Oil Refining

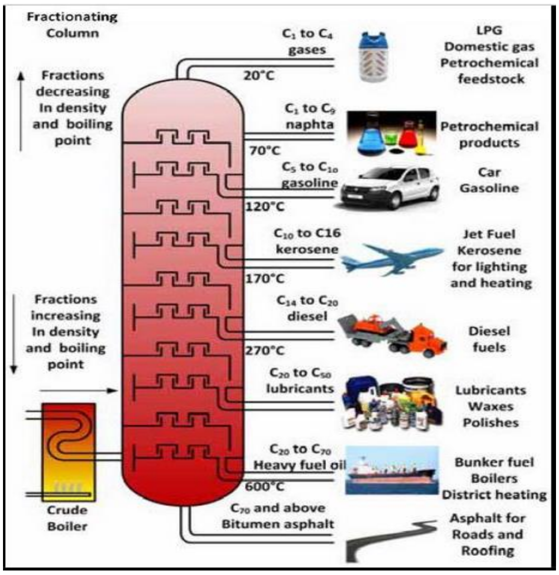
Dr. Ammar Al-kawaz

Crude Oil Distillation

Atmospheric distillation

The crude oil distillation process, also known as atmospheric distillation, is a key process in the refining of crude oil to obtain various petroleum products based on their boiling points or volatilities. The main steps of the process are:

- Heating the crude oil to almost 600 °C in a furnace
- Feeding the heated oil mixture into a distillation column, also known as a fractionating column
- Separating the oil mixture into different fractions by their boiling points and condensing them at different temperatures
- Collecting the fractions, such as gasoline, kerosene, diesel, and lubricating oils



Types of distillation column

- **According on the type of column internals**

Tray column - where trays of various designs are used to hold up the liquid to provide better contact between vapour and liquid, hence better separation

Packed column - where instead of trays, 'packings' are used to enhance contact between vapour and liquid

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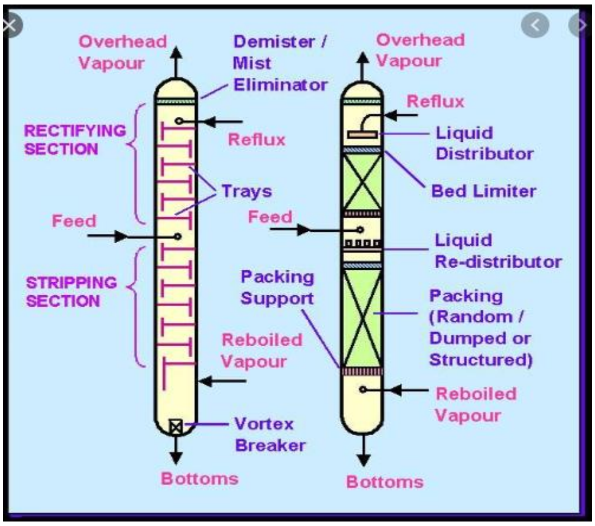
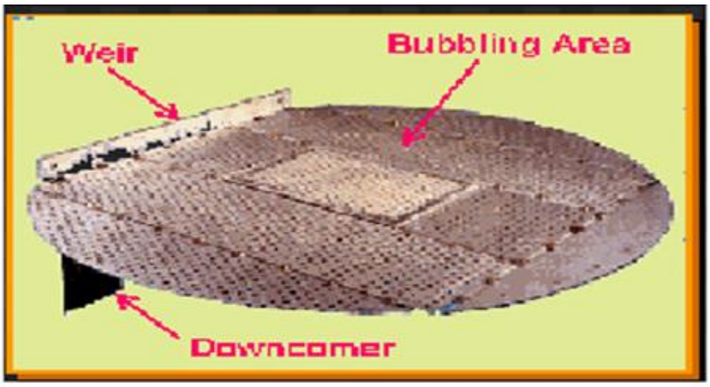


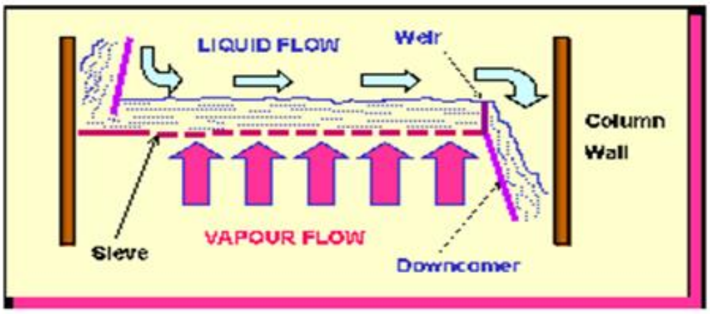
Trays types

There are five major types of tray column; bubble cap tray, sieve deck tray, dual flow tray, valve tray and baffle tray.

1. Sieve Trays

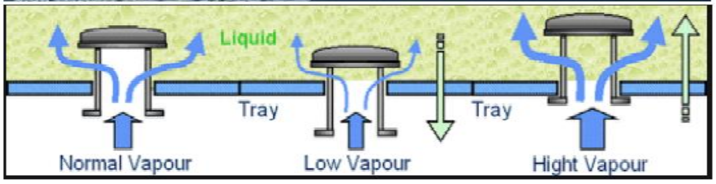
Sieves or perforated trays are plates with holes for vapor passage. It is simple to construct and the least expensive of these designs. Generally, the sieve tray has a higher capacity. At low vapor rates, it is susceptible to "weeping" or dumping of the liquid through the holes.





2. Valve Trays

A valve tray is a flat perforated plate, with each perforation fitted with a movable disk (the "valve"). The perforations and disks may be circular or rectangular. The valves should be heavy enough to prevent excessive opening at low vapour flow rates.



3. Bubble Cup trays

A bubble cap tray has riser or chimney fitted over each hole, and a cap that covers the riser. The cap is mounted so that there is a space between riser and cap to allow the passage of vapour.

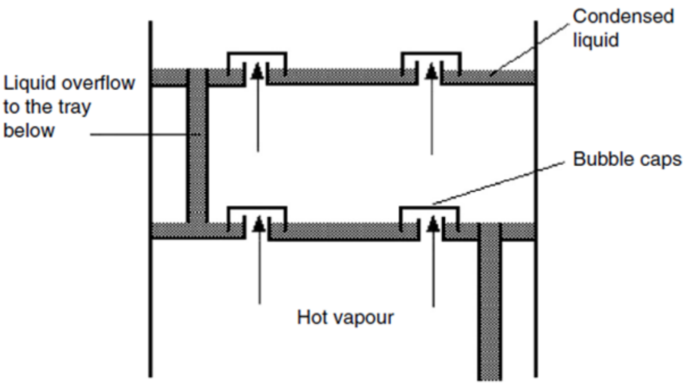
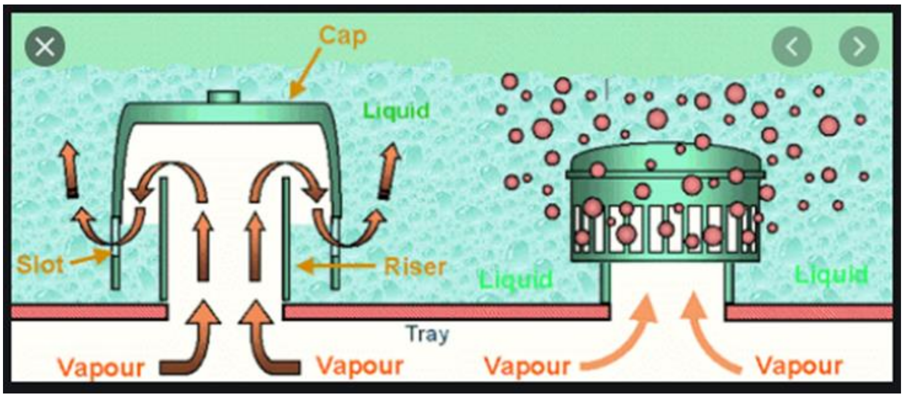


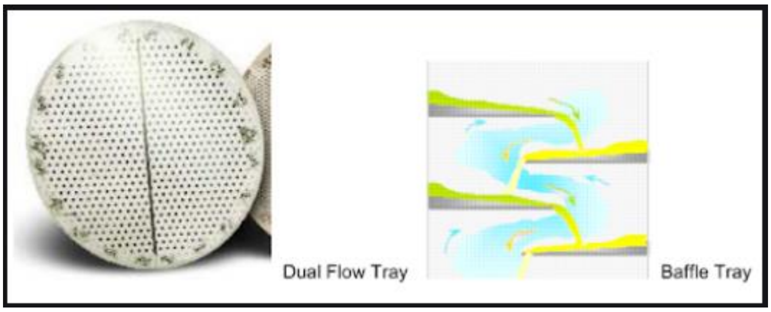
FIGURE 16.6 A bubble cap tray.

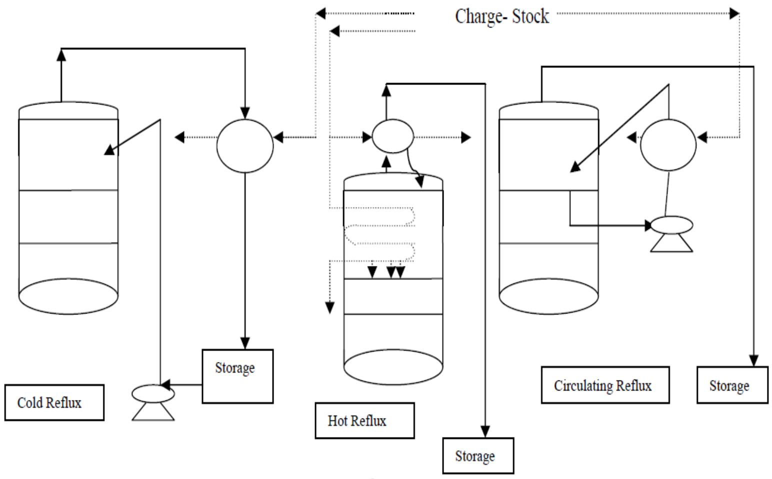


4. Daul Flow Trays

These trays are typically applied in severely fouling services. They are configured in a way that the liquid flows downwards through the column, splashing from one baffle to the next lower one.

5. Baffle Trays are unperforated trays with large open area for use in low-efficiency and highly fouling services with minimal contact between vapor and liquid. When multiple baffles are installed at the same level, these trays are often called Shed Decks.





Types of Reflux

Reflux ratio: is defined as the amount of internal reflux divided by the amount to top product. Heat reflux = heat in – heat out = Q in – Q out

Q in = crude oil heat + steam heat

1- Cold reflux is defined as reflux that is supplied at some temperature below the temperature at the top of the tower, each pound of this reflux removes a quantity of heat equal to the sum of its latent heat and the sensible heat required to raise its temperature from the storage tank.

$$Q = latent\ heat + sensible\ heat = m\lambda + mCp\Delta T$$

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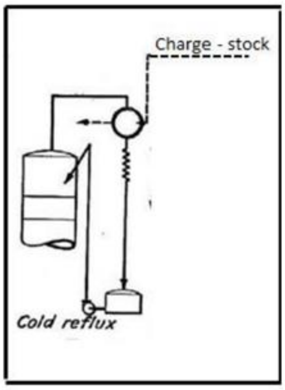
Usually take in this case temperature of reflux =100ºF



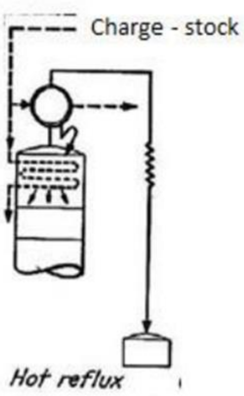
الارتداد البارد (**Cold Reflux**) في أعمدة التقطير هو إرجاع السائل المكثف إلى أعلى البرج بدرجة حرارة **أقل بكثير** من نقطة غليان السائل الموجود في الصينية العلوية.

إليك التأثيرات الأساسية لهذه العملية:

1. **تكثيف إضافي:** بمجرد دخول الارتداد البارد، يقوم بامتصاص الحرارة من الأبخرة الصاعدة، مما يؤدي لتكثيف جزء من هذه الأبخرة داخل البرج (Internal Reflux).
2. **زيادة كفاءة الفصل:** هذا التكثيف الإضافي يزيد من كمية السائل النازل، مما يحسن من عملية التلامس بين البخار والسائل، وبالتالي يرفع درجة **نقاوة** المنتج العلوي.
3. **تغيير الحمل الحراري:** يؤدي إلى زيادة الحمل على **الغلاية (Reboiler)** لأن البرج يحتاج لتعويض البرودة القادمة من الأعلى للحفاظ على توازن درجات الحرارة.
4. **تأثير التحميل (Loading):** إذا كان الارتداد بارداً جداً وبكميات كبيرة، قد يسبب زيادة مفاجئة في كمية السائل داخل البرج، مما قد يؤدي لظاهرة **الفيضان (Flooding)** أو خلل في الضغط.

2- Hot reflux is reflux that is admitted to the tower at the same as that maintained at top of the tower. Obviously, the reflux or overflow from plate to plate in the tower is essentially hot reflux because it is always substantially at its boiling point.

$$Q = latent\ heat = m\lambda$$



الارتداد الحار (**Hot Reflux**) هو إرجاع السائل المكثف إلى أعلى العمود عند درجة حرارة **قريبة جداً من نقطة غليانه** (أو عند درجة حرارة التشبع). بمعنى آخر، السائل لا يتم تبريده بشكل إضافي (Sub-cooling) بعد تكثيفه.

إليك أبرز خصائص وتأثيرات الارتداد الحار:

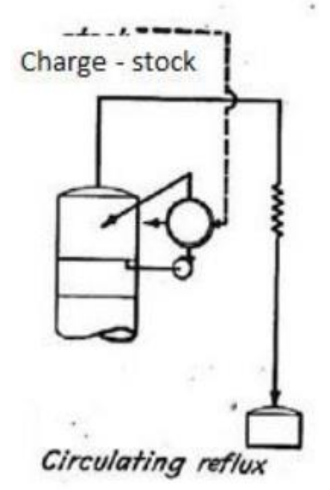
1. **استقرار التوازن الحراري:** لا يسبب صدمة حرارية أو تكثيفاً مفاجئاً للأبخرة الصاعدة، مما يجعل التحكم في توزيع درجات الحرارة داخل العمود أكثر استقراراً.
2. **كفاءة الطاقة:** يقلل الحمل على **الغلاية (Reboiler)** مقارنة بالارتداد البارد، لأن النظام لا يحتاج لطاقة إضافية لإعادة تسخين السائل الراجع إلى درجة الغليان.
3. **فصل أقل كثافة:** بما أنه لا ينتج "ارتداداً داخلياً" إضافياً (عن طريق تكثيف الأبخرة الصاعدة)، فإن كمية السائل النازل تكون هي نفس الكمية التي يتم ضخها من الأعلى فقط، مما قد يتطلب **نسبة ارتداد (Reflux Ratio)** أعلى لتحقيق نفس النقاوة التي يوفرها الارتداد البارد.

الفرق الجوهري:
بينما يُستخدم **الارتداد البارد** لزيادة قوة الفصل "قسرياً"، يُستخدم **الارتداد الحار** غالباً في العمليات التي تهدف لتوفير الطاقة أو عندما يكون التحكم الدقيق في حرارة الصواني العلوية أمراً حرجاً.

3- Circulating reflux, it is able to remove only sensible heat quantity, that is represented by its change in temperature as it circulate, that mean this reflux is withdrawn from the tower as a liquid at high temperature the tower and is returned to the tower after having been cooled.

$$Q = sensible\ heat = mCp\Delta T$$

This reflux withdrawn from the tower as a liquid at high temperature and returned to the tower after having been cooled.



الارتداد الدوراني (**Circulating Reflux**) أو ما يُعرف تقنياً بـ **Pumparound**، هو عملية سحب سائل من صينية معينة في عمود التقطير، تبريده عبر مبادل حراري خارجي، ثم إعادته إلى العمود في نقطة أعلى (عادةً فوق صينية السحب مباشرة).

يختلف هذا النوع عن الارتداد العلوي التقليدي بأنه **لا يغير تركيب المواد** (لا يهدف للفصل المباشر)، بل هدفه الأساسي **حراري**.

أهم وظائف الارتداد الدوراني:

1. **إزالة الحرارة الفائضة:** يُستخدم للتحكم في الحمل الحراري داخل العمود وتبريد الأبخرة الصاعدة في مناطق محددة (خاصة في أبراج التكرير الكبيرة مثل برج التقطير الجوي).
2. **موازنة حمل البخار:** يقلل من حجم الأبخرة الصاعدة في الجزء العلوي من العمود، مما يمنع ظاهرة **الفيضان (Flooding)** ويسمح بزيادة إنتاجية البرج.
3. **استعادة الطاقة:** الحرارة التي يتم سحبها من السائل في المبادل الخارجي تُستخدم غالباً لتسخين "اللقيم" (Crude Preheating)، مما يوفر استهلاك الوقود في الأفران.
4. **تقليل حجم المكثف العلوي:** من خلال سحب الحرارة من وسط العمود، يقل العبء على المكثف الموجود في قمة البرج، مما يسمح باستخدام معدات أصغر حجماً.

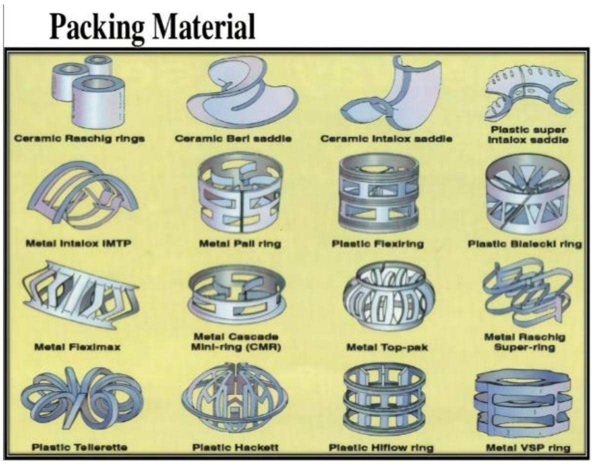
متى يُستخدم؟

شائع جداً في **مصافي النفط**، حيث تكون كميات الأبخرة هائلة والتحكم في توزيع الحرارة على طول البرج ضرورياً لضمان استقرار التشغيل.

Packed column

Packing Materials Types

Most of the column uses packing material for the vapor–liquid contacting because such packing has a lower pressure drop than distillation trays. This packing material can be either structured sheet metal or randomly dumped packing such as Raschig rings**.**



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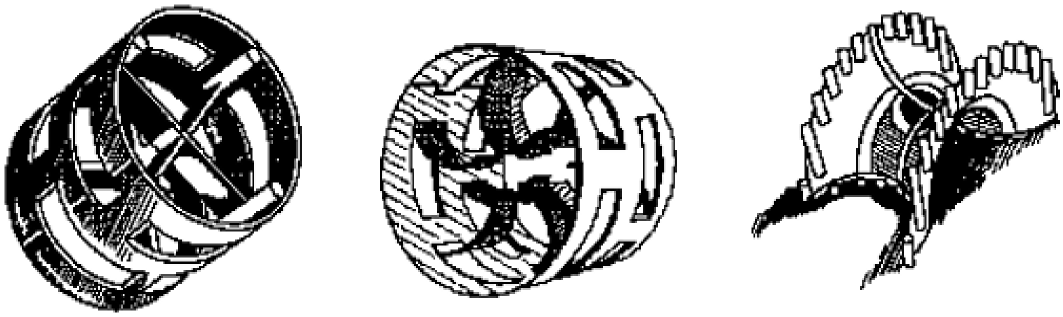
Packings

- Packings are passive devices designed to increase the interfacial area for vapour-liquid contact.
- They do not cause excessive pressure-drop across a packed section, which is important because a high pressure drop would mean that more energy is required to drive the vapour up the distillation column.
- Packed columns are called continuous-contact columns while trayed columns are called staged-contact columns because of the manner in which vapour and liquid are contacted.



Vacuum Distillation

Vacuum distillation of the atmospheric residue yields additional and valuable distillates, which could otherwise be thermally destroyed if further distillation was attempted at atmospheric pressure and above.

The atmospheric bottom, also known as reduced oil, is sent to the vacuum unit where it is further separated into vacuum gas oil and vacuum residues.

Vacuum distillation improves the separation of gas oil distillates from the reduced oil at temperatures less than those at which thermal cracking would normally take place.

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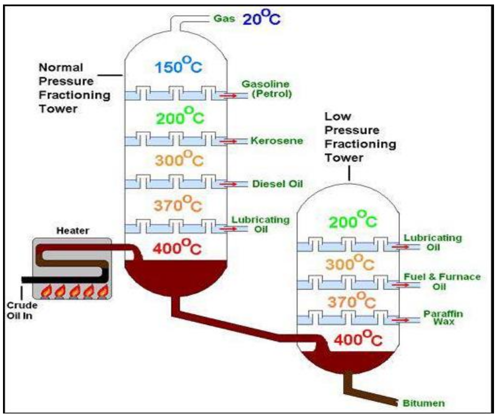


The basic idea on which vacuum distillation operates is that, at low pressure, the boiling points of any material are reduced, allowing various hydrocarbon components in the reduced crude oil to vaporize or boil at a lower temperature. Vacuum distillation of the heavier product avoids thermal cracking and hence product loss and equipment fouling.

Vacuum distillation can also be referred as "low temperature distillation".

In distilling the crude oil, it is important not to subject the crude oil to temperatures above 370 to 380 °C because the high molecular weight components in the crude oil will undergo thermal cracking and form petroleum coke at temperatures above that. Formation of coke would result in plugging the tubes in the furnace that heats the feed stream to the crude oil distillation column. Plugging would also occur in the piping from the furnace to the distillation column as well as in the column itself.

The constraint imposed by limiting the column inlet crude oil to a temperature of less than 370 to 380 °C yields a residual oil from the bottom of the atmospheric distillation column consisting entirely of hydrocarbons that boil above 370 to 380 °C.

To further distill the residual oil from the atmospheric distillation column, the distillation must be performed at absolute pressures as low as 10 to 40 mmHg (also referred to as Torr) so as to limit the operating temperature to less than 370 to 380 °C.

The absolute pressure of 10 to 40 mmHg in the vacuum column is most often achieved by using multiple stages of steam jet ejectors.

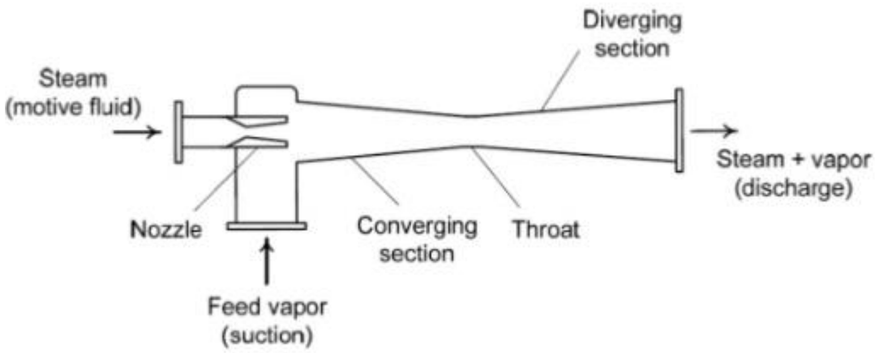


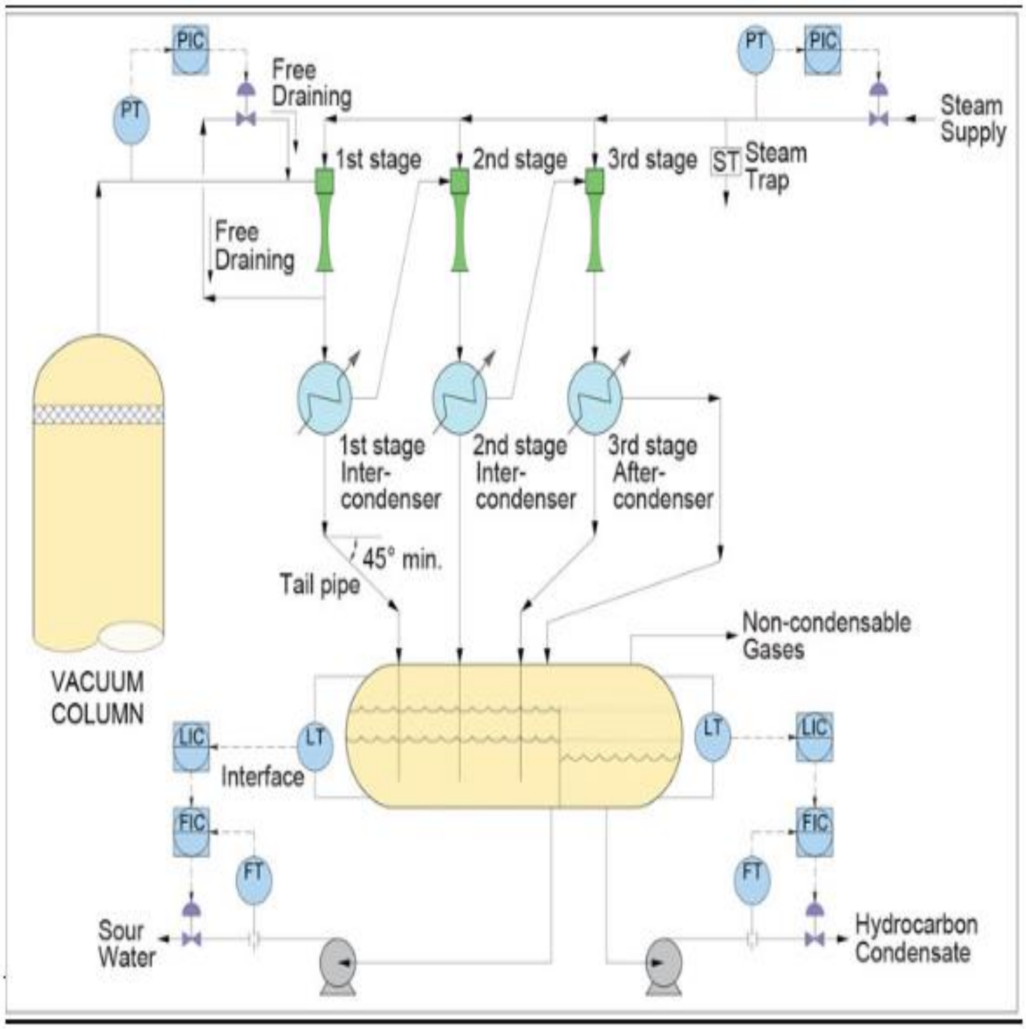
Figure: Steam ejector principle

Hot residual stream from the bottom of the atmospheric distillation column is flashed in a multiplated distillation column where vacuum (below atmospheric pressure) is maintained by steam ejectors by medium pressure superheated steam as the motive fluid that entrains the top hydrocarbon vapors, which are condensed by water coolers.

Steam ejector system mechanism

Usually, three ejectors are used; the first stage sends the uncondensed vapor to the second stage followed by condensation. The uncondensed vapor then enters the third stage followed by condensation and the uncondensed vapor from the third stage is vented out through a flare or stack.

A vacuum of 30–40 mm of mercury is maintained at the top of the column and 100–120 mm at the bottom. Condensates from these ejectors are collected in a drum, known as a hot well.



Typical boiling ranges at atmospheric pressure and the draw temperature under vacuum are listed below.

Typical Draw Temperatures of the Distillates from a Vacuum Distillation Column

Cuts	Equivalent boiling range (°C) at 1 atm	Draw temperature (°C) under vacuum
RCO	356+	Feed enters at 370
Overhead		80
Reflux		65
GO	265–362	180
SO	362–385	232
LO	385–462	276
IO	462–504	336
HO	504–542	356
SR	542+	360