Judgement Day!

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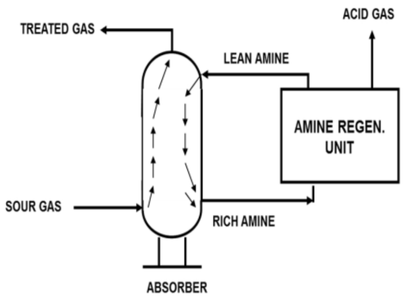
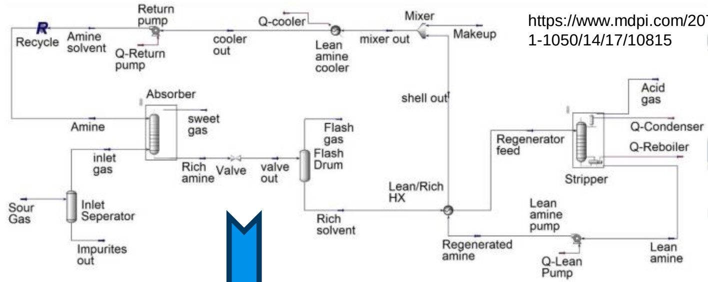
Evolution of PID

Process Development: e.g. I need to remove H_2S; amine unit can do the job

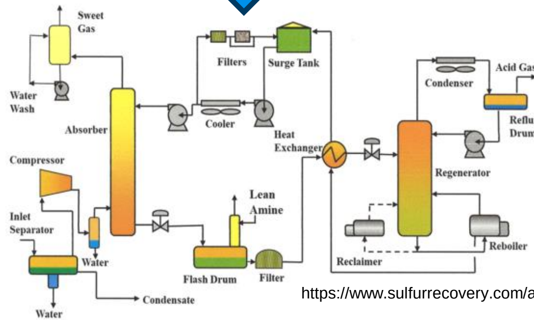


https://howebaker.com/amine-gas-sweetening-systems/

Process Design and Simulation: E.g. we will set amine circulation rate not to exceed rich loading of 0.33 mol/mol



https://www.mdpi.com/2071-1050/14/17/10815



https://www.sulfurrecovery.com/amine-the-process

PFD:

- Simulation flow diagram +
- Heat Integration +
- Major Process performance Controls +
- Equipment types e.g. kettle reboiler +
- Other support systems e.g. amine surge vessel, filters +
- Utilities decision e.g. hot oil or steam for reboiler
- Integration with rest of the plant / utilities e.g. amine regeneration vent to flare or SRU or Incinerator

Piping and Instrumentation Diagram:

- PFD + PSFD + MSD +
- Philosophies +
- Typical Assemblies +
- Pressure / elevation profile + Hydraulics +
- Vendor package +
- Symbols / numbering philosophy +
- PID Layout +
- Start-up / shutdown considerations+
- Judgement

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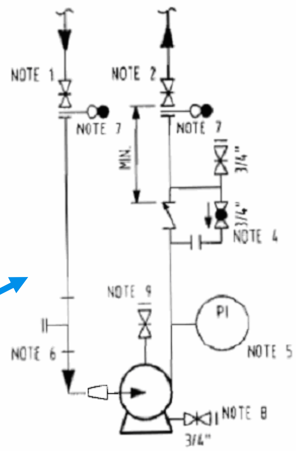
How to Develop PIDs?

- Plan PIDs from PFD
  - Usually one equipment per PID
  - Define line / instrument numbers / connectivity
- Get MSD from Metallurgy team
- Prepare PSFD
  - Add safety elements (e.g. PSV, shutdown valves) and their assemblies
  - Decide design pressure and temperature breaks
- Get pipe specs for different services from Piping
  - Line size, DP, DT, MOC, corrosion allowance, impurities (CO_2, BTEX, H_2S, SO_x, NO_x, Methanol, Ethylene Glycol, Mercaptans, COS)
- Depict typical assemblies around that equipment
  - E.g. pump, control valve, exchanger, vessel, tank etc
- Update assemblies as per isolation, vent/drain philosophies
- Decide pressure / elevation profile of the plant
- Decide line sizes and indicate line number with pipe spec
- Imagine yourself as an operator and:
  - You are asked to enter a vessel
  - One of the item develops a problem and needs to be taken for maintenance
  - Equipment / Instrument has failed and pressure / flow / level / temperature is increasing



P&IDs: Do's and Don'ts in Initial Revision

Do's

- Fix the skeleton of the plant
- Clear Hardware focus
- Focus on
  - Elevation profile
  - Pressure profile
  - Isolation philosophy
  - Big bore line size check verification
  - Changes in #rating / MOC / corrosion allowance
  - Appropriate HOLDs
  - Vendor scope item identification
- Check impact of datasheet notes

Don'ts

- Crowd P&IDs by small bore items details e.g. Control valve / LT vents to flare
- Fret about P&ID title block information consistency
- Add "Essay" notes
- Add notes / drawing that can be covered in legend typical
- Add too many control signal, Cause and Effect related notes
- Spectacle blind positions

- Small bore lines + Instrument hardware → in 2nd revision
- Control / Cause and Effect → in 3rd revision

Line Size Traps

- PSV inlet and outlet
  - For low set pressure PSVs, inlet line size may be larger than PSV outlet (allowed 3% line loss in inlet and 10-80% for outlet)
  - Refinery fractionators / condensate stabilizers overhead vapour line HOLD not to be removed till PSVs are finalized (large load, low set pressure)
  - High set pressure PSVs → outlet line size can be more than 2 sizes than PSV outlet flange
  - Flare headers shall not have size less than 2” connected to it
- Liquid / gas lines
  - Velocity and DP/100 criteria in guidelines is economic criteria and not performance
  - Lines are not sized merely on velocity criteria, pump / compressor / gravity flow / self-venting flow / slope etc criteria governs
  - For reasonable velocity close to optimum limit, pump / compressor is not usually dictated by friction head
  - For large bore piping, fittings dominate pressure drop. For small bore piping, straight length contributes the most to pressure drop
- Two-phase flow
  - Very rarely slug flow gets avoided by line size change
  - Barring thermosiphon reboilers / condenser outlet / amine flash drum outlet / heavy oil CPF etc, two-phase lines are not pressure drop constrained within process plant piping
  - GPSA superficial velocity charts for quick analysis of flow regime

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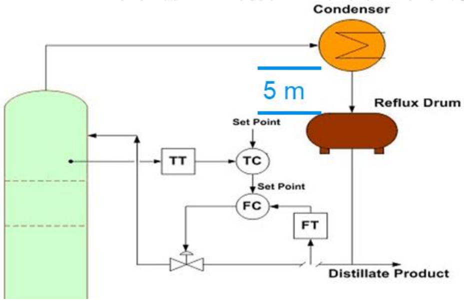
Self-Venting Flow

- Depropanizer air cooled condenser to reflux drum line
  - Elevation difference between condenser and drum = 5 m
  - Equivalent length = 50 m / 10”
- Let us estimate driving force / resistance
  - Driving force = 5 m x 439.7 kg/m3 x 9.81 x 1E-5 = 0.22 bar
  - Pressure drop = 0.0083 bar
- For steady state, driving force = pressure drop
- What will happen here?



Phase		Liquid
Pressure	bara	19.4
Temperature	Deg C	55.9
Mass flowrate	kg/hr	89904.9
Volume flowrate	m3/hr	204.5
Density	kg/m3	439.7
Viscosity	cP	0.068

Velocity Calcs		
Volume flow	204.50	m3/hr
Line size	250	mm
Pipe CS area	4.91E-02	m2
Velocity	1.16	m/s
Pressure drop calcs		
Viscosity	0.07	cP
Length	13.50	m
Elbows	4.00	
Gate valves	2.00	
Reducer	0.00	
Lequivalent	50.00	m
Reynolds number	1870476.11	
Friction factor	0.0035	
Pressure drop	833.33	N/m2
Pressure drop	0.0083	bar

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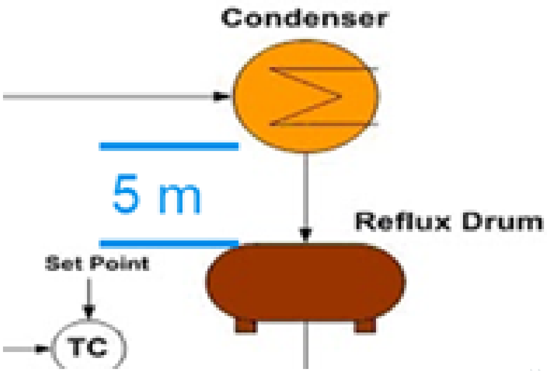
Self-Venting Flow

- Liquid flowrate increases to have pressure drop same as driving force
  - Approximately 1100 m3/hr @ 6.2 m/s velocity
  - This is not acceptable
- Check line size
  - 10” line size @ 1.2 m/s = 0.008 bar → low resistance
  - 6” line size @ 3.2 m/s = 0.083 bar → low resistance
  - 4” line size @ 7.2 m/s = 0.53 bar → too high resistance
- Line size can not be varied to have driving force and resistance equal
- What will happen if we persist with 10” or 6” line size
  - Liquid out flowrate would be higher than inflow to pipe
  - This gushing out of liquid will lead to entrainment of vapour

Self-Venting Flow

- Two possibilities
  - Vapour is entrained all the way to reflux drum
  - Vapour due to its lower density is entrained to certain distance and then flows up to condenser

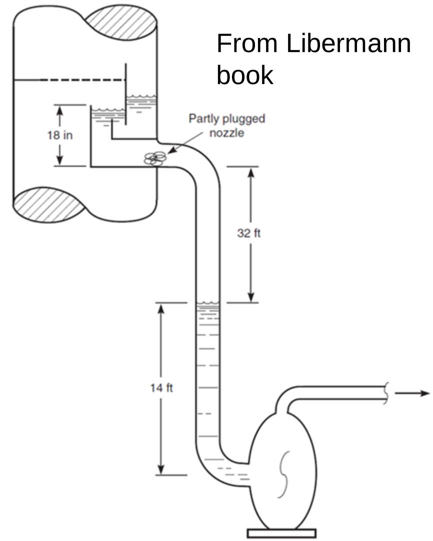


- Vapour entrained all the way to reflux drum
  - Our problem is liquid static head driving force is much more than pressure drop
  - Vapour density = 46 kg/m3; liquid density = 439 kg/m3
  - Vapour entrainment leads to two-phase flow in pipe
  - Two-phase density lower than liquid → driving force (h*rho*g) would be lower and pressure drop higher in two-phase flow
  - Vapour entrains till decreased driving force equals increased pressure drop
  - Vapour entrainment is not desired

Self-Venting Flow

- Vapour entrains till mid-way and flows up giving clear liquid height for rest of the path
  - i.e. vapour + liquid for 2.5 m and clear liquid for rest 2.5 m
  - This is called self-venting flow
  - Line needs to be sized for self-venting flow
  - Self venting flow is achieved if Froude Number (Fr) < 0.3

$$Fr\# = \frac{Inertial\ Forces}{Gravity\ Foreces} = \frac{v}{\sqrt{gD}}$$



From Libermann book

Inputs		
Flowrate	204.9	m3/hr
Pipe diameter	10	in
Calculations		
Pipe diameter	0.25	m
Pipe area	0.05	m2
Velocity	1.12	m/s
Froude number	0.71	
Line size self-venting	NO	

Depropanizer Condenser Outlet Line

- Driving force = 0.22 bar
- Pressure drop of liquid full lines
  - 10” line = 0.0083 bar
  - 6” line = 0.083 bar
  - 4” line = 0.53 bar
- Froude number for 10” line = 0.71
- Problem with 10” line
  - Driving force >> resistance → pipe will not run flooded
  - Fr > 0.3 → pipe not self-venting
  - 10” line will lead to vapour entrainment and pulsating flow
- Solutions
  - Increase line size to self-venting flow
  - Talk to piping, change elevation difference between condenser / reflux drum and decrease line size

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Vendor Packages - 1

- Two types of vendor packages
  - OEMs
  - Aggregators
- OEMs --> know their subject matter and read documents thoroughly but do not venture outside their area
- Aggregators --> fabricators / small EPCs who have developed experience due to past records

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Vendor Packages - 2

- E.g. Sour Water stripper package
  - SWS column, reboiler / condenser or stripping gas
  - Stripped water pump
  - Stripped water Air cooler
  - Stripped water storage tank
- Mostly will go to Aggregator
- Notes in package datasheets:
  - "Vendor shall review use of alternate stripping methods like fuel gas or air" → unlikely to be resolved
  - You keep HOLD in fuel gas documents for stripping option and hot oil documents for reboiler option
- Layout challenges e.g. storage tank / air cooler

Vendor Packages - 3

- Packages which do not work
  - Hot oil system
  - Condensate stabilization
  - Multi-stage Compressor with interstage cooling / KODs
  - Molecular sieve packages
  - SWS
- Packages which work
  - Self-contained refrigeration package
  - Amine Acid gas removal / SRU
  - Glycol dehydration
  - Desalter
  - Produced water treatment

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