Process Plant Design

Session 2

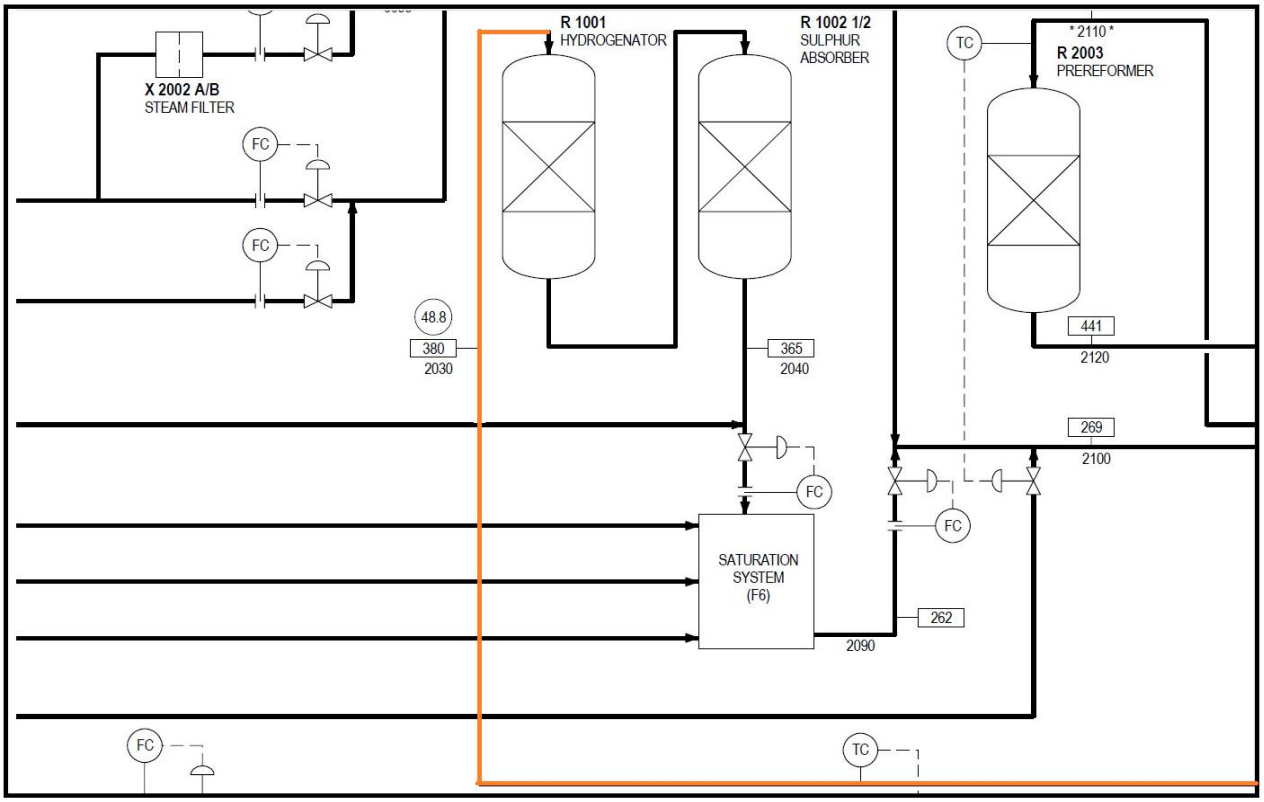
Imagine you are working in an international project in Saudi Arabia and the project is the design and construction of Ammonia plant. You work as a junior process engineer and your supervisor has asked you to perform the line sizing for two parts of the plant and validate licensor basic design.

Practice 1:

Determine the size of the pipe connected to hydrodesulfurization reactors.

Note: In most petrochemical plants, ammonia included, the first process unit is desulfurization unit in which sulfur is removed by means of desulfurization reactors. Simply the sulfur is absorbed by catalysts inside the reactors. If we don't remove sulfur, it poisons the downstream catalysts.

Here is the PFD of the part:



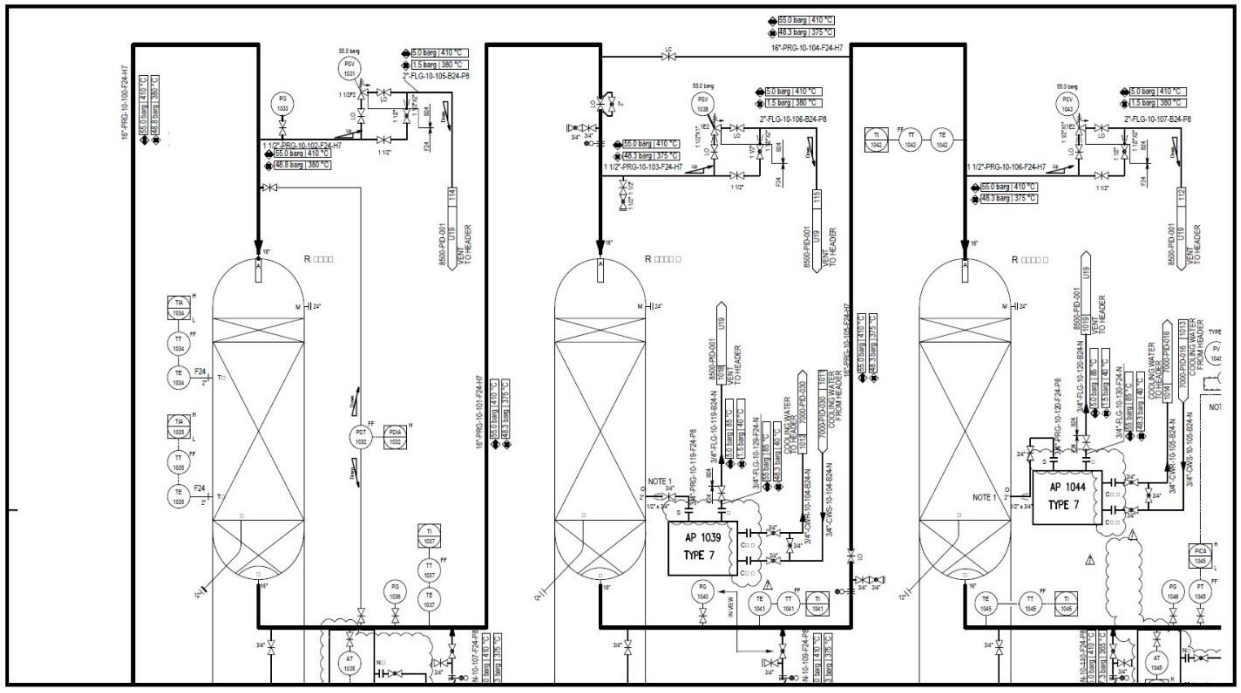
And here is the stream table from which you can extract the info required for the line sizing excel sheet.

Stream no. 2030						
Total Stream						
	Temperature	380	°C	Pressure	47,6	bar g
	Mass flow	123295	kg/h	Molar flow	7467	kmol/h
	Vapor fraction (mass basis)	100	%	Phase type	Vapor	
	Molecular weight	16,51	kg/kmol	Enthalpy	-99,88	Gcal/h
	Lower heating value	33876	kJ/Nm³	Higher heating value	37588	kJ/Nm³
Vapor Phase						
	Mass flow	123295	kg/h	Molar flow	7467	kmol/h
	Normal volume flow	167362	Nm³/h	Molecular weight	16,51	kg/kmol
	Density	14,7	kg/m³	Viscosity	0,021	cP
	Specific Enthalpy	-810	kcal/kg	Specific gravity air	0,5700	1/1 (Dimless)
	Thermal conductivity	0,083	kcal/m/h/°C	Specific heat capacity	0,785	kcal/kg/°C
	Heat capacity ratio	1,1827	1/1 (Dimless)	Compressibility	1,0077	1/1 (Dimless)

Total Stream Composition

	Component Name and HTAS No.		wt %	kg/h	Mole %	kmol/h
	Argon	7	0,01	13	43 ppm	0
	Byproducts	-1	17 ppmw	2	5.4 ppm	0
	C2+	-1	1,38	1700	0,65	49
	Carbon Dioxide	6	1,15	1413	0,43	32
	Carbon Monoxide	5	0,13	158	0,08	6
	Higher Alcohols	-1	0.1 ppmw	0	0.033 ppm	0
	Hydrogen	1	0,25	304	2,02	151
	Methane	8	90,02	110994	92,66	6919
	Methanol	65	0,03	41	0,02	1
	Nitrogen	3	7,03	8664	4,14	309
	Water	2	45 ppmw	6	42 ppm	0

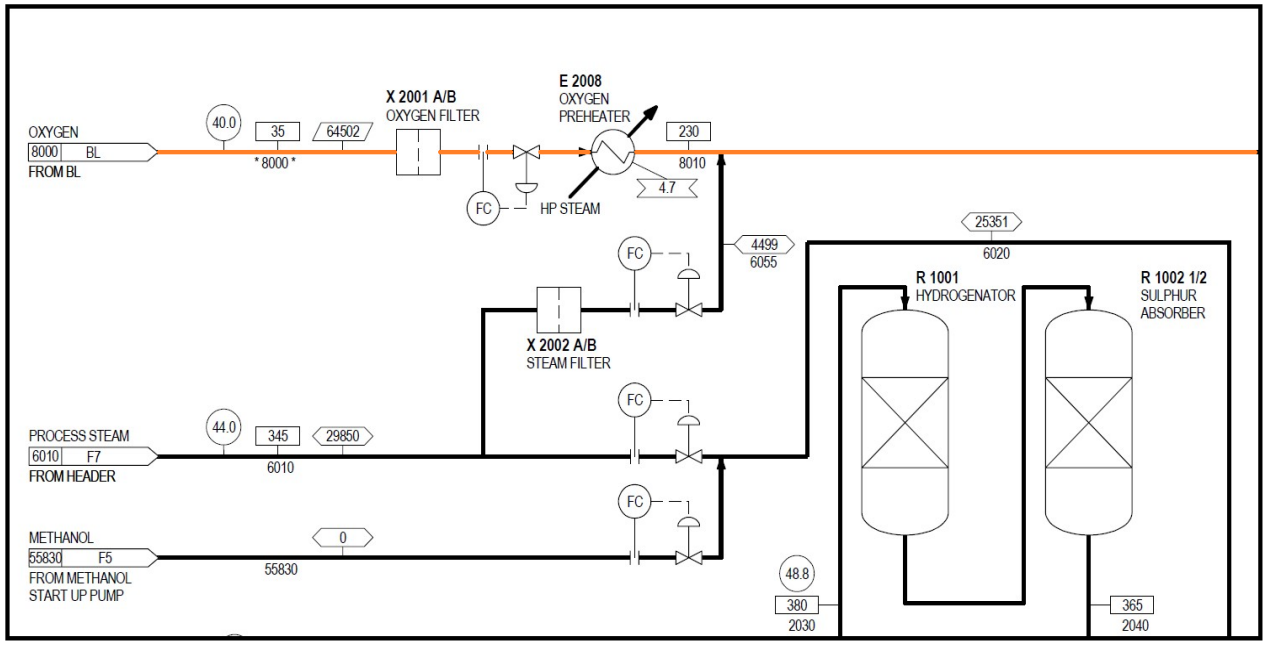
Here is the final solution: 16”



Practice 2

In methanol plants, oxygen is a valuable feedstock, which reacts with methane in an Auto Thermal Reactor or simply ATR to produce syngas which contains hydrogen, CO, CO_2.

The oxygen before entering the reactor, should be filtered and preheated to be suitable for the reaction. Here is the PFD for that part:



Here is the stream table for the stream:

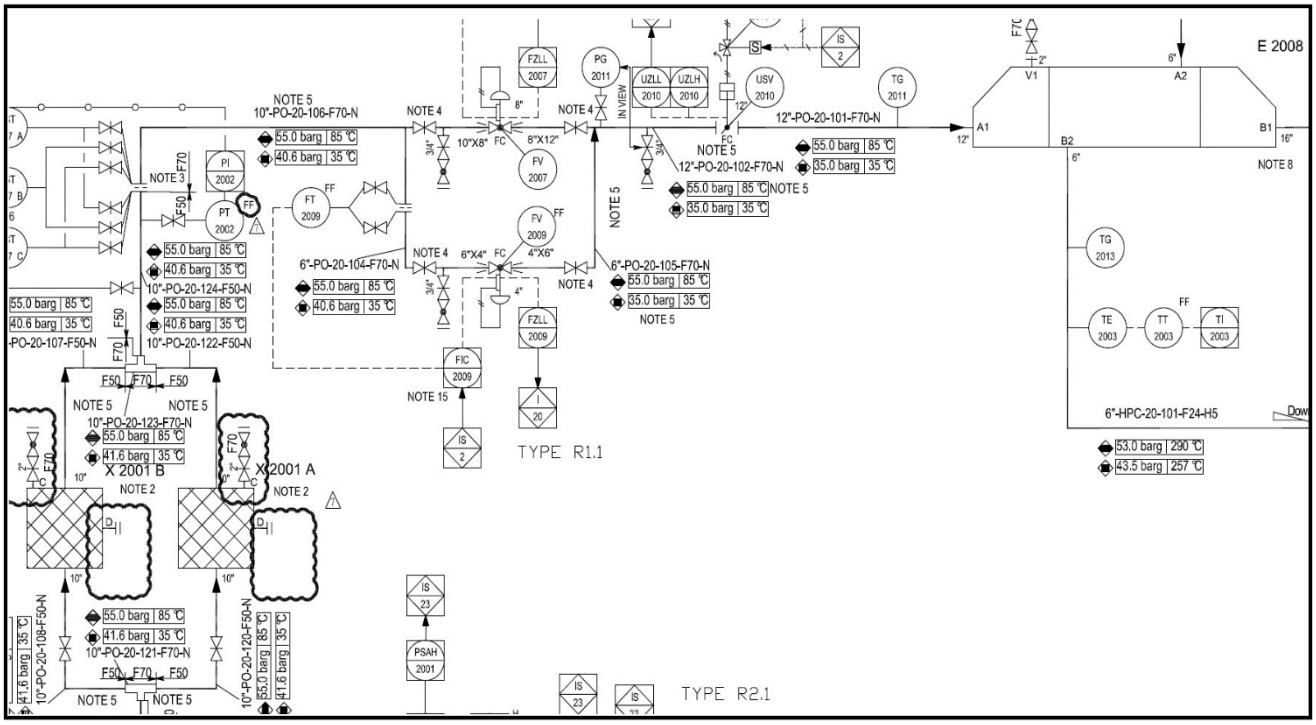
Stream no. 8000						
Total Stream						
	Temperature	35	°C	Pressure	40	bar g
	Mass flow	82734	kg/h	Molar flow	2584	kmol/h
	Vapor fraction (mass basis)	100	%	Phase type	Vapor	
	Molecular weight	32,01	kg/kmol	Enthalpy	0,18	Gcal/h
	Lower heating value	0	kJ/Nm³	Higher heating value	0	kJ/Nm³
Vapor Phase						
	Mass flow	82734	kg/h	Molar flow	2584	kmol/h
	Normal volume flow	57925	Nm³/h	Molecular weight	32,01	kg/kmol
	Density	52,5	kg/m³	Viscosity	0,022	cP
	Specific Enthalpy	2	kcal/kg	Specific gravity air	1,1052	1/1 (Dimless)
	Thermal conductivity	0,024	kcal/m/h/°C	Specific heat capacity	0,216	kcal/kg/°C
	Heat capacity ratio	1,3888	1/1 (Dimless)	Compressibility	0,9764	1/1 (Dimless)

Total Stream Composition					
	Component Name and HTAS No.	**wt %**	**kg/h**	**Mole %**	**kmol/h**
	Argon 7	0,24	201	0,19	5
	Nitrogen 3	44 ppmw	4	50 ppm	0
	Oxygen 0	99,75	82529	99,80	2579

Practice 3:

For oxygen application, determine the design temperature and pressure.

Here is the answer to practice 2 and practice 3:



The size of the line is 10” and design temperature and pressure are 85C and 55 barg, respectively.

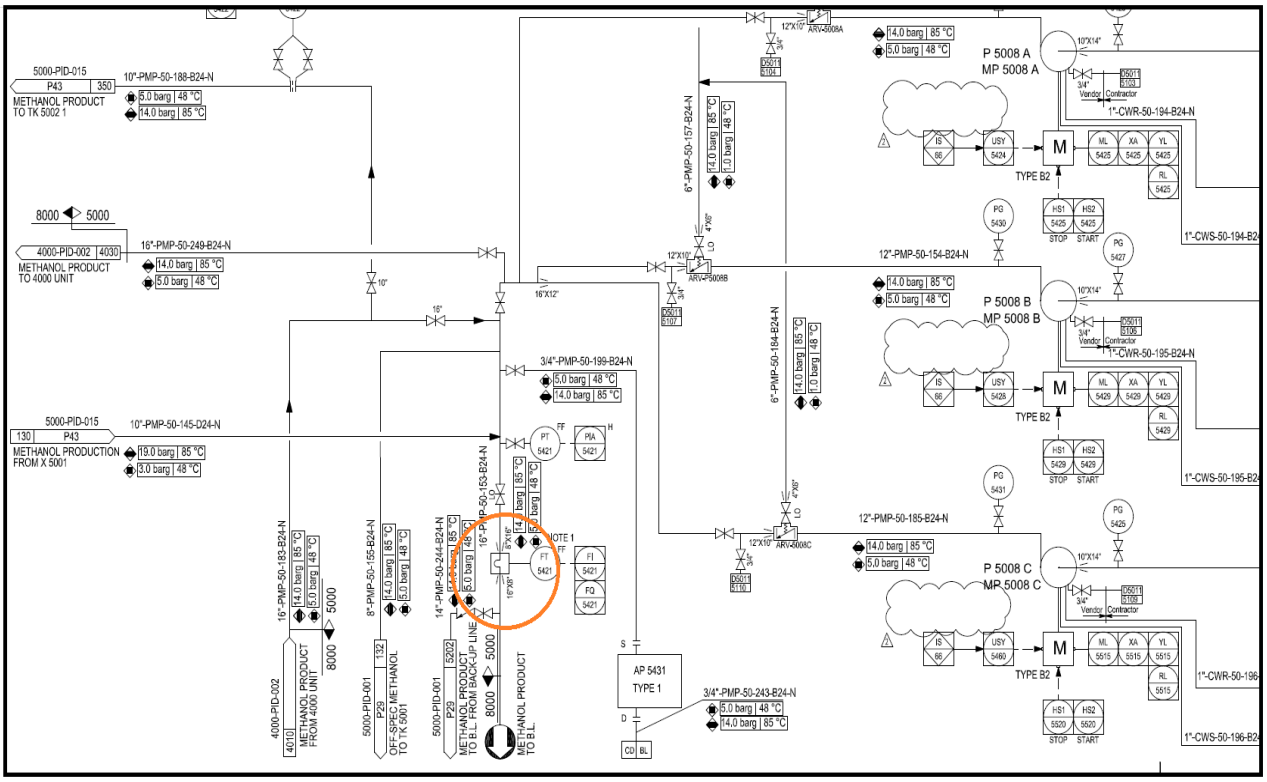
Do you know why just before the shell and tube heat exchanger the pipe expanded to 12 inches? Think about that.

Practice 4: Based on Process Design Example we gave you in the zip, determine the best type of flowmeter for this application.

Since we want to control flow of the oxygen, we need orifice flowmeter.

Application	Flowmeter Type
Gas station	Ultrasonic
Fuel system	Ultrasonic-Turbine-Vortex
Fluid with high amount of conductivity	Magnetic
Fluids with conductivity less than 5 us/m	Vortex
Low pressure gases	Venturi
High pressure steam services	Flow nozzle
High erosion present	Flow nozzle
Battery limit-Product	Coriolis
Process unit where controlling parameters is a high priority	Orifice

Practice 5: Based on the P&ID explain why Coriolis flowmeter is selected?



Since the flowmeter is used for product, we then use Coriolis flowmeter.

Practice 6: Select a flowmeter for cooling water application and oily water and DMW.

Since the cooling water and oily water conductivity is more than 5, then we use magnetic flowmeter.

For Demineralized Water since the conductivity is less than 5, then we can use vortex flowmeter.

Practice 7: Specify a flowmeter type for a steam with operating temperature of 330 C and pressure of 100 barg.

Based on Process Design Example, for steams it is normal practice to use nozzle flowmeters.

Summarization

Application	Flowmeter
Cooling Water	Magnetic
DMW	Vortex
Oily Water	Magnetic
Steam	Nozzle Flowmeter
Oxygen	Orifice *Controlling
Distillation Column	Orifice
Methanol	Coriolis

Practice 8: Based on Process Design Example we gave you in the zip, determine the best type of control valve for this application. (Oxygen Service)

Criteria for Valve Selection:

1. When the pressure drop is very high or there is the risk of accumulation of solids, or the fluid velocity is extreme an angle valve is used.

   Just remember using angle type poses some ramifications.

   2. Characterized ball valve is used when the fluid tends to crystallize or where a high Cv is required. Should they be used for as tight shut-off valve, the maximum pipe sizing should be 4 inch.

   3. Butterfly valves are used for services with large flow rate and low pressure drop (less than 5 bar). They can be used as tight shut-off valve when the pipe diameter is more than 4 inch. High duty butterfly or triple offset butterfly are commonly used types.

   Notice that single seated, unbalanced, line sized and full-sized trim globe valve as shut-down valve can be used if desired.

   4. Single-seated globe valves is the standard type in sizes bellow 8 inch in non-severe services where the shutoff pressure and pressure drop can be handled. Cage guided globe valve shall be used for more rough services, balanced trim can be used for bigger sizes.

Condition / Valve Type	ΔP very high	Solid	V Very high	Cv high	Crystallization	Large flow with low ΔP	Tight shutoff Up to 4 inch	Tight shutoff Above 4 inch	Standrad
Globe									×
Angle	×	×	×						
Butterfly						×		×	
Ball				×	×		×		

Since ΔP is not high, there is no solid, Velocity is not very high, there is no crystallization, the flow is not that much high, it is not used for shut-off services, then we use globe valve.

Practice 9: Select a proper valve type for a fluid with the inlet pressure of 42 barg and outlet pressure is of barg.

Since the pressure drop is high and we have flashing, then we select angle type.

Valve characteristics

A unique and simple procedure for valve characteristic determination for almost all Chemical Plants.

1. Use Equal Percentage if the valve functions as FV or TV

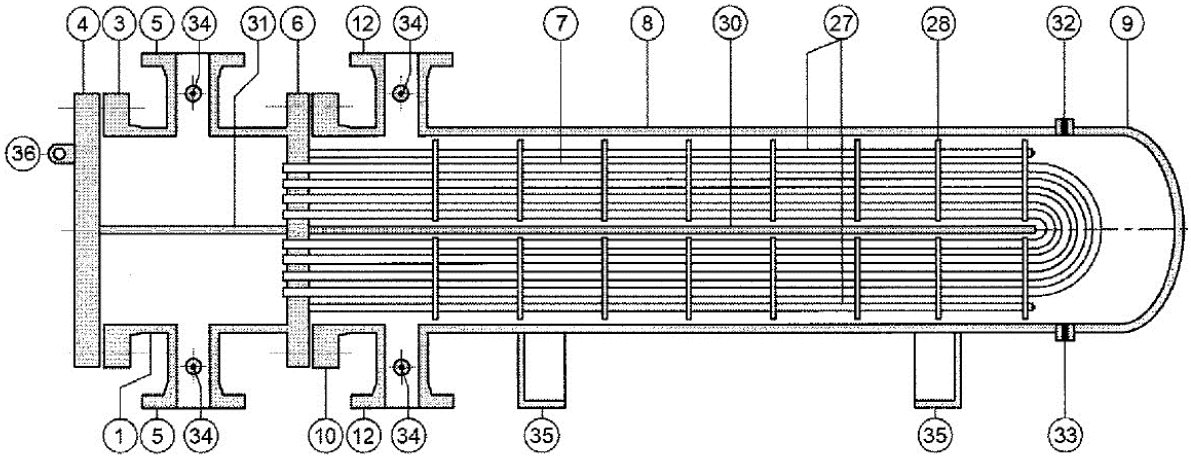
2. Use Linear if the valve functions as PV or LV

3. Use Linear if there is Split Range Control

Note: Due to process demands, above rules might not apply to some situations.

Pictures

Heat Exchanger



Control Valve