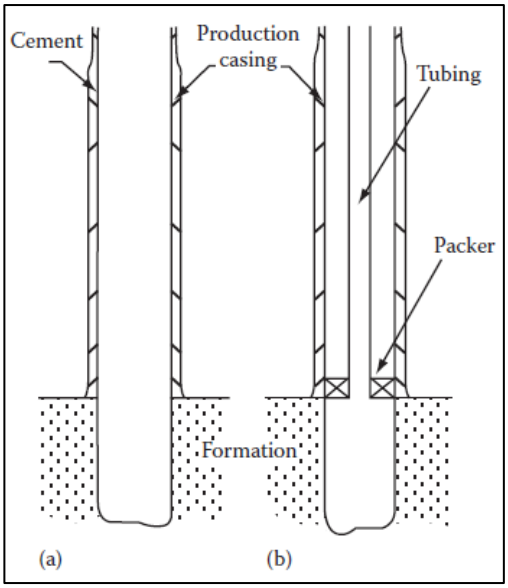
7. Production Engineering

- Production engineers are responsible for designing and installing the well completions that are capable of producing the desired volumes of oil/gas with the methods of production.
- They are also responsible for maintaining the wells at their best producing conditions throughout the life of the field.
- These two major responsibilities are classified as subsurface production engineering. Still, production engineers are responsible for designing, installing, operating, and maintaining all surface production facilities starting from the flow lines at the wellhead and ending with the delivery of oil and gas to the end user. This is classified as surface production engineering.
- The main objective of that system is to obtain maximum recovery in the most economical and safe manner.

7.1. Well Completion Design

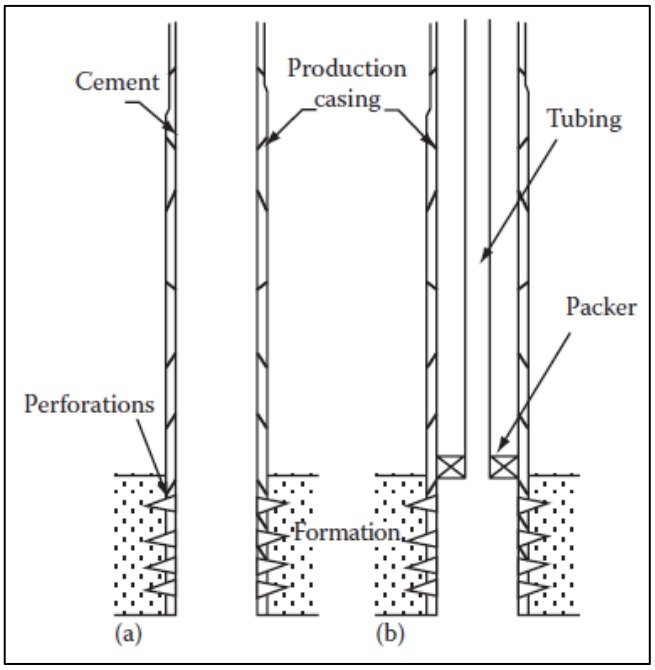
- The well completion is the subsurface mechanical configuration of the well that provides the passage for the produced fluids from the face of the formation to the wellhead at the surface.
- There are three major types of well completion: **open hole completion**, **cased hole (perforated) completion**, and **liner completion**.

1. **Open hole completions:** the well is drilled down to a depth that is just above the target petroleum formation. The production casing is then lowered into the well and cemented. The target formation is then drilled and is left **uncased (open)**. Depending on the production rate and the properties of the produced fluids, the well may be produced through the production casing or through production tubing placed above the producing formation with a **packer** that provides a seal between the tubing and casing. One of the functions of the packer is to protect the casing from the produced fluids. Figure below illustrates this type of well completion.



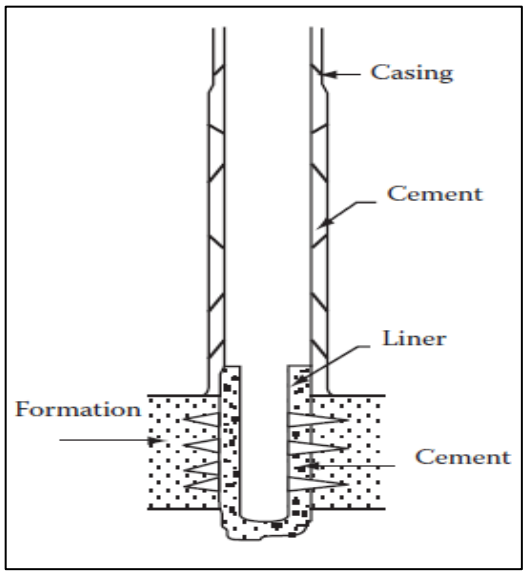
Open hole completion: (a) production through casing and (b) with tubing and packer

2. **Cased hole (perforated) completions:** the well is drilled all the way through the producing zone and the production casing is lowered and cemented. The casing is then perforated across the producing zone to establish communication between the formation and the well, as illustrated in Figure below. Again, depending on the producing conditions, production could be either through the casing or through a tubing.



Cased hole completion: (a) without tubing and (b) with tubing packer.

3. **liner completion:** the production casing is set and cemented above the petroleum formation similar to an open hole completion. **A liner** (basically a smaller diameter casing) is then set and cemented across the producing formation. The liner is then perforated to establish communication between the well and the formation.



Liner completion

7.2. Well Productivity

- Production of fluid from a well can be quantified using the concept of **well productivity**.
- Consider the case of radial flow into a vertical well. Volumetric flow rate q_ℓ for phase ℓ is proportional to pressure differential Δp so that

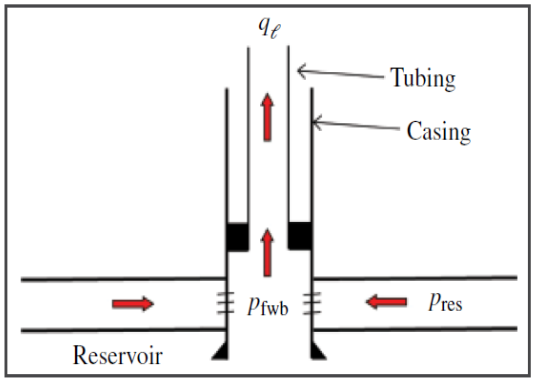
$$q_\ell = PI * \Delta P$$

where the proportionality factor is **the productivity index PI**.

- The pressure differential is the difference between reservoir pressure and flowing wellbore pressure, or

$$\Delta P = P_{res} - P_{fwb}$$

- The productivity index terms are illustrated in Figure below. Fluid flows from the reservoir, through perforations in the casing into the wellbore, and up the tubing to the surface.



Example: A 20 psia pressure drawdown is required to produce 500 STBO/day. Use well PI to estimate the oil production rate at 10 psia pressure drawdown.

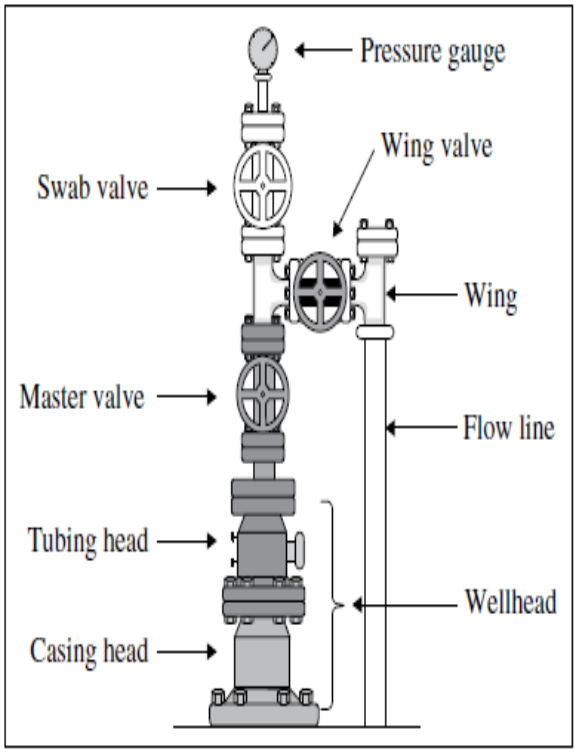
$$PI = \frac{q_o}{\Delta p} = \frac{500\,\text{STBO/day}}{20\,\text{psia}} = 25\,\text{STBO/day/pisa}$$

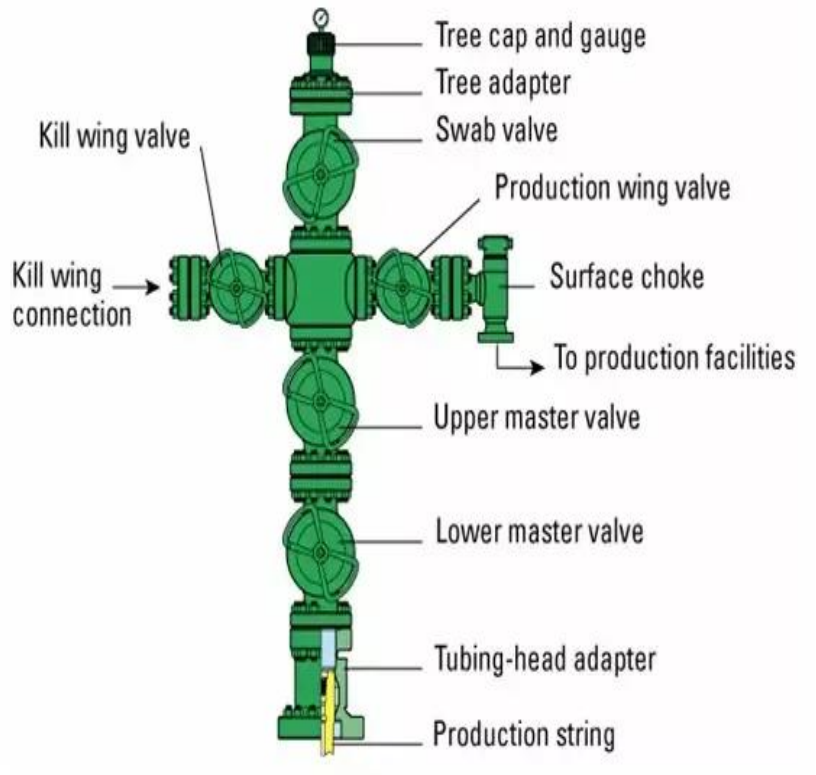
Therefore

$$q_o = PI \times \Delta p = \left(25\,\text{STBO/day/psia}\right) \times 10\,\text{psia} = 250\,\text{STBO/day}$$

7.3. Wellbore and Surface Hardware

- All of the previous sections deal with connecting the formation to the wellbore. In addition, wellbore and surface hardware are needed to complete the well and then produce oil, gas, and associated water.
- Wellbore hardware includes **production tubing**, **nipples**, **subsurface safety valves**, **packers**, and **pumping equipment**.
- Surface hardware includes the **wellhead**, the **Christmas tree**, a **pump driver**, a **separator, storage tanks**, and **pipelines.**
- The **wellhead** provides mechanical support for the casing and tubing and access through valves to annular spaces between successive casing strings and tubing.
- The **Christmas tree** is a collection of valves and fittings to control fluid produced from the tubing. It bolted to the top of the wellhead and is connected to the tubing. Figure below illustrates a Christmas tree and wellhead.


Pressure gauge
Wing valve
Swab valve
Wing
Master valve
Flow line
Tubing head
Wellhead
Casing head


Tree cap and gauge
Tree adapter
Swab valve
Kill wing valve
Production wing valve
Kill wing connection
Surface choke
To production facilities
Upper master valve
Lower master valve
Tubing-head adapter
Production string

A typical tree will have at least four or five valves.

1. The two lower valves are called the master valves (upper and lower respectively). Master valves are normally in the fully open position. The lower master valve will normally be manually operated, while the upper master valve is often hydraulically actuated, allowing it to be used as a means of remotely shutting in the well in the event of emergency.
2. The wing valve is normally used to shut in the well when flowing. Hydraulic operated wing valves are usually built to be fail safe closed, meaning they require active hydraulic pressure to stay open. This feature means that if control fluid fails the well will automatically shut itself in without operator action.
3. The right-hand valve is often called the flow wing valve or the production wing valve, because it is in the flow path the hydrocarbons take to production facilities.
4. The left-hand valve is often called the kill wing valve (KWV). It is primarily used for injection of fluids such as corrosion inhibitors or methanol to prevent hydrate formation.
5. The valve at the top is called the swab valve and lies in the path used for well interventions like wireline and coiled tubing. For such operations, a lubricator is rigged up onto the top of the tree and the wire or coil is lowered through the lubricator, past the swab valve and into the well. This valve is typically manually operated.