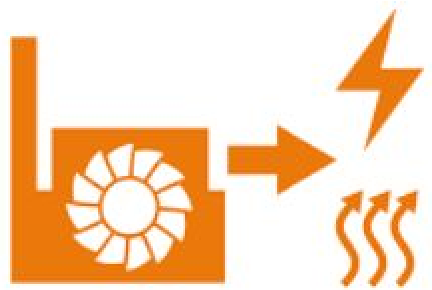
Waste Heat Management



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Introduction

Waste heat is the unused heat given to the surrounding environment due to some exothermic reaction, which may not be utilized. Utilizing waste heat not only increases the efficiency of the plant, but also creates added profits for the company. We can implement a variety of ways to utilize waste heat. But, we are not going to implement these processes first in the actual plant. So, to avoid such situation and to avoid the wastage of crores of money, we are now learning process control and simulation of waste heat management using Aspen Plus software to predict the feasibility of these processes before implementing it.

Aim

Our project aim is to design and simulate a waste heat management flowsheet and to increase the efficiency of plant by using waste heat and to make optimum use of fuel. We are using **ASPEN PLUS** software to design the flowsheet and simulate it under given conditions.

Unit Operations and Unit Process

Unit operations - It involves the physical changes in products obtained during various chemical unit processes.

Example - evaporation , distillation , liquid - liquid extraction.

Unit process - It involves principal chemical conversions leading to synthesis of various useful products and provides basic information regarding reaction temperature and pressure, extent of chemical conversions and yield of product of reaction nature whether the reaction is exothermic or endothermic ,type of catalyst used.

Example - oxidation, reduction, nitration, sulfonation etc.

Types of flow diagram

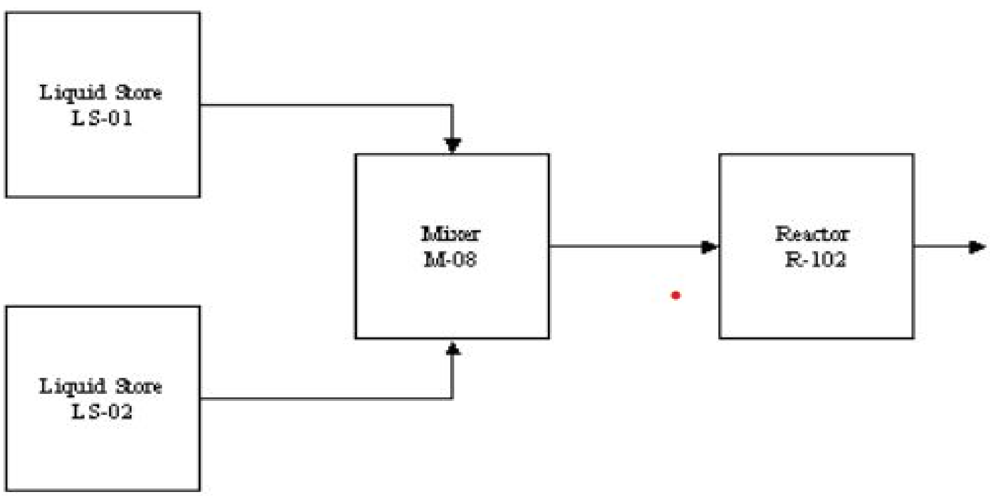
1. Block flow diagram

A block flow diagram (BFD) is a drawing of chemical processes used to simplify and understand the basic structure of a system. A BFD is the simplest form of the flow diagrams used in industry. Blocks in a BFD can represent anything from a single piece of equipment to an entire plant.

All unit operations and group of unit operations are represented as rectangles with labels.

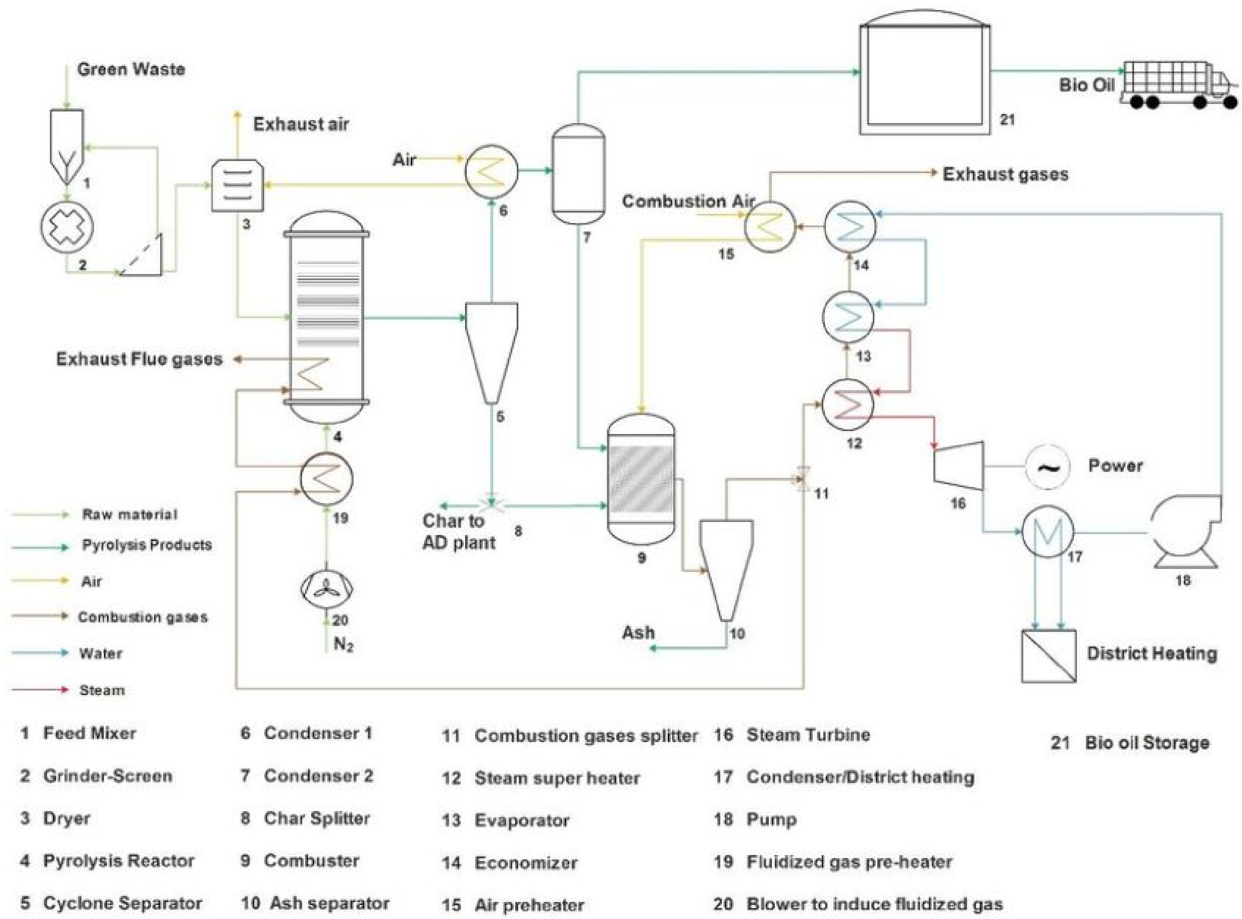
All input and output process flow streams are represented using arrows. Blocks are connected by straight lines representing process flow streams. (eg: mixture of liquid, gases and solids, or solids being carried on a conveyer belt),flow streams should be numbered sequentially in logical order.

Eg: separators , reactors , distillation column etc.



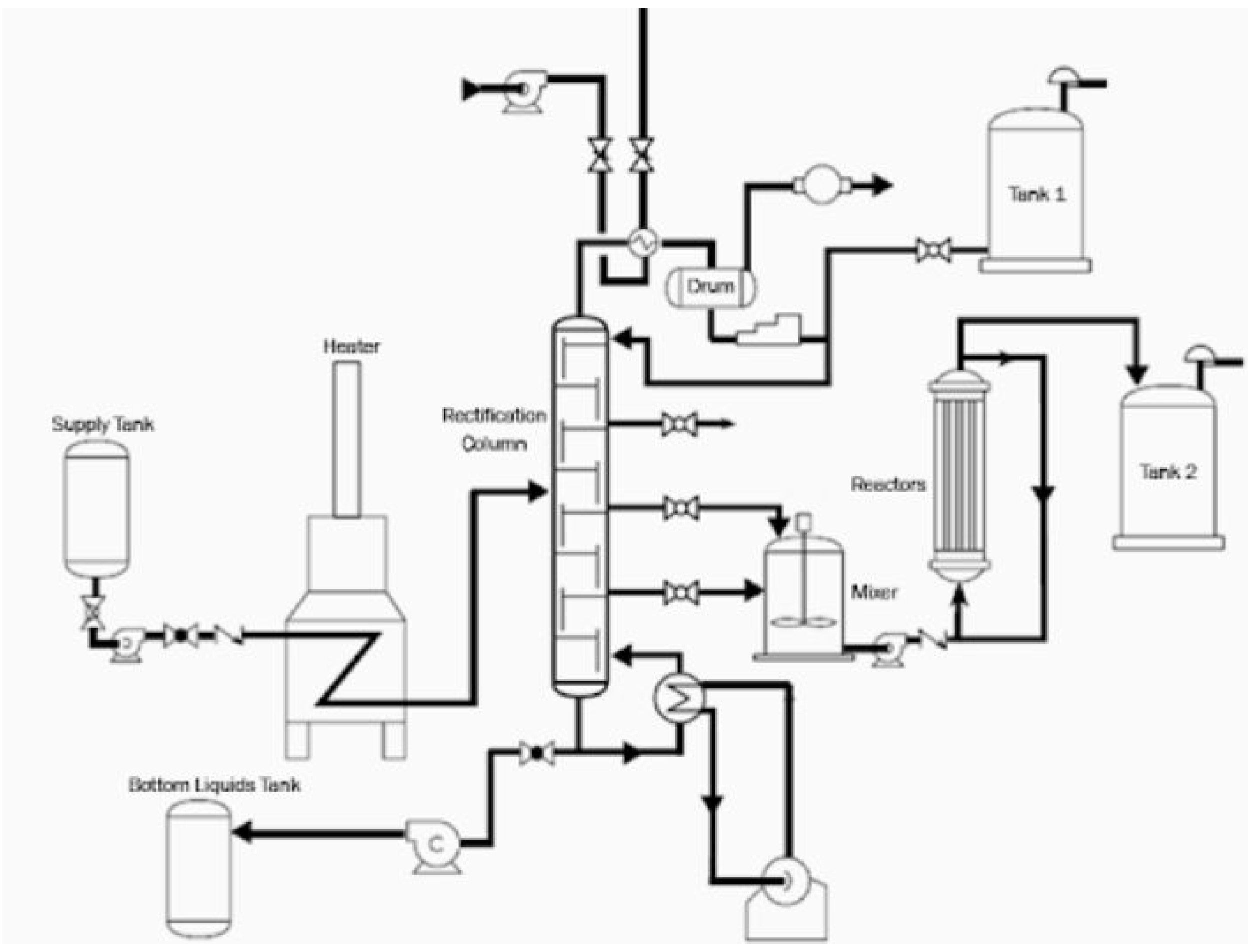
2. Process flow diagram

A process flow diagram (PFD) is a diagram commonly used in chemical and process engineering to indicate the general flow of plant processes and equipment. The PFD displays the relationship between major equipment of a plant facility and does not show minor details such as piping details and designations



3. Piping and instrumentation

It shows graphical description of the processes and process equipment using standard symbols. P&ID is used by field technicians, engineers and operators to better understand the process and how the instrumentation is interconnected. More detail than PFD. Major and Minor flows, control loops and instrumentation. Show process flow, measuring sensors and transducer & final control elements and devices. The elements that are included are pipes, hydraulic elements, electrical and instruments.



Components of flow diagram

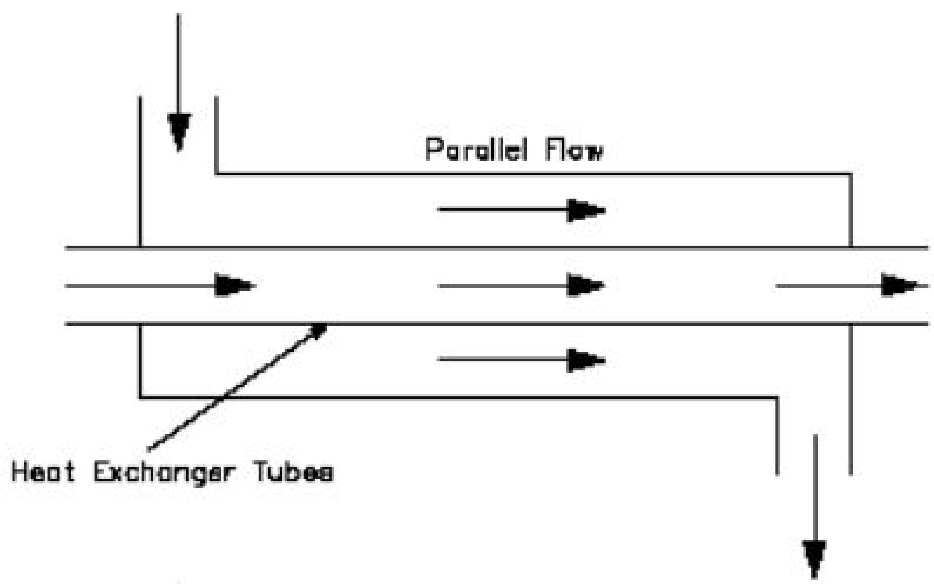
1. Heat exchanger

1. Parallel flow heat exchanger

In this type of heat exchanger both fluids flow in same direction. Parallel flow heat exchanger is useful when two fluids are required to be brought to nearly same temperature.

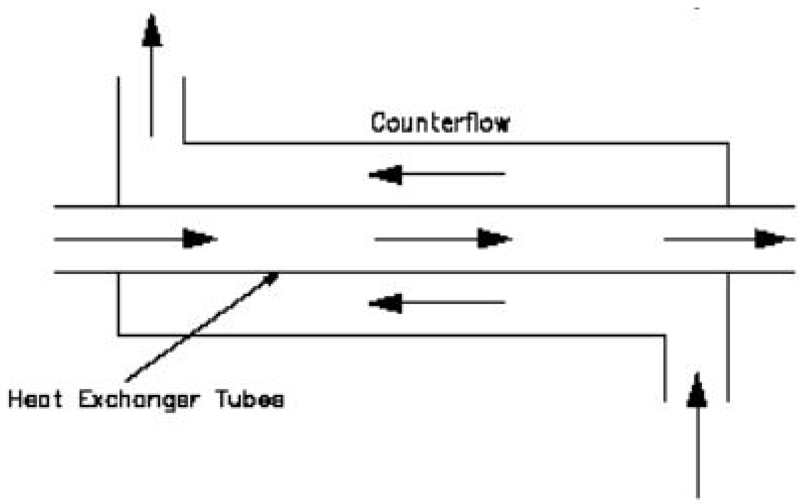
Disadvantages of parallel flow heat exchanger are-

1. The large temperature difference at ends causes large thermal stress.
2. The temperature of the cold fluid exiting the heat exchanger never exceeds the lowest temperate of hot fluid.



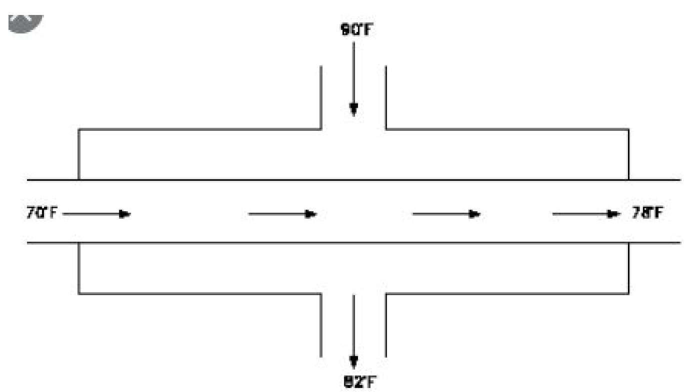
2. Counter flow heat exchanger

In this type of heat exchanger both fluids flow in opposite direction. The counter flow heat exchanger has three advantages over parallel flow heat exchanger. The more uniform temperature difference between the two fluids minimises the thermal stress throughout the exchanger. The outlet temperature of the cold fluid can approach the highest temperature of the hot fluid. The more uniform temperature difference produces a more uniform rate of heat transfer throughout the heat exchanger



3. Cross flow heat exchanger

A cross flow heat exchanger exchanges thermal energy from one airstream to another in an air handling unit.A cross-flow heat exchanger is used in a cooling and ventilation system that requires heat to be transferred from one airstream to another. A cross-flow heat exchanger is made of thin metal panels, normally aluminium. The thermal energy is exchanged via the panels.



4. Shell and tube

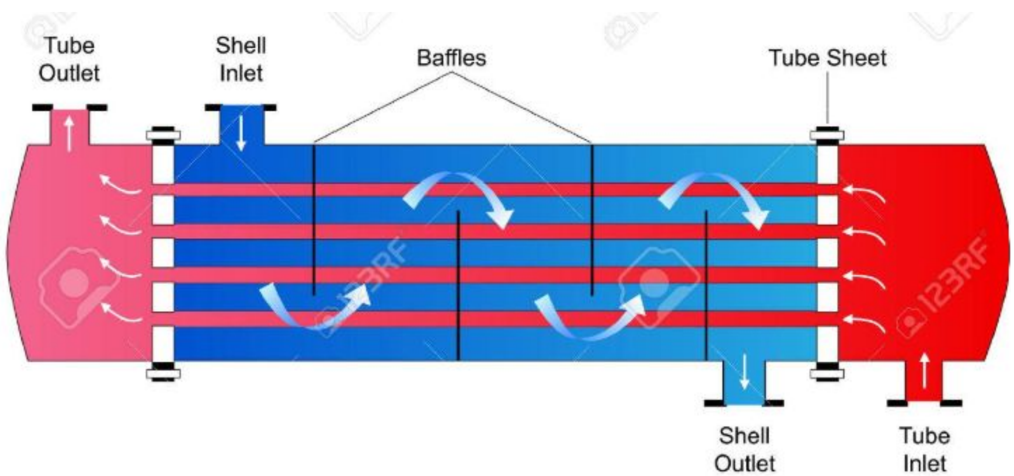
A shell and tube exchanger consists of two numbers of tubes mounted inside a cylindrical shell. Two fluids can exchange heat, one fluid flows over the outside of the tubes while the second fluid flows through the tubes.

The shell and tube exchanger consists of four major parts:

Front Header—this is where the fluid enters the tubeside of the exchanger. It is sometimes referred to as the Stationary Header.

Rear Header—this is where the tubeside fluid leaves the exchanger or where it is returned to the front header in exchangers with multiple tubeside passes.

Tube bundle—this comprises of the tubes, tube sheets, baffles and tie rod Shell

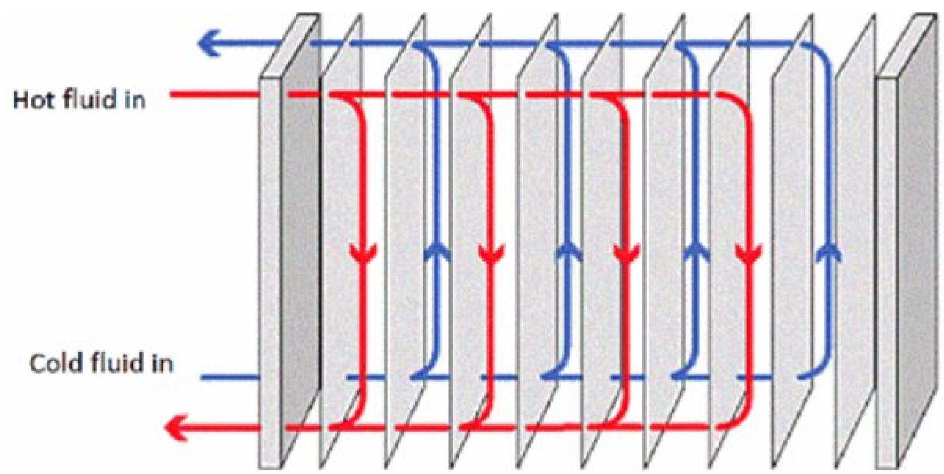


5. Compact heat exchangers

Compact heat exchanger can be characterized by its high ‘area density’ this means that is has a high ratio of heat transfer surface to heat exchanger volume. So Compact heat exchange is characterized by high heat transfer surface-area to volume ratios and high heat transfer coefficients compared to other exchanger types

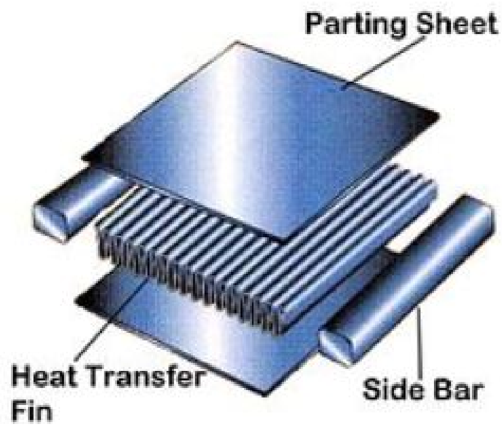
1. Plate and frame

Plate and frame heat exchangers are made of corrugated plates on a frame. This design creates high turbulence and high wall shear stress, both of which lead to a high heat transfer coefficient and a high fouling resistance. Fluids travel within the heat exchanger. The two streams flow counter currently. The hot fluid flows down one plate while the cold fluid flows up the other plate.



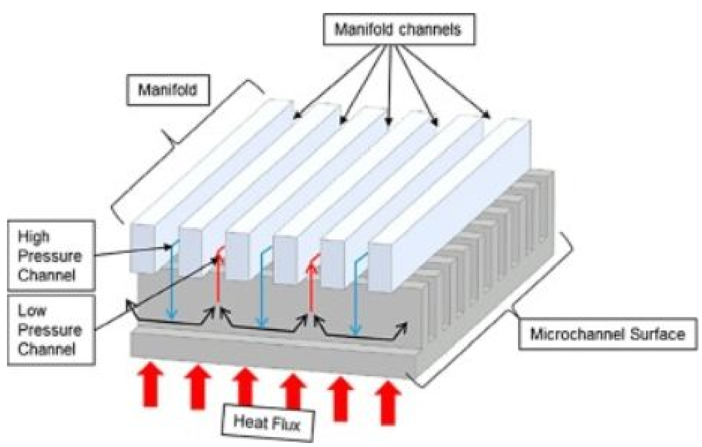
2. Plate and fin

A plate exchanger consists of a series of parallel plates that are placed one above the other so as to allow the formation of a series of channels for fluids to flow between them. The space between two adjacent plates forms the channel in which the fluid flows.Inlet and outlet holes at the corners of the plates allow hot and cold fluids through alternating channels in the exchanger so that a plate is always in contact on one side with the hot fluid and the other with the cold



3. Microchannel heat exchanger

The micro channel heat exchanger (MCHE) is ideal for use in residential and commercial air conditioning systems as well as in refrigeration equipment driven by energy efficiency and reduction of the refrigerant charge.With the MCHE you get an ingeniously simple, all-aluminium design that is not only lightweight but is also immune to galvanic corrosion. The aluminium construction makes it one of the most sustainable solutions in the market due to its high strength, sealed design and recyclable materials



2. <u>Heaters</u>

1. Immersion heaters

Used in many different industries to heat liquids in large vats, containers and tanks. Immersion heaters use a direct heat transfer to heat liquids, which increases the speed at which the liquid reaches the desired temperature. works well for liquids with vastly different properties and they usually require little in the way of maintenance

2. Pipe heaters

Pipe heaters are designed to fit inside 2-3 inch pipes and provide heat. Pipe heaters work well for applications that require low heat like making waxes ,tar, molasses or with more corrosive material.in pipe heaters heating is done by the element heating the pipe from the inside and the pipe heating the liquid.

3. Circulation heaters

One of the type of immersion heaters they are also called in line heaters and the typically come in a wide range of different watt densities. The density is usually specifically designed for the type of liquid that is being heated. things like flow rate and viscosity help to determine the exact type of circulation heater that is used.

4. Cartridge heaters

Designed to heat up solids by fitting snuggly inside a mould or cavity and reaching high temperature. Cartridge heaters are able to carry thermocouple ,which helps to control and maintain the heaters temperature with a greater degree of accuracy.

5. Duct heaters

They are either used for airflow ventilation or process heating applications. There are three basic types of duct heaters, including tubular,finned tubular and open coiled. These heating elements are directly inserted into the duct or flanged.

3. Packed column

A packed column is a pressure vessel that has a packed section. Columns used in certain types of chromatography consisting of a tube filled with packing material can also be called packed columns and their structure has similarities to packed beds.

They are used for distillation, gas absorption, desorption kind of processes. Liquid flows down the column over the packing surface and the gas/vapour, counter currently, up the column. The performance of packed column is very dependent on the maintenance of good liquid and gas distribution throughout the packed bed.

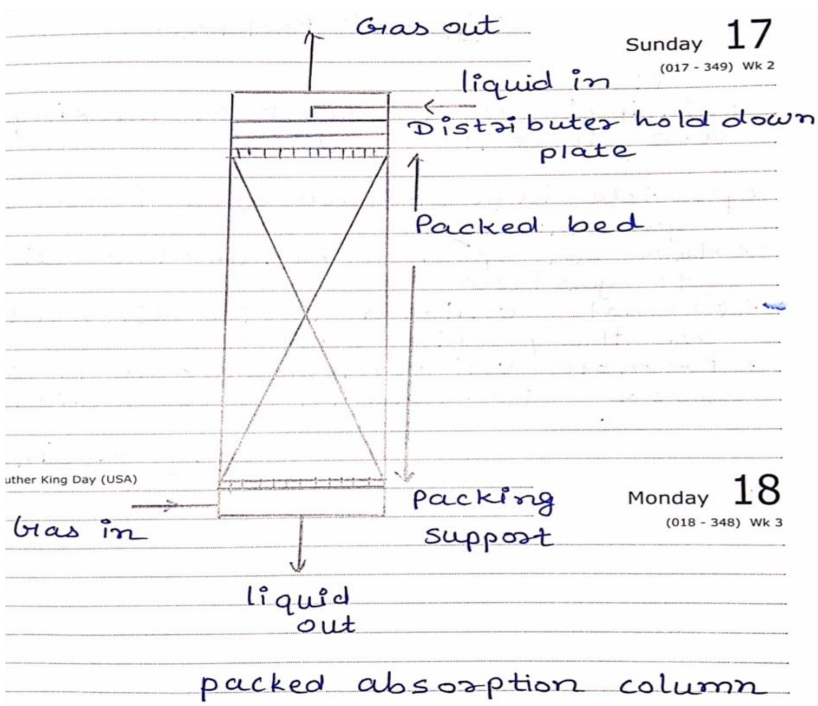
Principal requirements of packing are that it should:

1. It should provide large surface area between gas and liquid.

2.Have an open structure: low resistance to gas flow.

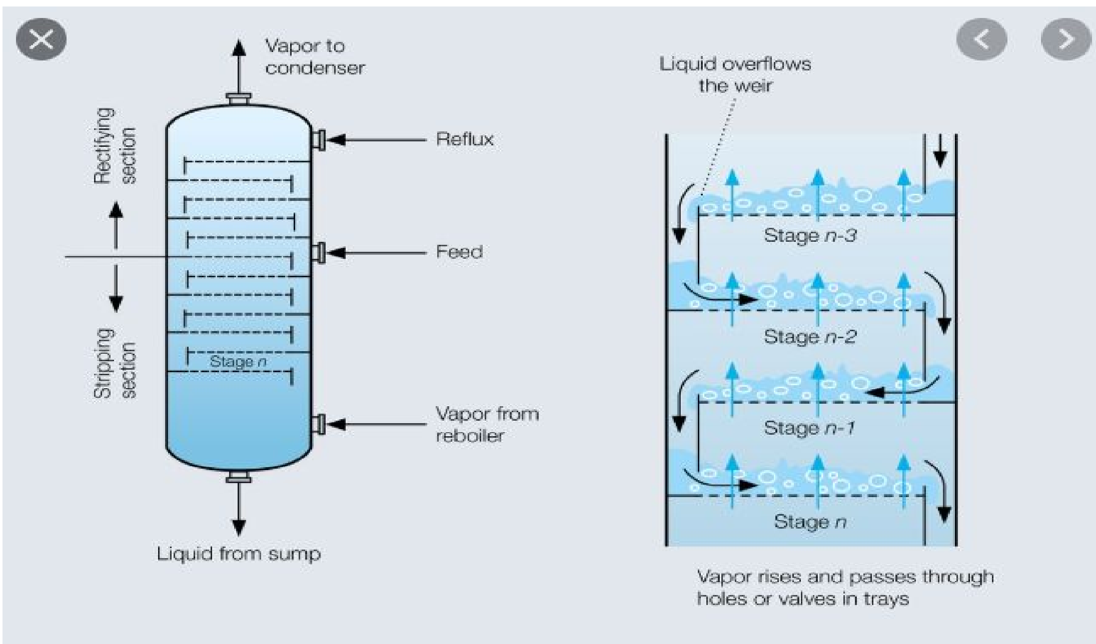
3.Promote uniform liquid distribution on the packing surface.

4.Promote uniform vapour gas flow across the column cross-section.



4.Tray tower

Liquid is supplied from top and moves through the **downcomer** region. The liquid depth is maintained by the **Outlet wear**. The liquid interacts with the vapour in the **Bubbling Area** (the region from the down comer to the outlet area). **Froth region** gas bubbles dispersed in liquid. Under certain conditions a **spray zone** can also form where liquid droplets are dispersed in continuous vapour .Froth flows over the outlet wear into the down comer to the tray below. **Downcomer** region should allow sufficient time for disengagement between liquid and vapour in the over flowing froth. The goal is for only clear liquid and no froth to be present at the bottom of the downcomer and flowing out to the tray below .



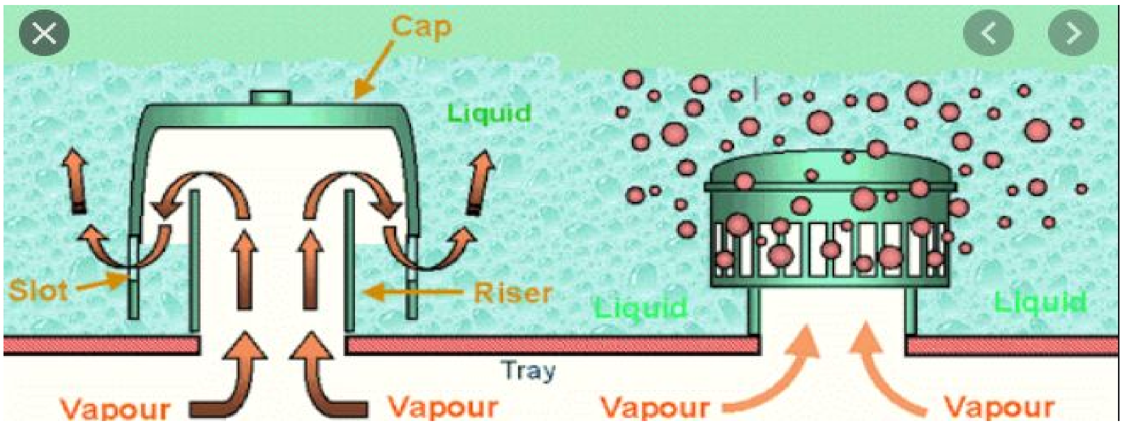
Types of trays in a tray tower :

1. Bubble cap trays
2. Sieve trays
3. Valve trays

1. Bubble cap trays

Design : It has a riser (chimney) fitted at each hole , and a cap that covers the riser . The cap is mounted so that there is a space between riser and the cap to allow the passage of vapour

Working: Vapour rises through the riser chimney is directed downward by the cap discharged through slots bubbling through liquid on the tray .

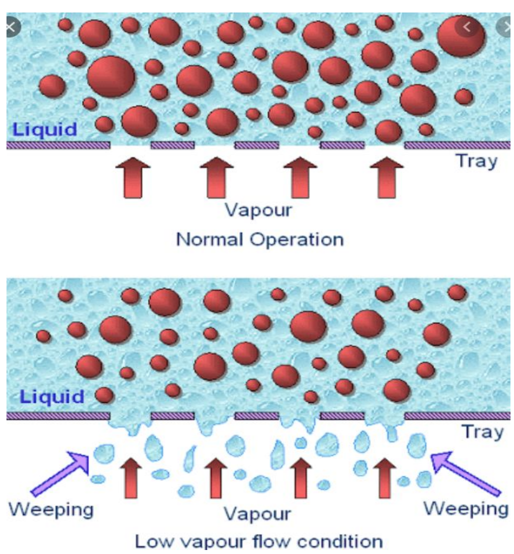


2. Sieve trays

Design : Metals plates with holes in them

Design parameters: arrangement , number , size of holes .

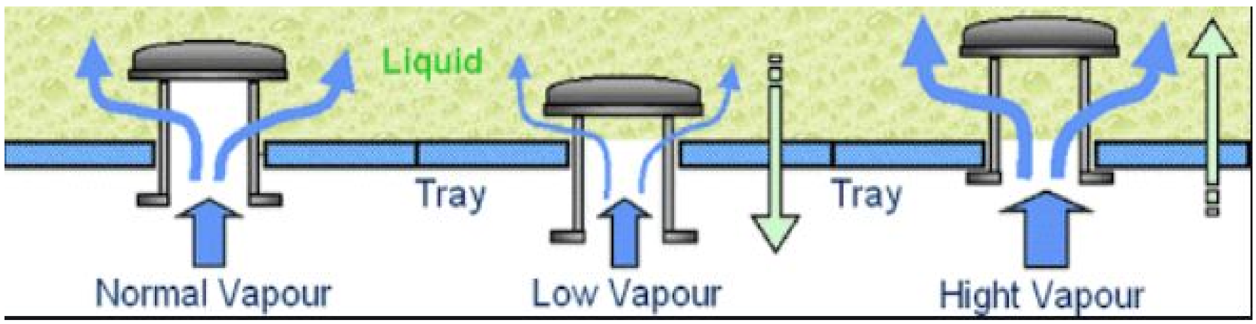
Working: Vapour passes straight upward through the liquid on the plates .



3. Valve trays

Design : Liftable caps .

Working: Vapour flow lifts the caps creating a flow area for the passage of vapour. lifting cap directs the vapour to flow horizontally into the liquid thus better mixing than sieve trays .



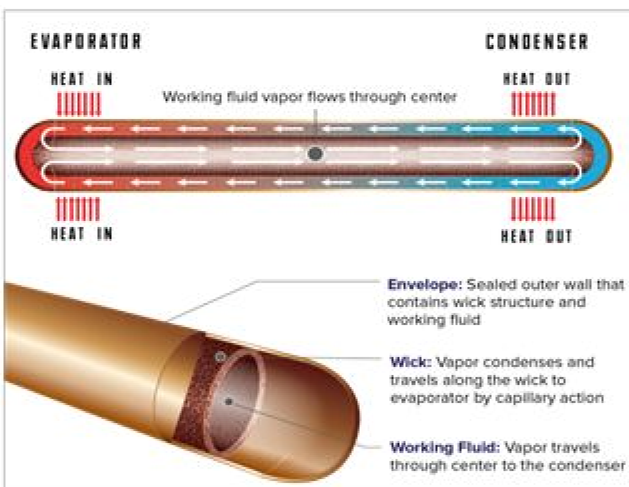
5.HEAT PIPE

Heat pipe is a thermal transfer device capable of transferring heat and energy efficiently that uses a liquid–vapor phase transformation and the associated fluid flow to achieve the transfer of heat from a hot point to a cold point.

As heat is applied to one end (the evaporator), the working liquid evaporates from the wick, while the removal of heat from some other portion of the surface (the condenser) causes the vapour to condensate on the wick. At the other end condensation takes place, so that the working liquid fills in the wick. Due to capillary forces, the result is a pressure gradient in the liquid that causes the working liquid to flow through the wick towards the evaporator end, in the opposite direction to that of the flowing vapour in the core region, completing the flow circuit .

A typical heat pipe consists of a sealed pipe or tube made of a material that is compatible with the working fluid such as copper for water heat pipes, or aluminium for ammonia heat pipes.

Heat pipe Advantages : Passive Operation, Long Life, Zero cross contamination (since streams of source and sink are physically separated), Minimum Maintenance, Compact Size, Practically zero back pressure.



Management of waste heat

-Heat recovery provides valuable energy sources and reduces energy consumption

-Waste heat in a power plant may be used for preheating Demineralised water make up, vapour absorption,air cooling systems

It increases efficiency of combustion

-It can be used for electrical and mechanical power.

About aspen

Aspen

Founded in 1981, AspenTech was born out a joint research project between the Massachusetts Institute of Technology (MIT) and US Department of Energy—an Advanced System for Process Engineering (ASPEN) Project.

What is Aspen Plus

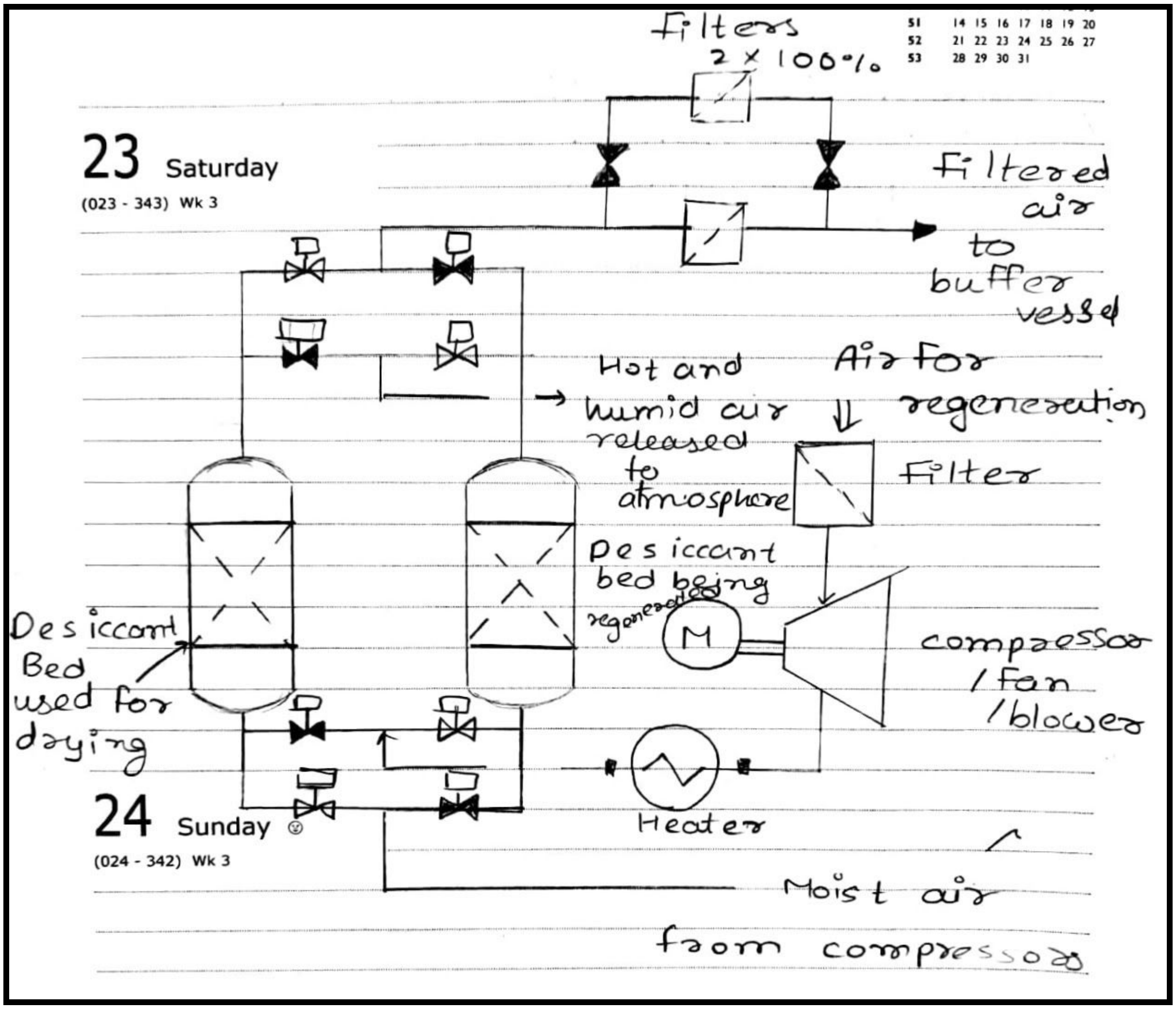
Aspen Plus is a market-leading process modeling tool for conceptual design, optimization, and performance monitoring for the chemical, polymer, specialty chemical, metals and minerals, and coal power industries.

What Aspen Plus provides

Physical Property Models. World's largest database of pure component and phase equilibrium data for conventional chemicals, electrolytes, solids, and polymers. Regularly updated with data from U. S. National Institute of Standards and Technology (NIST). Comprehensive Library of Unit Operation Models. Addresses a wide range of solid, liquid, and gas processing equipment. Extends steady-state simulation to dynamic simulation for safety and controllability studies, sizing relief valves, and optimizing transition, startup, and boj yo down policies. Enables you build your own libraries using Aspen Custom Modeler or programming languages (User-defined models).

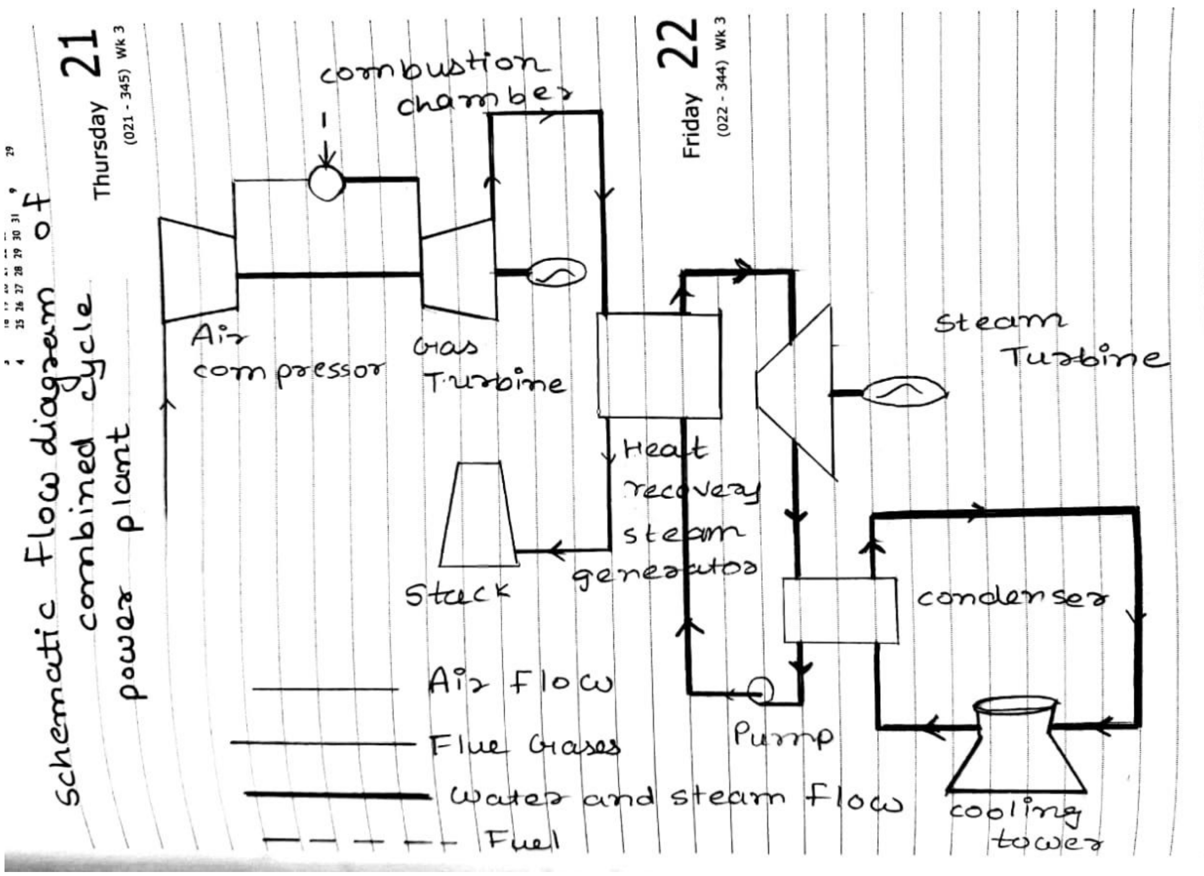
Flowsheets studied

1.Air Dryer and Filter System



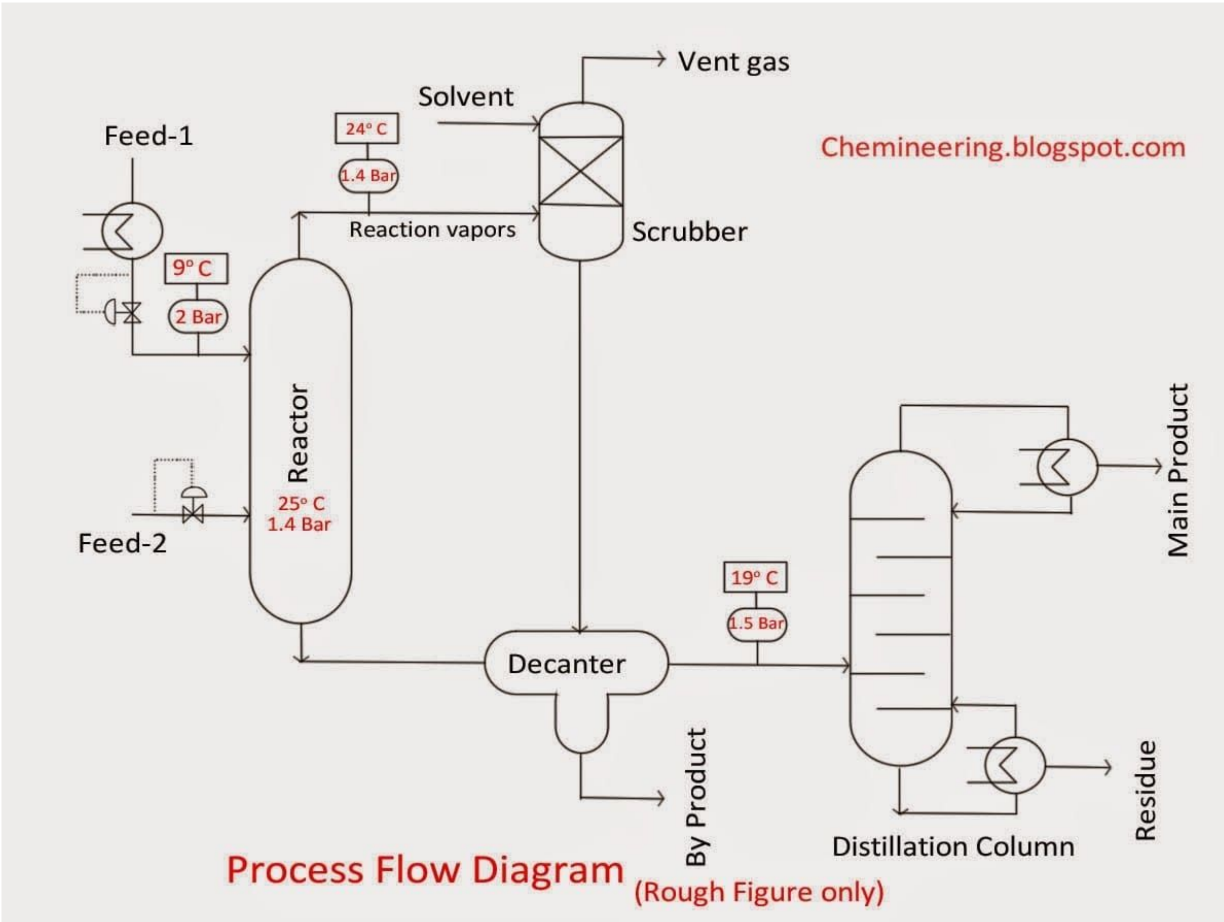
Instrument air (extremely clean supply of compressed air) is made available to the instrument air headers by compressing the atmospheric air. The compressed air being used for instruments is needed to be dry to a certain extent, whereas ambient air usually comes with moisture. When the moist air is compressed, some of the water content tends to condense under pressure and is removed using knock out drums at the discharge of instrument air compressors. The air coming out of knock out drums is still somewhat moist and further drying of this air is carried out by using Instrument Air Dryer and Filter System.

2. Combined cycle power plant



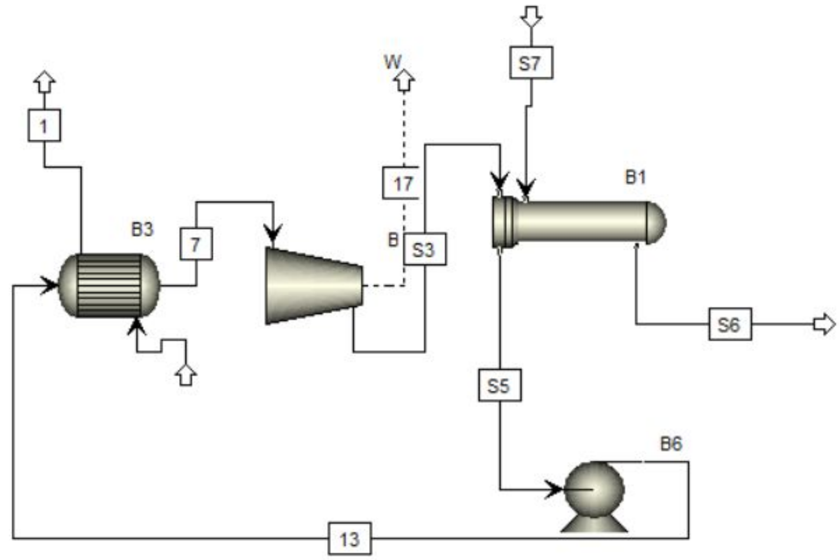
Ambient air at Normal Temperature and Pressure (NTP) is compressed by the air compressor to decrease its volume. Air at elevated temperature and pressure is directed to the combustion chamber. The compressed air is mixed with CNG from the fuel supply system to produce hot combustion gas in combustion chamber at constant pressure. Hot combustion gas enters the gas turbine where power is generated. HRSG is the link between the gas turbine and the steam turbine process, whose function is to transfer heat energy from exhaust gases to high pressure water and produces high pressure steam. The steam is separated in the boiler drum and supplied to the super heater section and boiler condenser section. The super heated steam produced in the super heater then enters into steam turbine through the turbine stop valve. After expansion in the turbine the exhaust steam is condensed in the condenser. In the cooling water system, heat recovered from the steam turbine exhaust is carried by the circulation water to the cooling tower, which rejects the heat to the atmosphere.

3. Dual feed



Feed 1 is passed through an industrial heater . Temperature of feed 1 is altered . **Control valve** - controls the flow of fluid (alters flow rate , pressure , temperature , liquid level) . Feed 1 is flowing at 9 degree Celsius and 2 bar enters the reactor from top (input) . Feed 2 , through the control valve enters in the reactor (input 2) . Top product - reaction vapours in pipe at 1.4 bar and 24 degree Celsius . Bottom product is liquid at 1.4 bar . Top product of first reactor enters into packed bed tray tower as feed . External solvent is also added . Top product of the tower is vent gas (gas released through vent pipes) . **Scrubber** are air pollution control devices . The bottom product is passed to a **decanter** (sedimentation tank) . Liquid left is at 1.5 bar and 19 degree Celsius enters the distillation tower and further distillation occurs .

4. Electricity



Combustion of fossil fuels takes place and heat is produced. This heat is passed to the boiler where water enters through the pump. This water is converted to steam.

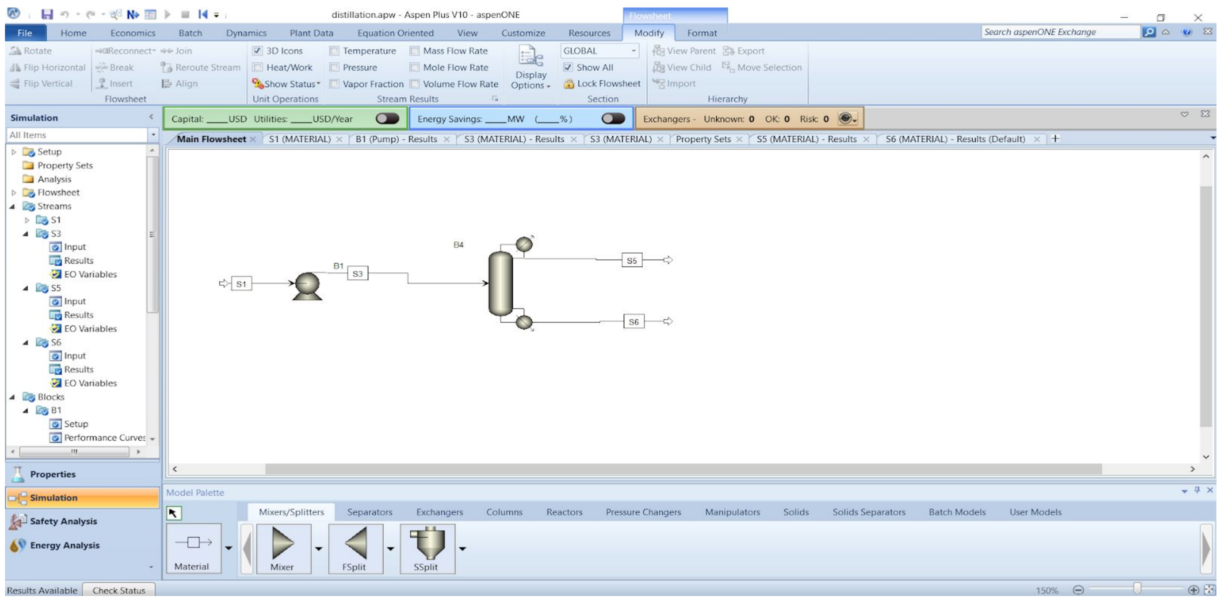
Now this steam is passed to the turbine where electricity is produced .

Remains of the steam is passed to condensor where steam is converted to its liquid form. This liquid is entered to the pump where the pressure increases.

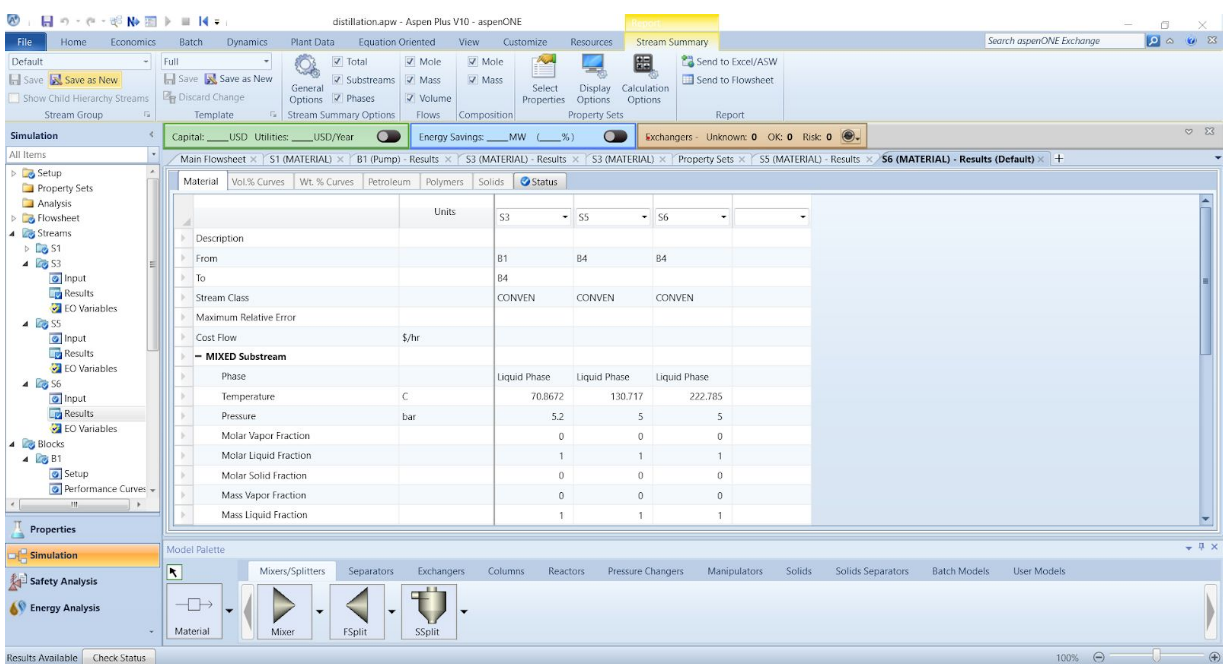
This liquid from pump enters again to the boiler and the cycle continues.

Flowsheets made by us

1.

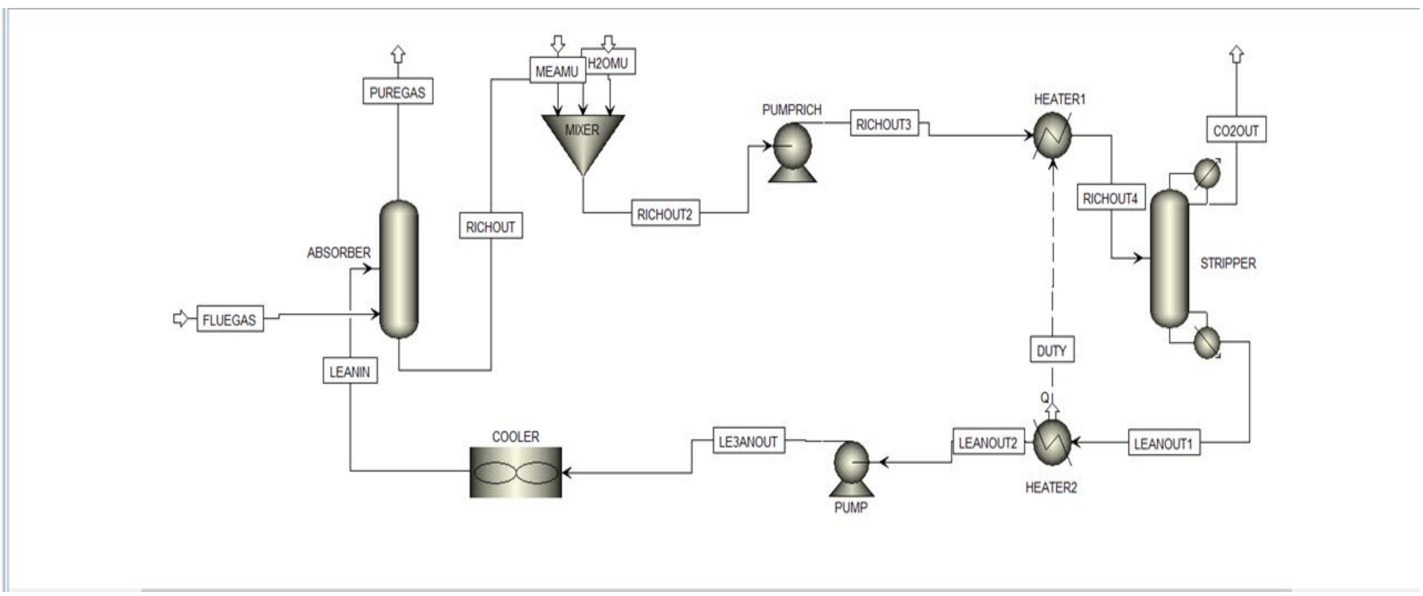


Result of above flow sheet:

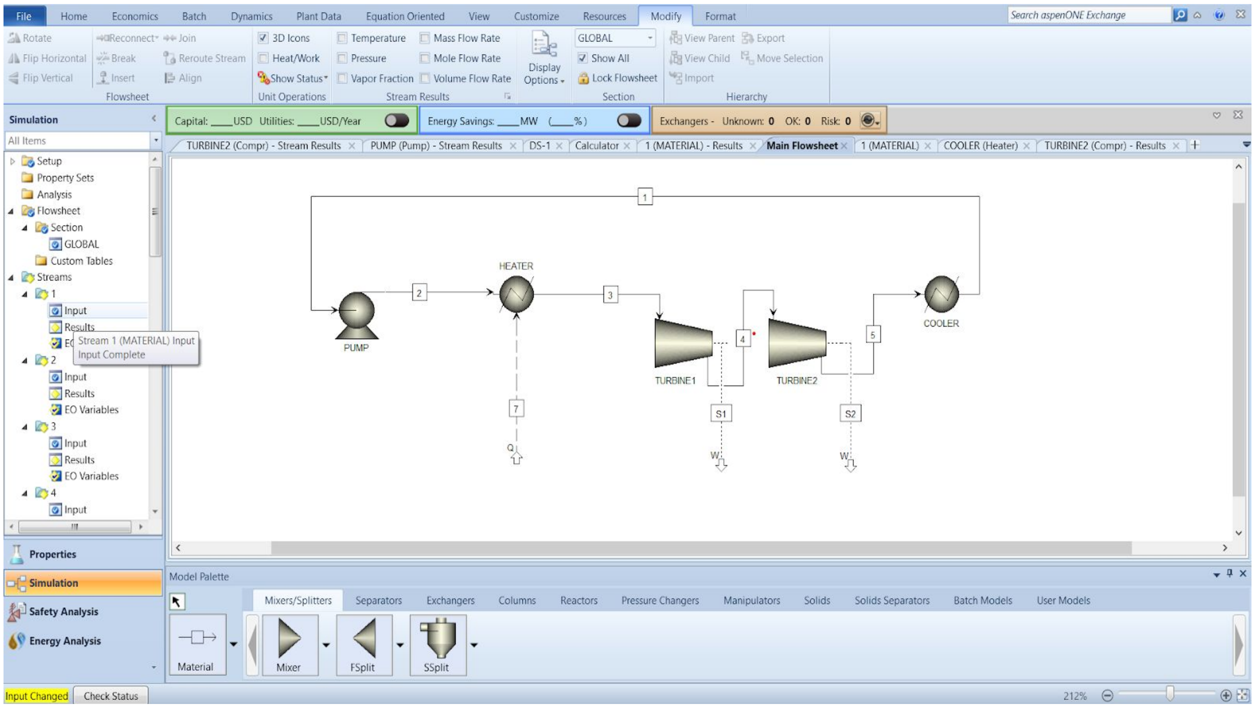


2. CO_2 Capture plant

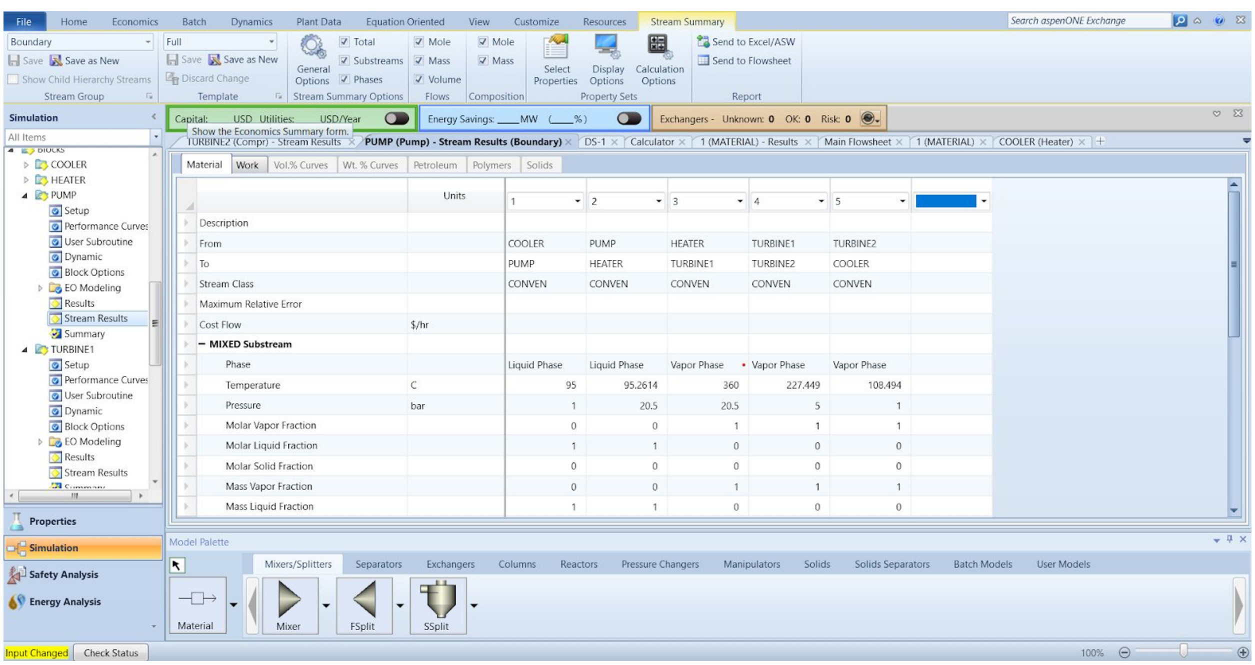
In this we are using flue gases as input and in absorber some soluble components are absorbed and gas which is not absorbed is thrown out as pure gas after that the component we absorbed goes to mixer. In the mixer we mix with absorbed components some water and other components from there feed goes to the pump where we increase its pressure and then we heat it and convert them to vapours. In the stripping section we separate gases. From the upper section we get pure carbon dioxide and the remaining gas goes to the air cooler and from there it again goes into the absorber.

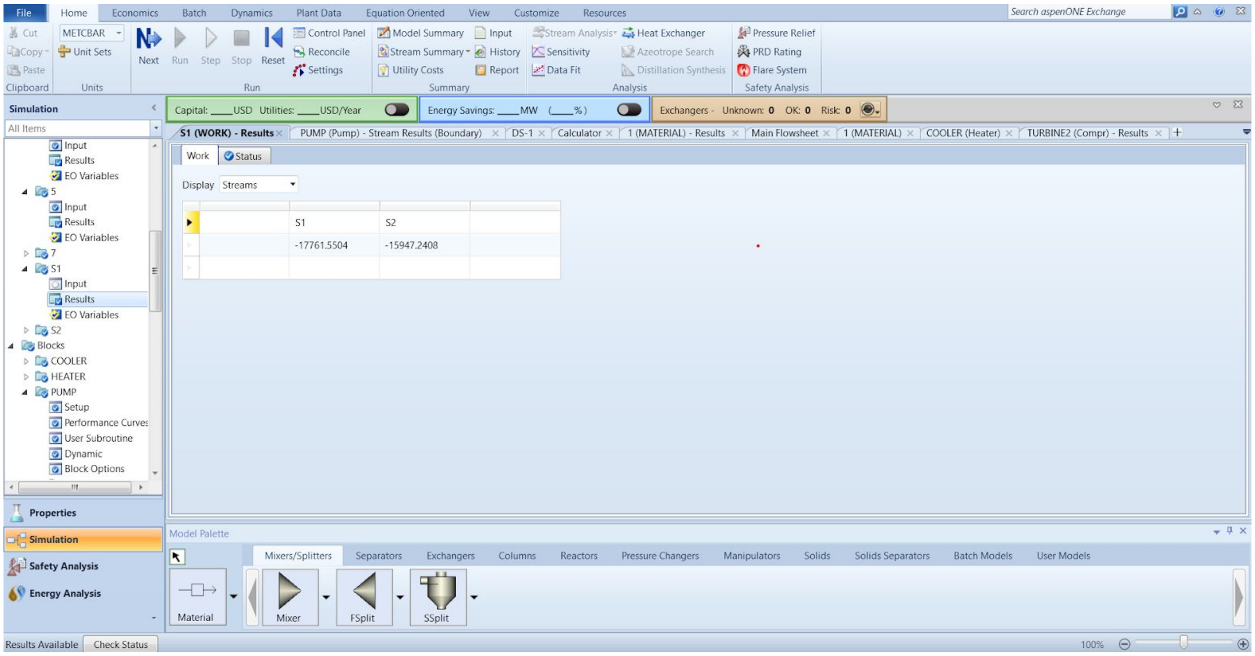


Main Flowsheet



Results





In this we are simulating a plant in which we are using water as our feed. Water goes firstly to pump where we increase its pressure then water goes to heat exchanger, where we use waste hot fluid to heat our cold fluid(water) and convert it to steam through which we rotate our turbines to generate electricity, the purpose of using two turbines is to maximise our efficiency as one turbine is for high pressure steam and other one is for low pressure steam, as steam passes through first turbine its pressure decreases. After these processes the temperature of steam decreases and then steam goes to condenser where we convert it back to water and put it back in pump.

Conclusion

So we have seen how different parameters influence the output of plants. By changing different properties, different outputs can be generated. Waste heat can be used to increase the efficiency of plants and reduce the use of fuel.