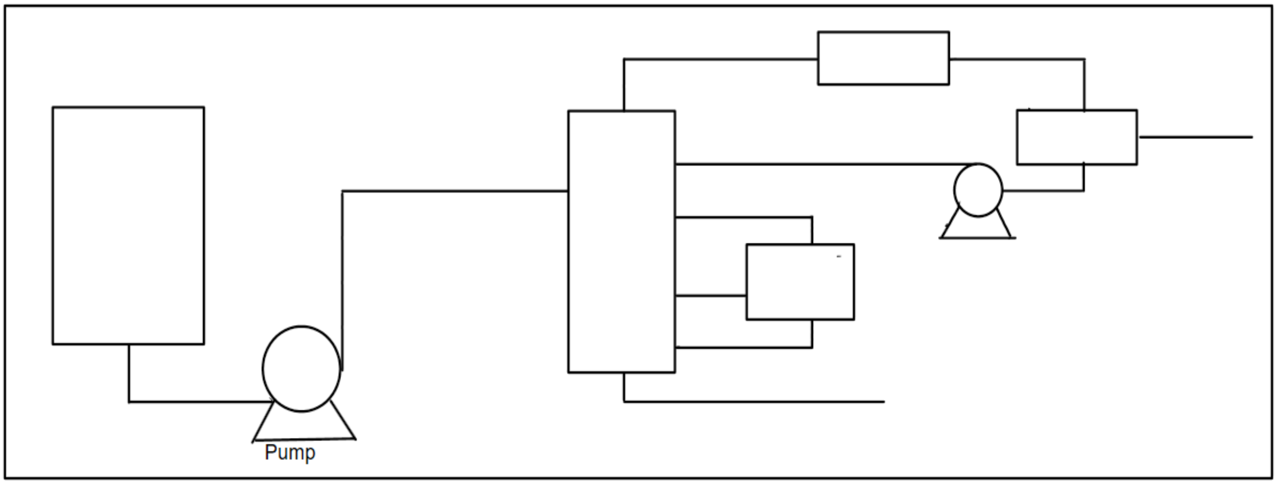
Distillation Unit PFD Design

Distillation column objective: purification of raw product

Distillation column components

- Storage tank: to store the product and prevent any disturbance to distillation column. Remember we had the same design in polishing unit.
- Pumps: we need pumps to transfer mixture between columns.
- Columns: we need columns to do the purification for us.
- Column overhead section: that's where purification happens. The overhead stream is a hot vapor which should be cooled down. Since overhead temperature is not that much high, the design note we talked about in last session could be used. The cooled overhead stream which is now in liquid state should be stored. Based on separator note since it is liquid dominant, we select horizontal configuration. As a basic, we know that we should have a reflux stream to distillation towers. Don't think that everything belonging to overhead section should be in sky! It is not practical in terms of maintenance and construction. It means that they are located on the ground, which also means we need a reflux pump to pump reflux stream to above part of the column.
- Column bottom section: that's where unpurified component dominates. Also, the bottom mixture should go through a reboiler so that the light component can be vaporized and easily goes up. For each reboiler, we need LPS as hot medium. One pipe should be connected from tower to reboiler so that the mixture can enter the reboiler. One pipe is connected from reboiler to tower so that the vaporized light component can come back to the tower and lastly, we need another pipe which connect bottom part of reboiler to tower to send the heavy component back to the tower.

So, the first edition of the PFD becomes like this:



Now let's apply the rule for our plant and improve the process:

1.Storage tank

- Why should I design the storage tank at pressure above 1 barg to increase my cost when there is no need to?
- The mixture comes from higher pressure; so when it comes to a tank with lower pressure, we should expect flashing and vaporization of a part of the mixture. Since the we don't want the mixture to be vaporized specially the light component, then we should take a measure to get the vaporized light component back to the tank. How about directing all vapor to a pipe and wash the vapor with water in countercurrent flow? This is a good idea. Let's improve it now, you know that packings could be used to increase the surface area and as a result, increase heat transfer and mass balance. So we will use it with a packing.

2.Columns

- Since still there are some dissolved gas and some byproducts which we should expect in each reaction, we need a distillation column just to remove these components and make it more pure before the main purification starts. Since we are not going to take out any distillate (product) from this column, then we consider the reflux to be total. For the column since the overhead stream binary mixture analysis is above 65 C, then we are supposed to use an air-cooled heat exchanger. So we use it but the outlet temperature as stated before it is 65C whatever the condition is. Oddly enough, the dew point of methanol is exactly 65C, which means that we don't need a water-cooled heat exchanger anymore to cool-down the temperature to 48C.

We need a horizontal drum to hold-up the mixture, then we a orifice flowmeter and globe control valve to measure and control the reflux flow to column. We also need two reboilers. Based on last session we can use hot Syngas energy to provide the heat to column. But during the start-up we need also heat which cannot be provided by Syngas since we don't have it during start-up. Thus, we have to have a steam-heated reboiler to provide the heat to the column.

So far, we have understood that now the main separation starts here between two-component mixture. When we have two components, based on our experience it is really difficult to have one tower do all separation, we can do it but it is not "relaxed".

For the second tower column since based on the overhead stream binary mixture analysis, the overhead temperature is above 65 C, then we are supposed to use an air-cooled heat exchanger. So we use it but the outlet temperature as stated before it is 65C whatever the condition is. Oddly enough, the dew point of methanol is exactly 65C, which means that we don't need a water-cooled heat exchanger anymore to cool-down the temperature to 48C. Now we need a horizontal drum to hold-up the condensed mixture which is pure. A part of this is refluxed via a pump; now it is clear that we should have orifice flowmeter and globe control valve to measure and control the reflux flow. Now we can send a part of the pure condensed product to storage tanks so that we can later sell it. Since as process engineer, I want to decrease the cost, I create the storage tanks for atmospheric conditions, which means that I need a heat exchanger to cool down the product.

For the bottom part we need 2 reboilers.

For the third tower column since based on the overhead stream binary mixture analysis, the overhead temperature is above 65 C, then we are supposed to use an air-cooled heat exchanger. So we use it but the outlet temperature as stated before it is 65C whatever the condition is. Oddly enough, the dew point of methanol is exactly 65C, which means that we don't need a water-cooled heat exchanger anymore to cool-down the temperature to 48C. Now we need a horizontal drum to hold-up the condensed mixture which is pure. A part of this is refluxed via a pump; now it is clear that we should have orifice flowmeter and globe control valve to measure and control the reflux flow. Now we can send a part of the pure condensed product to storage tanks so that we can later sell it. Since as process engineer, I want to decrease the cost, I create the storage tanks for atmospheric conditions, which means that I need a heat exchanger to cool down the product.

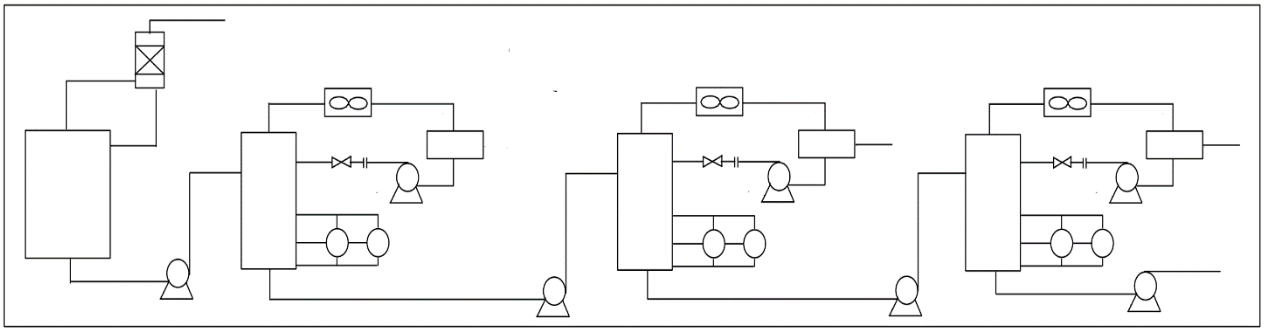
For the bottom part we need 2 reboilers.

3.Pumps

Here is the list of locations we need pump.

1. For transfer from crude storage tank to first tower
2. For transfer from first tower to second tower
3. For transfer from second tower to third tower.
4. For all reflux streams
5. For bottom parts of third tower
6. For transfer of pure product from storage tank

If we incorporate all above parameter into our design, then the following would be the result:

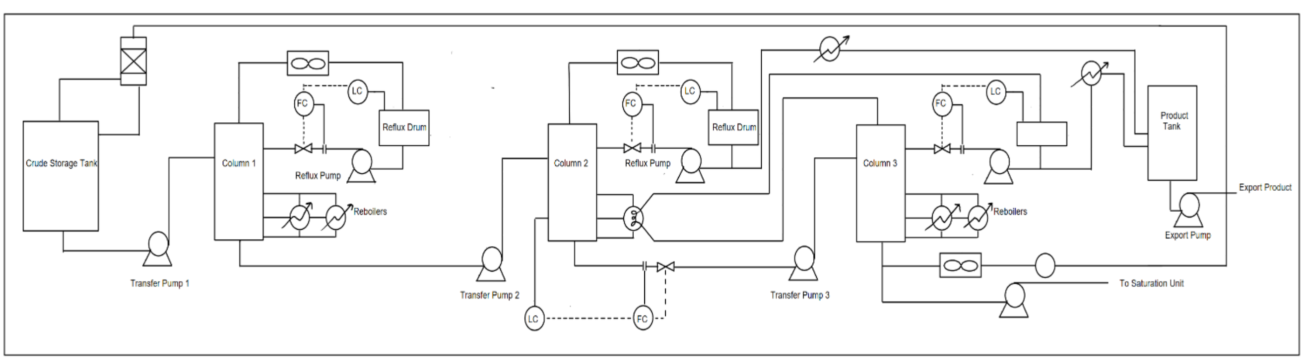


Now let’s finalize our PFD and make last improvement in basic design:

1.Mass balance —— Since the bottom of third tower is mainly water then we can use it as washing water for packed column which is used above crude storage tank. The bottom product temperature is more than 65C, so we can use an air-cooled heat exchanger first and then a water-cooled heat exchanger to reduce its temperature.

2.Heat exchanger network design —— By checking Aspen Hysys report, we find out the duty of second tower reboiler is the same as the duty of third tower condenser. It means that we can use the energy of third tower condenser to maintain the duty of second tower reboiler duty.

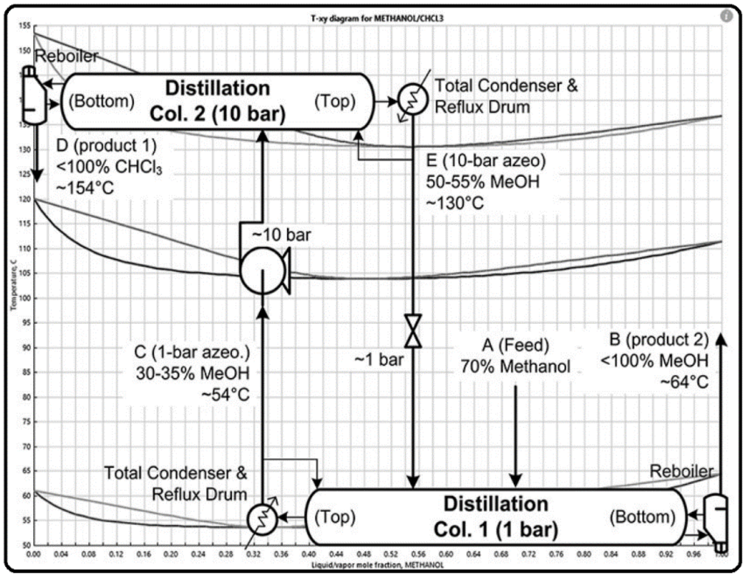
3.Simple control loop —— For distillation column it is a normal practice to consider cascade control loop for both reflux drum and bottom of the towers. The reason why we use cascade control loop is that we want two parameters namely level of drum and flow of the reflux to be controlled at the same time.



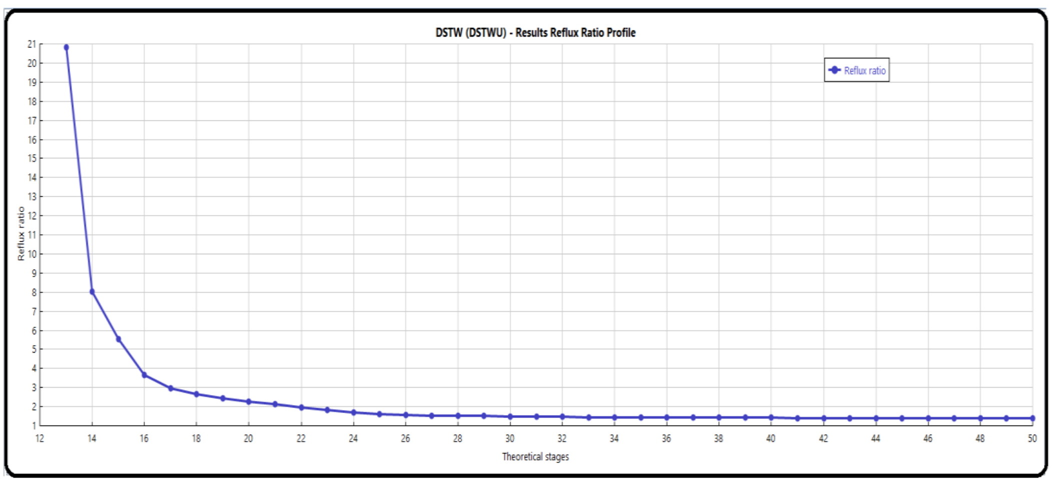
Appendix A

Tower design procedure

1.Use binary mixture analysis in Aspen Plus or Hysys to propose a distillation unit



2.Simulate the distillation column in Aspen Plus or Hysys to calculate the number of trays in a way that results meet the specification.



3.Report tray load using Aspen Plus or Hysys

Maximum Load in different Zones

Vapor Load in Zone 1

Performance point	Design
Temperature	102
Gas flow	440752
Gas density	4,07
Gas viscosity	0,012
Gas molecular weight	32,04

Vapor Load in Zone 2

Performance point	Design
Temperature	109
Gas flow	422422
Gas density	4,23
Gas viscosity	0,013
Gas molecular weight	30,52

Vapor Load in Zone 3

Performance point	Design
Temperature	116
Gas flow	402338
Gas density	4,3
Gas viscosity	0,013
Gas molecular weight	29,70

Liquid Load in Zone 1

Performance point	Design
Temperature	104
Liquid flow	359831
Liquid density	709
Liquid viscosity	0,225
Liquid surface tension	15

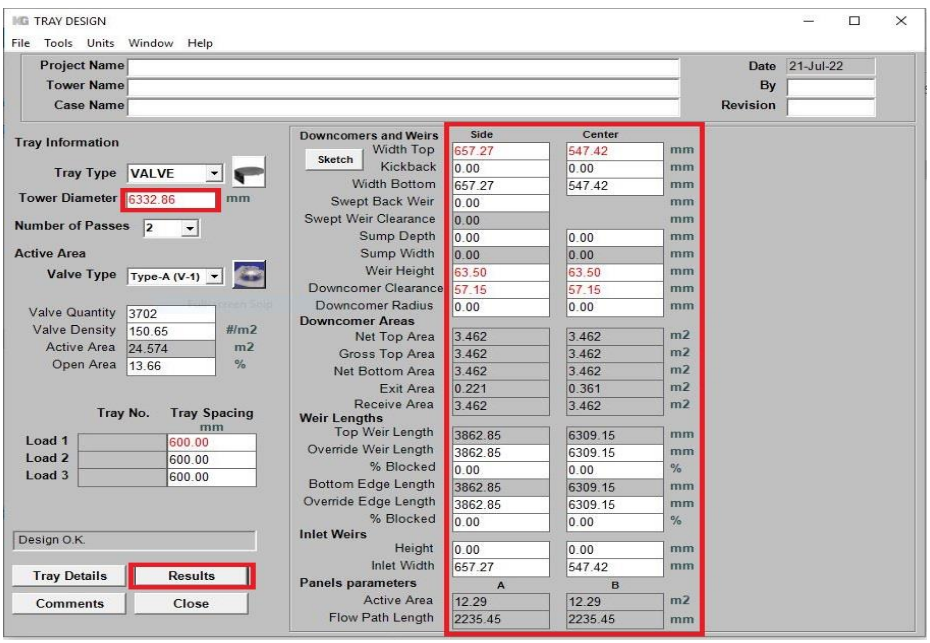
Liquid Load in Zone 2

Performance point	Design
Temperature	111
Liquid flow	460397
Liquid density	727
Liquid viscosity	0,221
Liquid surface tension	17

Liquid Load in Zone 3

Performance point	Design
Temperature	116
Liquid flow	406821
Liquid density	751
Liquid viscosity	0,221
Liquid surface tension	20

4.Use Aspen Plus or Hysys for estimation of ID and height of the columns.
5.Use Excel sheet to estimate diameter and height-optional
6.Use vendor or specialized software to verify and finalized your calculations concerning diameter and height of the column.



Appendix B

Reboiler