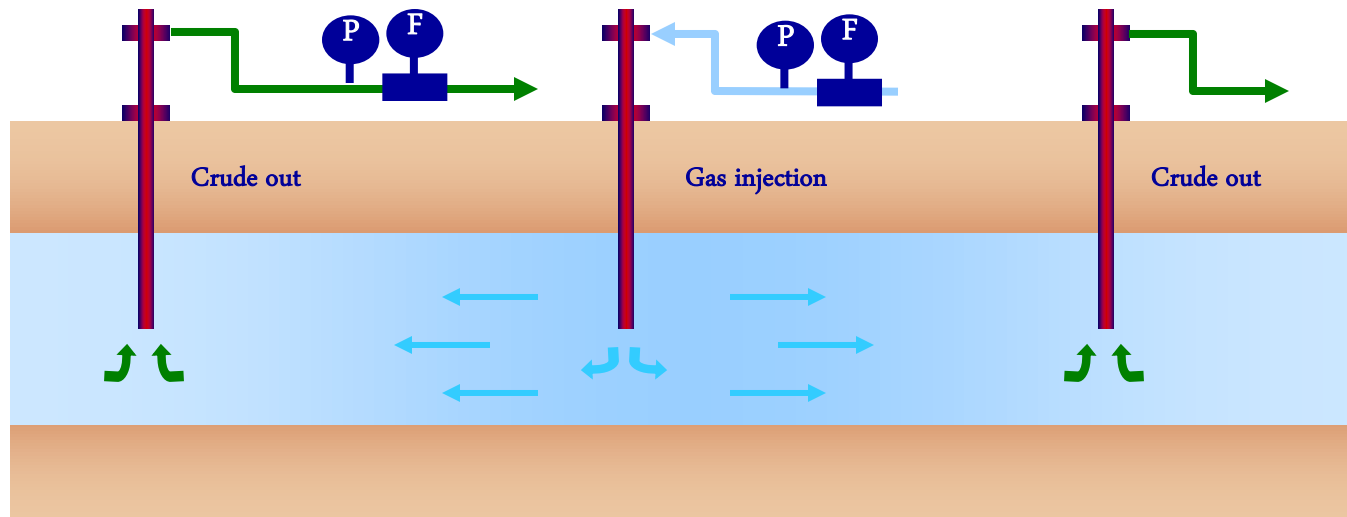
Separators separate oil and water. Latter is being reinjected.

## Steam injection



Petroleum in very shallow reservoirs is usually very viscous and at relatively low temperatures. A method to make even these oils flow at commercially interesting rates to the well is by injecting steam. The steam increases the reservoir pressure and also its temperature. Thus increasing the flow rate and the total oil recovery.

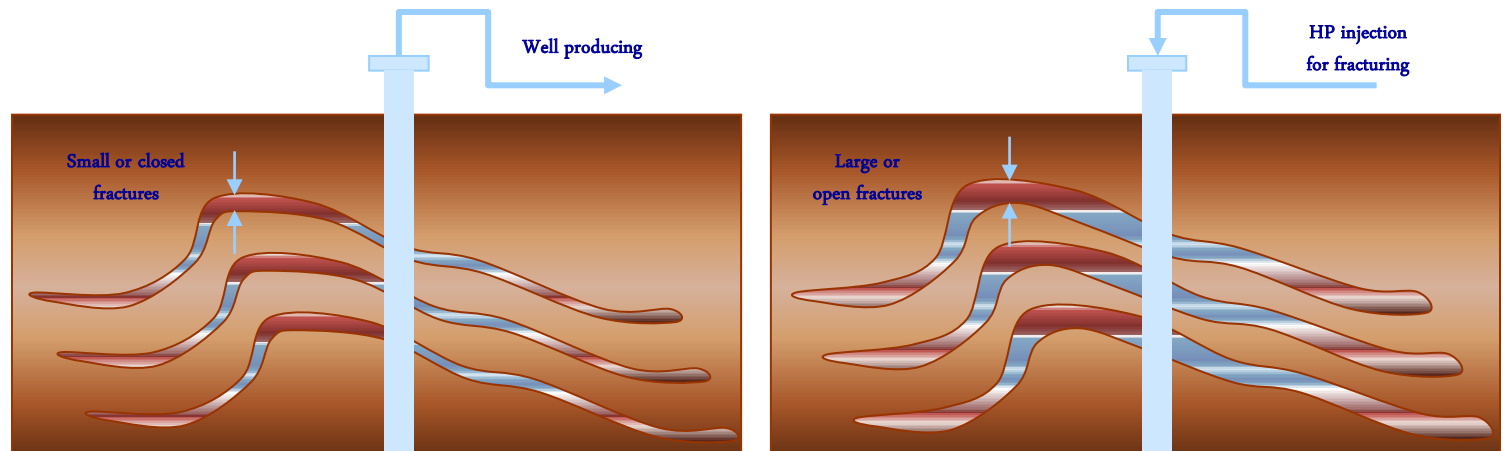
## Gas injection



In offshore and in remote locations, exportation of gas is much more difficult than of oil. For this reason most of the time gas used to be flared off. Nowadays the separated gas is also reinjected to maintain a good reservoir pressure and possibly for future exploitation.

Some countries apply a high  $\text{CO}_2$ -tax to released  $\text{CO}_2$ . To avoid this tax oil companies have a great interest in reinjecting this unwanted gas.

# Fracturing

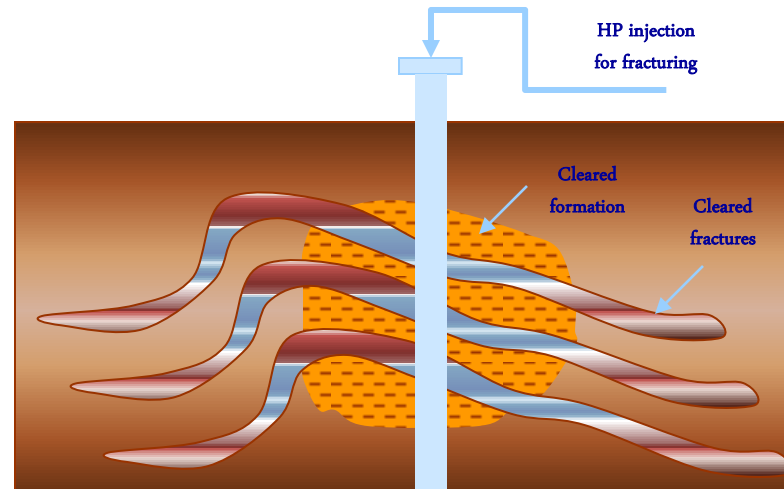


A method to increase permeability of a reservoir and thus the ability of the petroleum to flow towards the well with only a little pressure loss is fracturing the formation.

Strong pumps (also used for cementing the well) apply high pressure to the well.

The rock physically cracks under the high pressure applied. Fine sand is injected to flush into the opened cracks. The sand grains keep the fractures open when pump pressure is released.

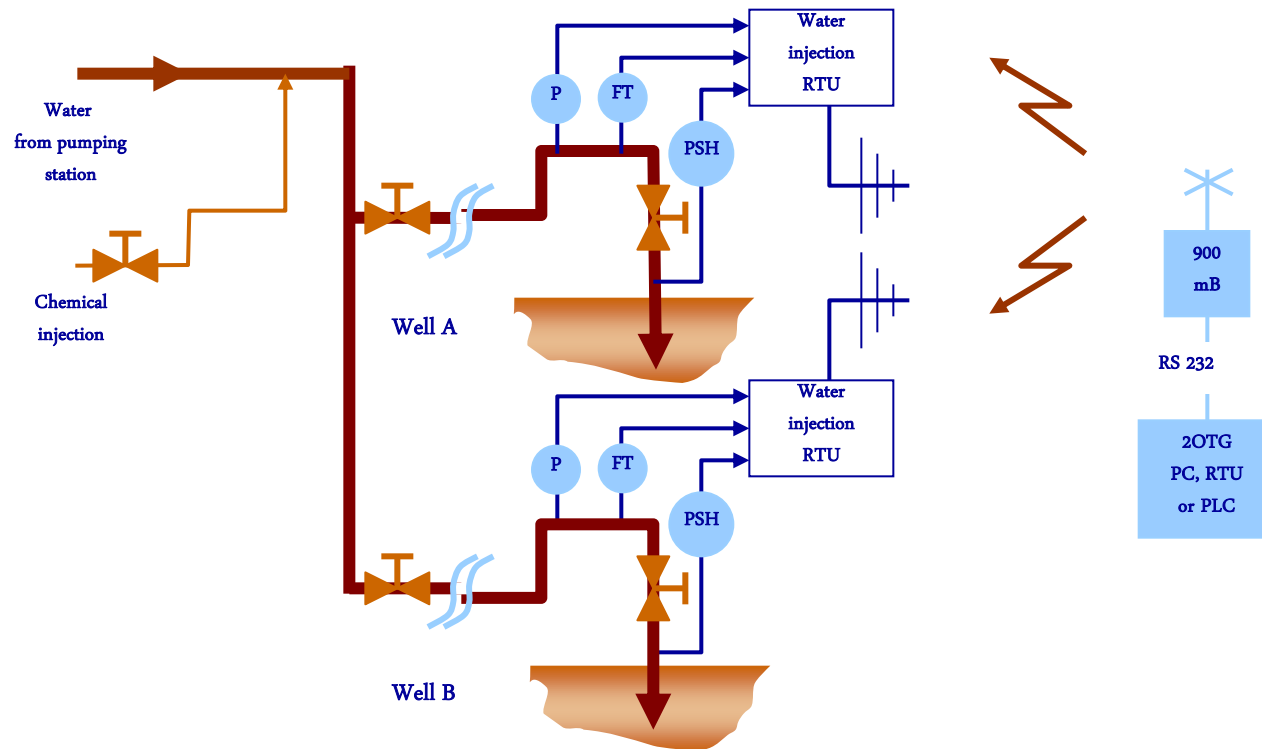
# Acid job



The flow from the reservoir into the openings done by the perforations might be blocked by perforation debris. Also the general permeability of the reservoir might be low due to a high degree of formation cementation between the individual sand grains.

With the injection of e.g. 20% NaCl acid, the perforations are cleaned and the formation rock around the well becomes more permeable, in this way increasing the surface area of easy flow and thus the total flow rate.

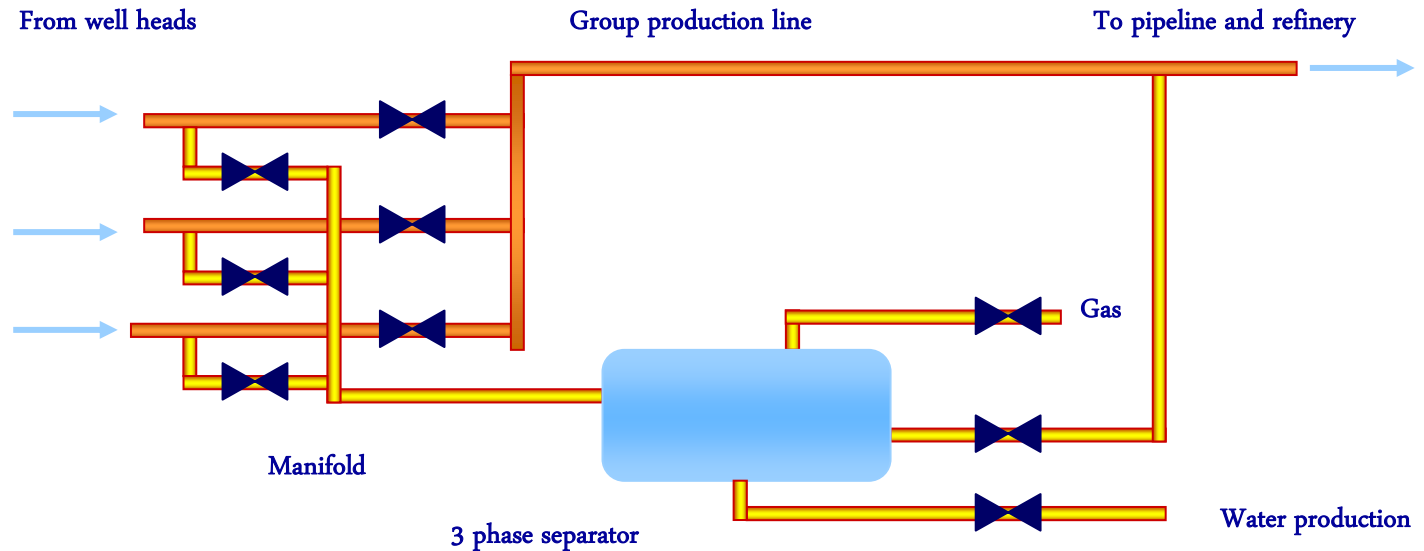
# Injection well monitoring



Wellheads are always in remote and hostile locations.

Monitoring of flow conditions (petroleum and injection) is still very poor. The flow and injection rates and pressures as well as chemical injection rates are transmitted to a central control station.

## Gathering station



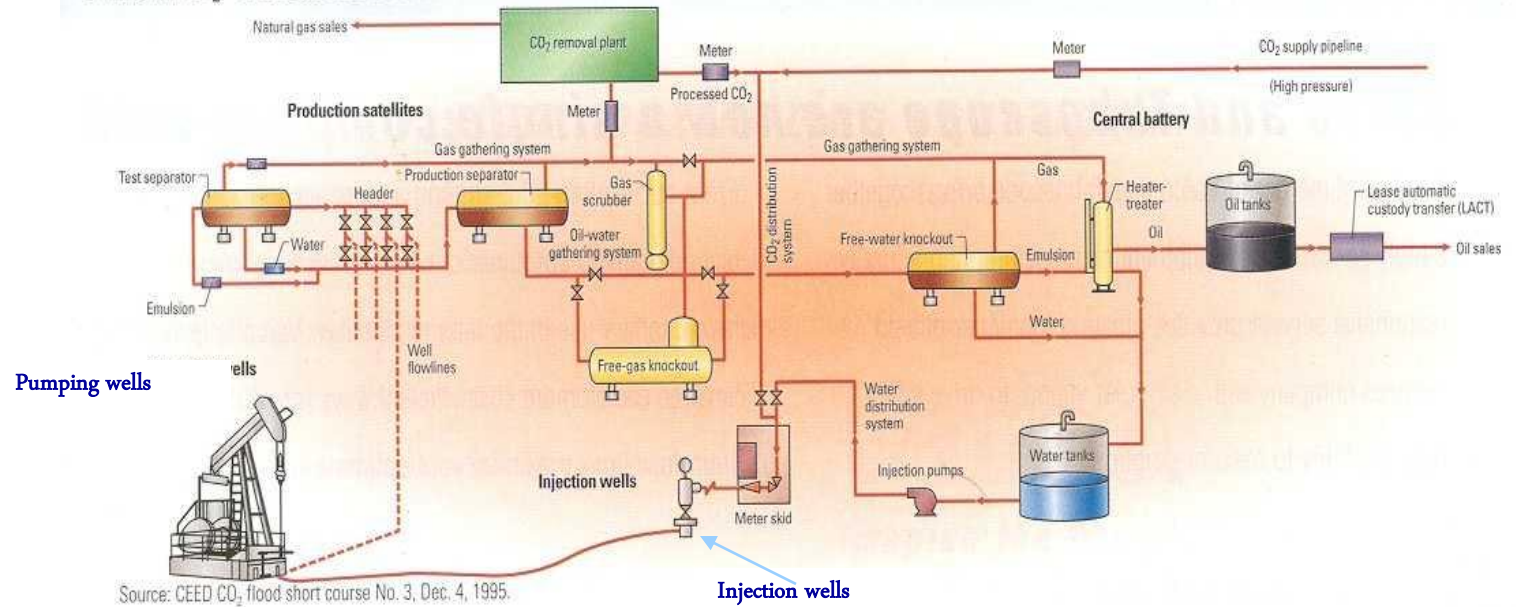
Typically some 20 wells are piped into a gathering station, satellite or cluster. All wells feed into one group production line. In the satellite station the wells can be tested individually. The station might have some instruments, control room and test equipment, but there is usually no automatic or sophisticated test set-up available.



# CO<sub>2</sub> water flood

## TYPICAL CO<sub>2</sub>-WATERFLOOD OPERATION

Fig. 2

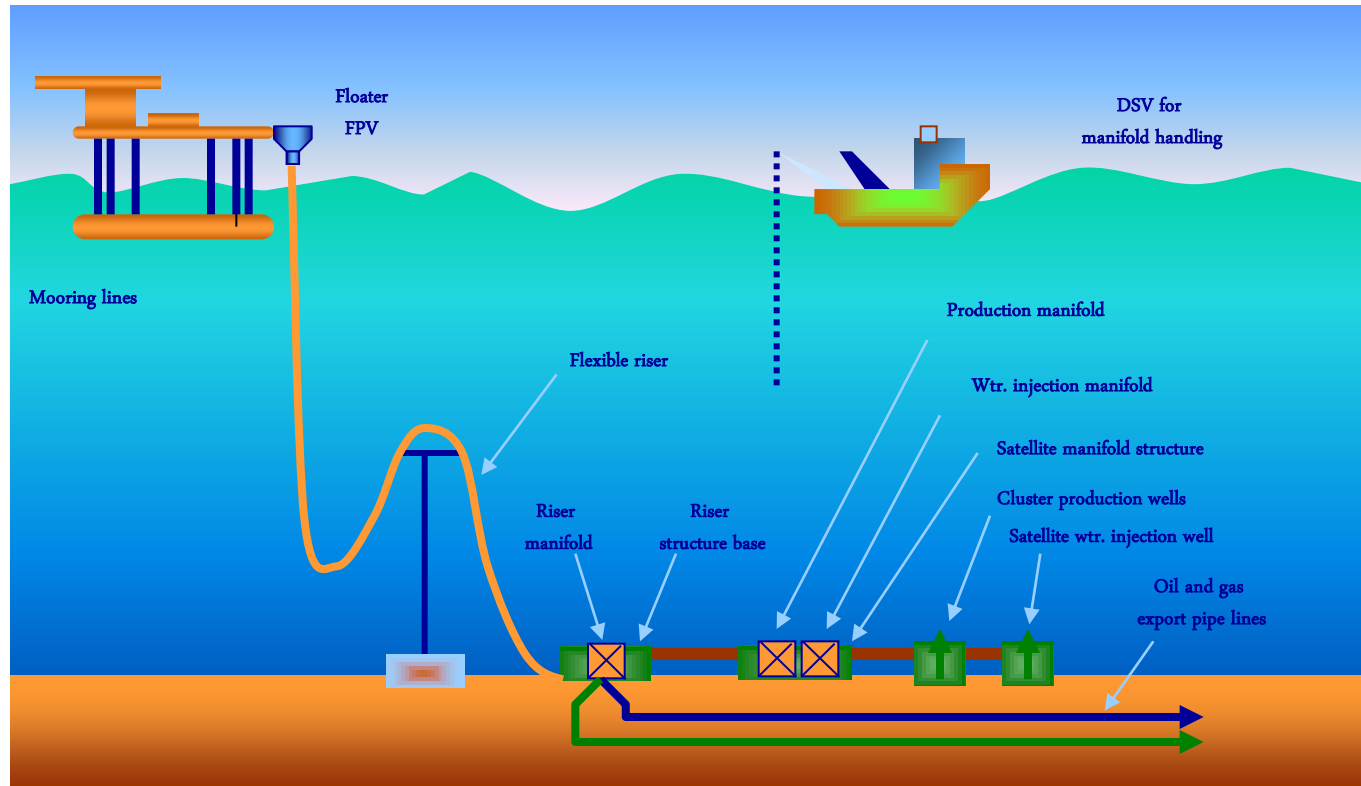


Produced petroleum is separated into oil, gas and water.

An additional plant isolates the unwanted CO<sub>2</sub>.

Injection wells press the CO<sub>2</sub> and water back into the reservoir.

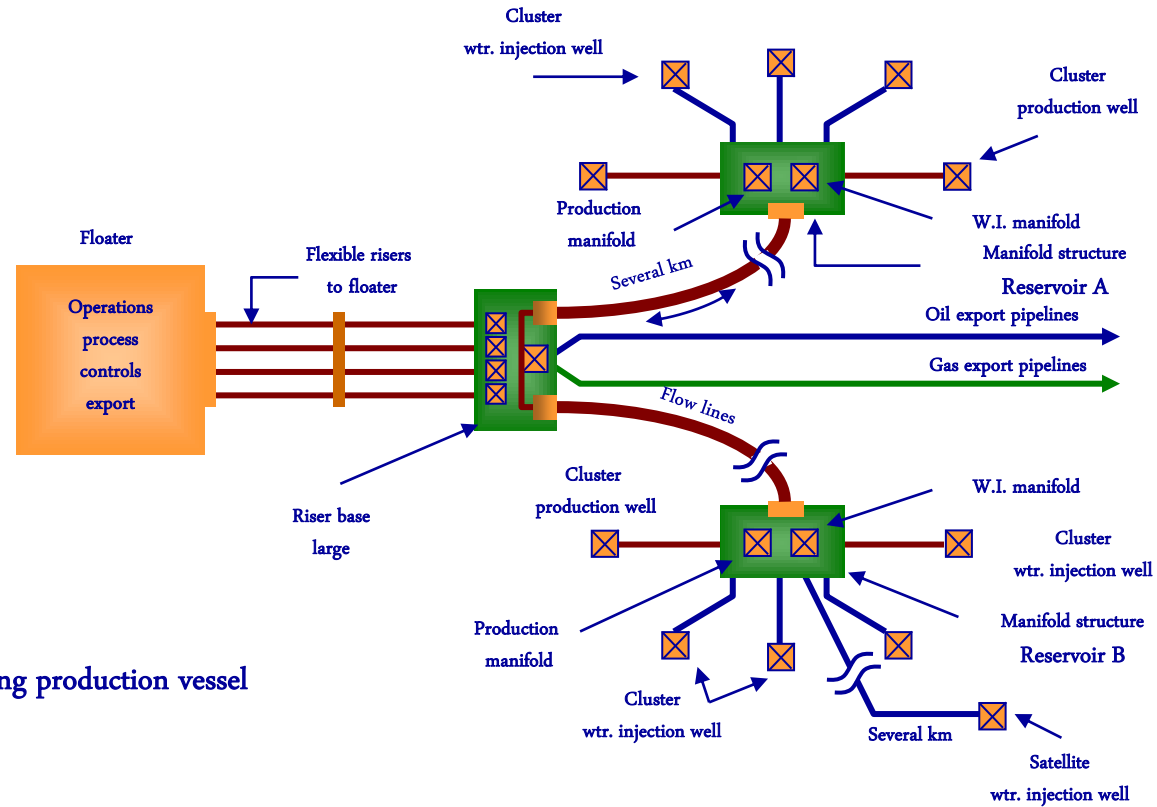
# Offshore FPV



A typical offshore production set-up for petroleum production and water injection from a floating production vessel. Flexible risers connect the subsea base plate with the floating production vessel.

A service vessel with mini submarines and divers maintains the subsea manifolds and satellite subsea wellheads.

## Offshore FPV - top view

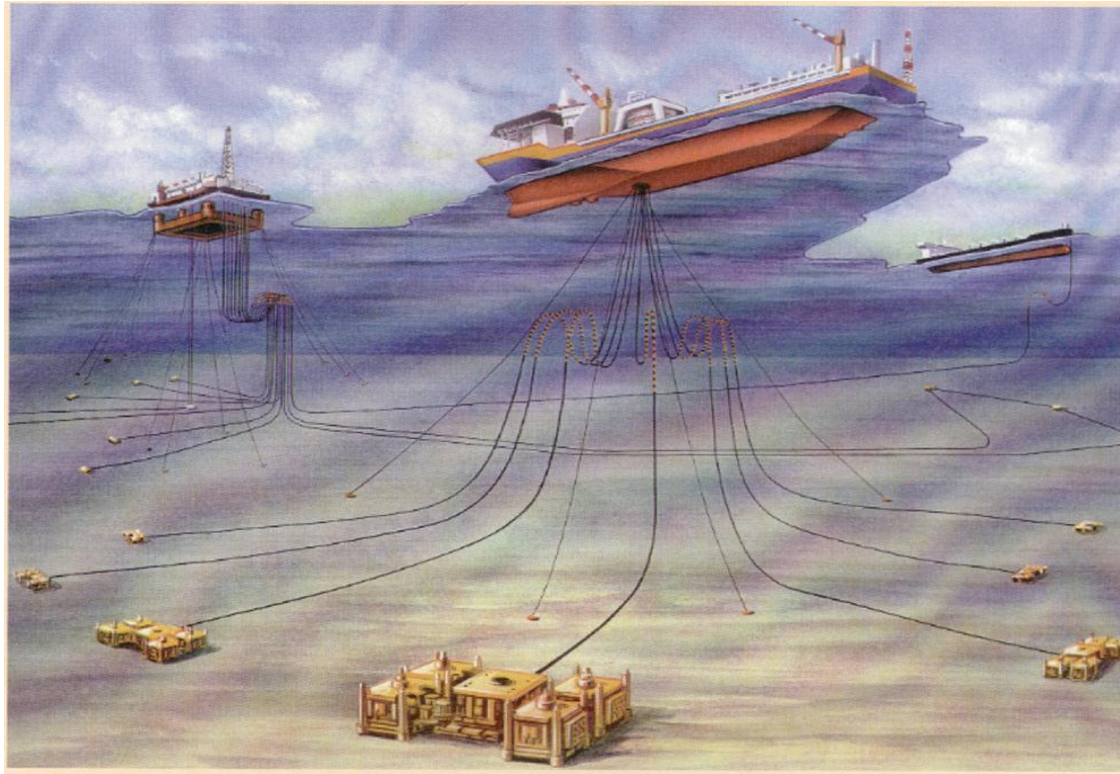


Floating production vessel

The same completion in top view. There are 2 subsea manifolds to exploit reservoir A and B. Many water injection wells maintain crude production of a few production wells.

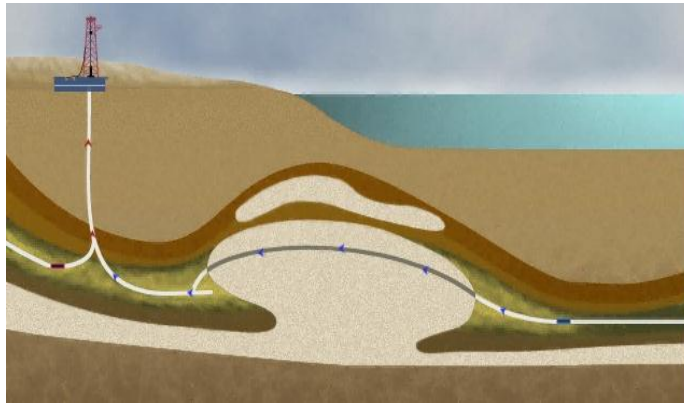
A gas and an oil pipeline export the separated petroleum. Control and chemical injection lines are not shown.

## FPSO, FPV, tanker



**This example shows a FPSO in the centre and a FPSV on the left both connected to several down hole manifolds. While the FPSO stores its production in its own tanks the FPSV needs the tanker on the right for its crude storage.**

# Welltesting



Isolated well section being tested

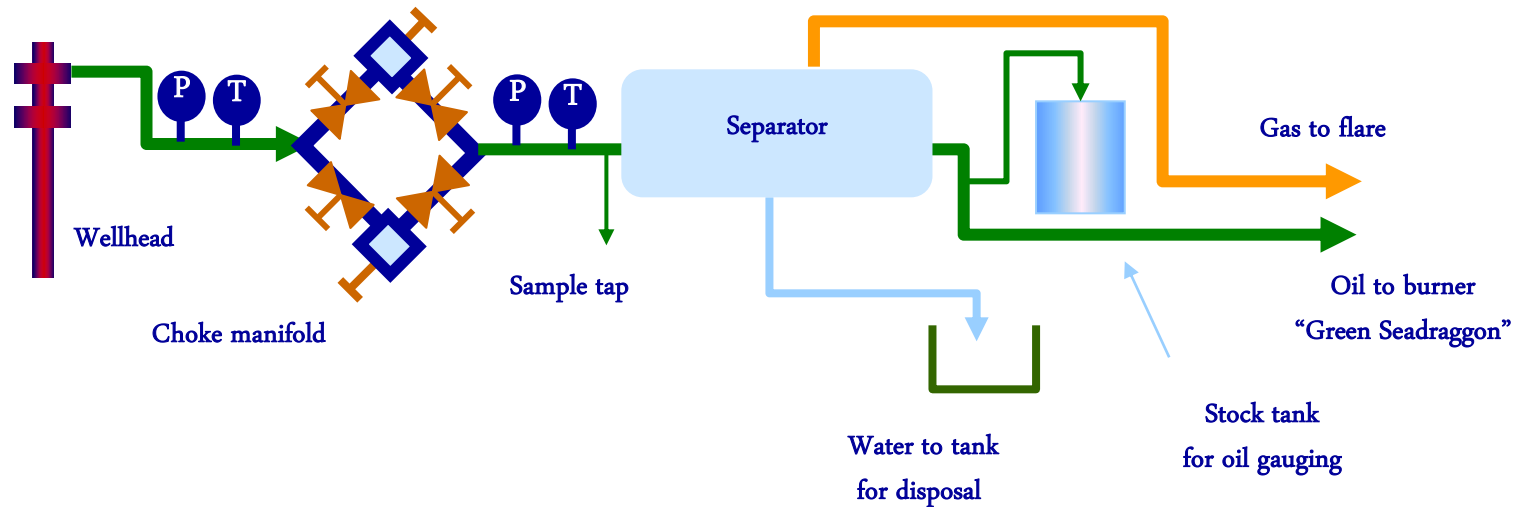


Land welltest; gas is flared off, oil stored

The only way to estimate the size of the reservoir and the volume of recoverable petroleum is by testing the well. First time it is done with the drilling rig still on site. The result of the initial welltest has great influence on the wealth of a company since the stock market strongly reacts to the results.

A welltest usually takes only 24 to 72 hrs., has slightly different flow conditions as compared to normal production and as such represents only a poor picture of the real well flow conditions. Under ideal conditions with accurate equipment the minimum error is  $\pm 15\%$ .

## Welltest set-up



A welltest setup consists of three sections

**Choke manifold**; to reduce well pressure to separator pressure and adjust the flow rate. The manifold has one fixed and one variable choke - strong orifice type restrictions.

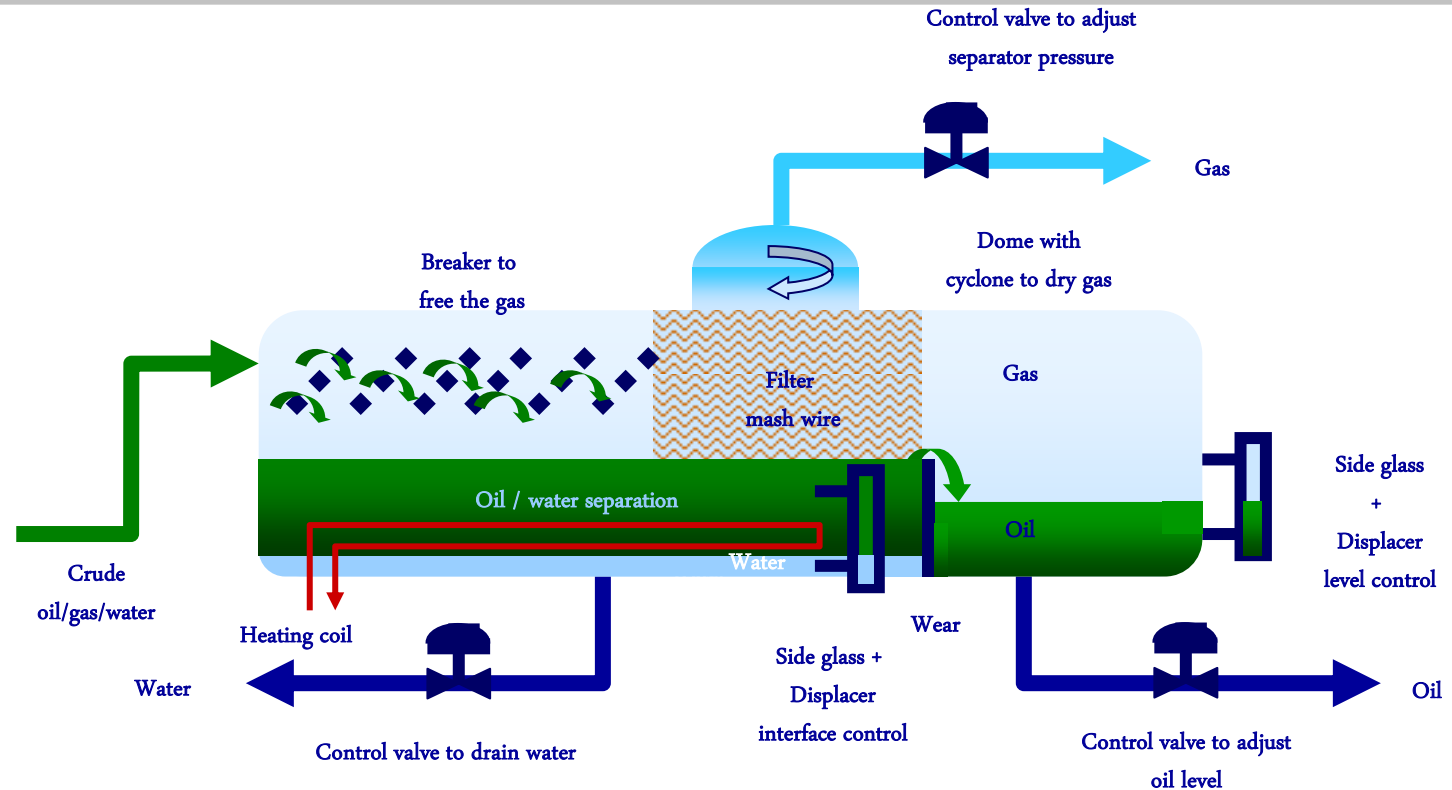
**Separator**; to separate oil-gas-water. Operating pressure around 10 to 20 bar, rated 100 bar.

**Metering**; flow meters (PD and DP) and gauge tank to determine the volume flow of oil, gas and water

During the test the welltest operator takes open and pressurised samples of the fluid and gas to be analysed in the lab.

The produced gas is always flared off, the water in the oil might be collected for disposal. Offshore the oil is usually burned off with a special burner at the end of a long boom alongside the rig.

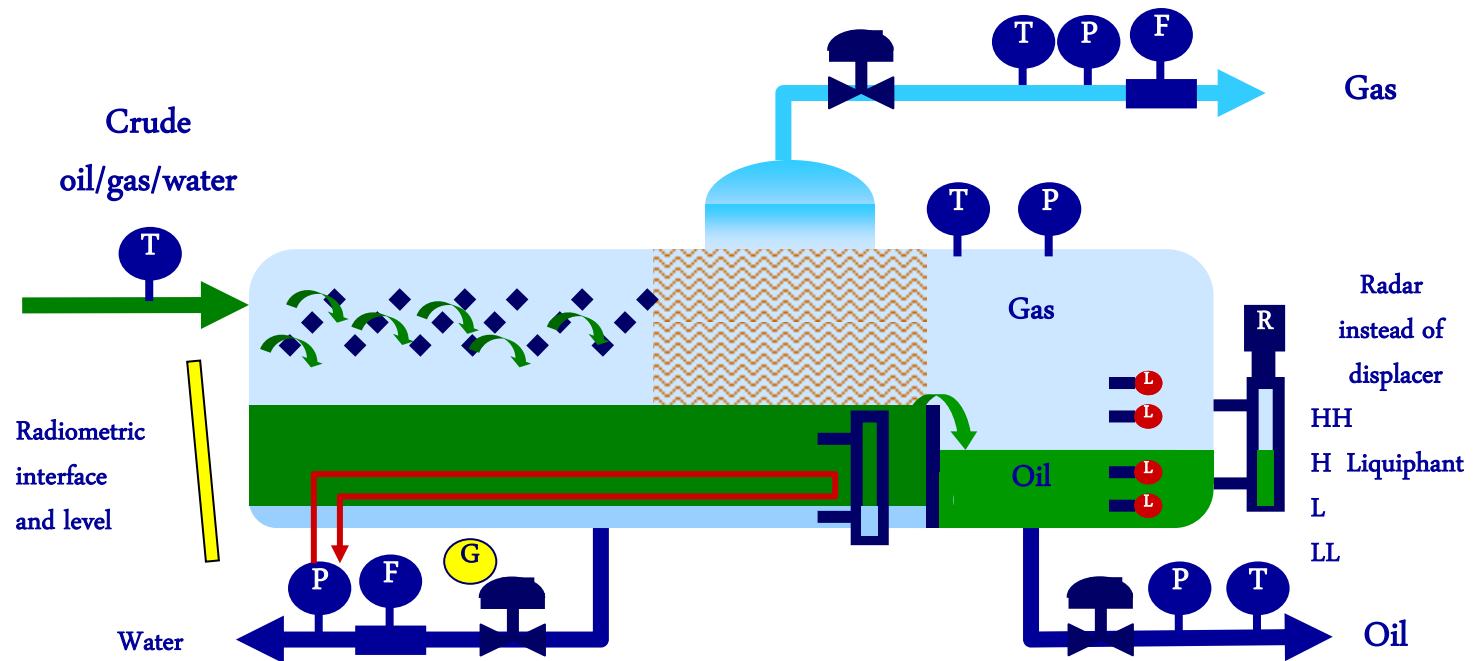
## Three stage separator



The well fluid first hits breakers in a separator to break up the flow into small droplets. Gas breaks out and is further dried in a filter of meshed wire. A cyclone using the gas velocity and centrifugal forces takes the last liquids out of the gas.

Oil and water is allowed to separate in a big vessel for a few minutes. Foam floats over the oil-water emulsion. The light oil swims at the top and runs over the weir into the oil section. Control valves keep the oil and crude level constant.

## Instruments on separator

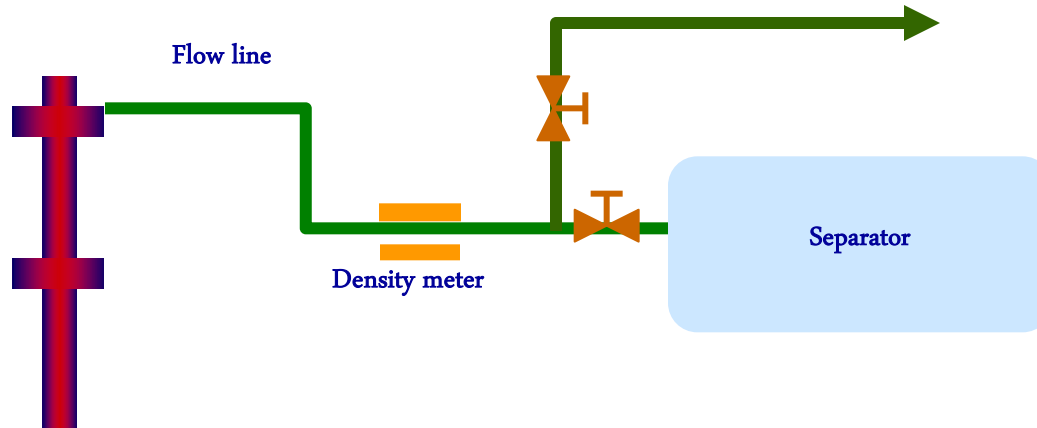


Separators are thick walled vessels (>40 mm steel), have few openings and contain many obstructions. This makes the use of radar impossible, DP is in direct contact with crude and displacers might block with sand (level indication is always good!) and require annual/ biannual maintenance (recommended from producer).

Separators in refineries and on platforms require radiometric interface level measurements.



## Sand control



In most cases sand is produced together with petroleum.

In older wells this sand can come to surface in quantities.

Due to the fact that sand is not constantly produced but rather in slugs it is necessary to detect the sand slug before it enters the separator. Standard separators are not capable of handling sand, they fill up and have no space for petroleum separation left. To clean the separator it has to be opened and the sand removed manually by a volunteer!

A density meter will detect the sand in petroleum and the flow will be diverted to a special sand treatment section.



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