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Drums

Objectives

- Identify Differences Between Drums And Tanks
- Process Overview Of Drum Uses
- Mechanical Overview Of Drum Design

Pressure Vessel Vs Tank

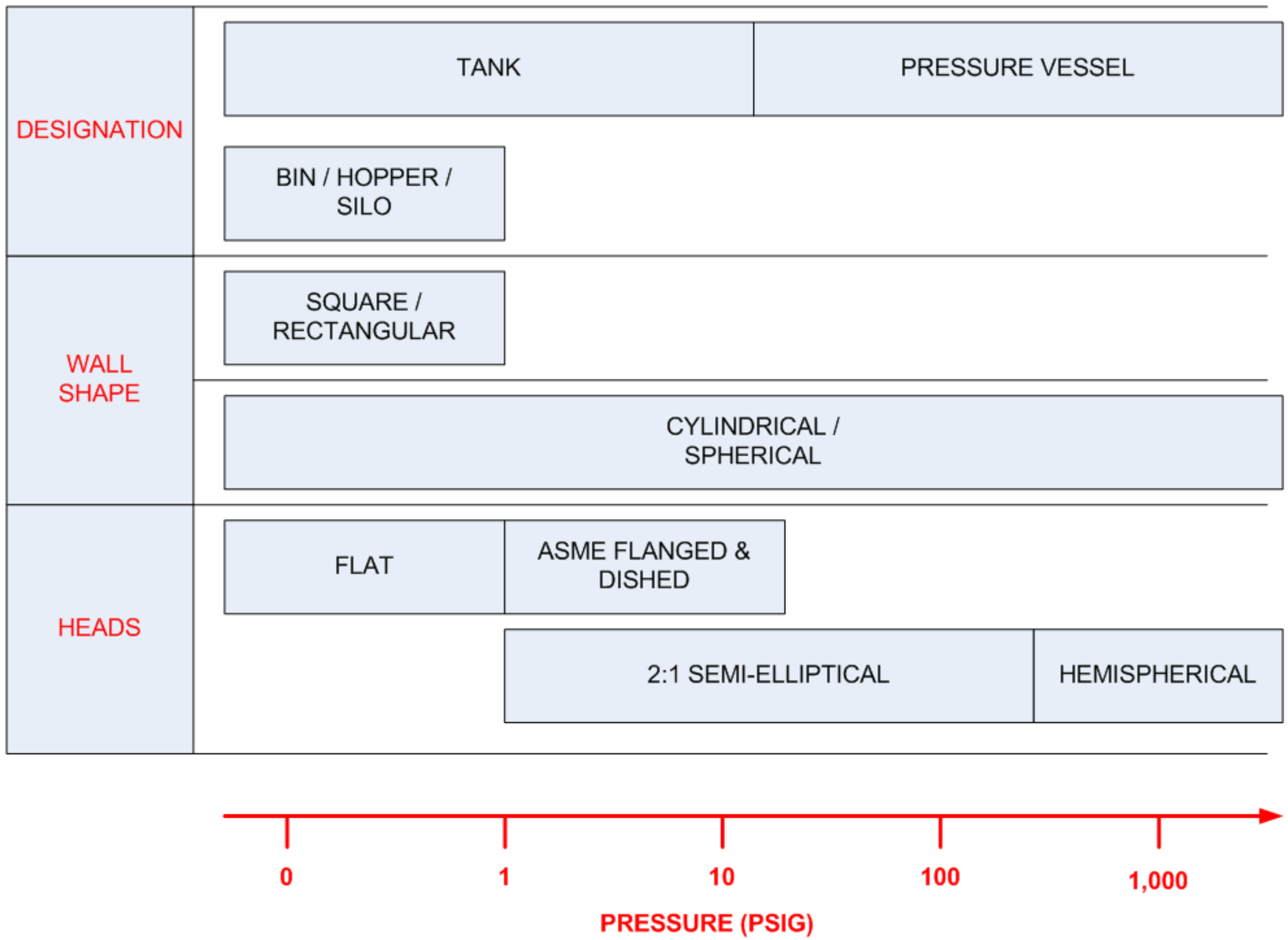
What Is A Pressure Vessel?

- Designed To Contain Or Hold A Fluid
- Capable Of Withstanding Internal Pressure At Least 15 psi Above Atmospheric Pressure
- Cylindrical Section With Shaped Ends
- Fabricated of Metal Typically But Plastics Can Be Used
- Design and Construction Per Legal Code (ASME Section VIII)
- Protected From Overpressure By Pressure Relief Device (Relief Valve or Rupture Disk)

Pressure Vessel Vs Tank

Design Criteria	Pressure Vessel	Tank
Pressure	15 psig & Greater	Less Than 15 psig
Temperature	Limited By Selected Materials	Preferably 200 °F Maximum
Capacity (Cost per Unit Volume)	Medium To High	Low
Design Standards	ASME Division VIII	API 650 (Up to 2.5 psig) API 620 (Up to 15 psig)
Pressure Safety	API 520	API 2000

Pressure Vs Design Options



Process Overview

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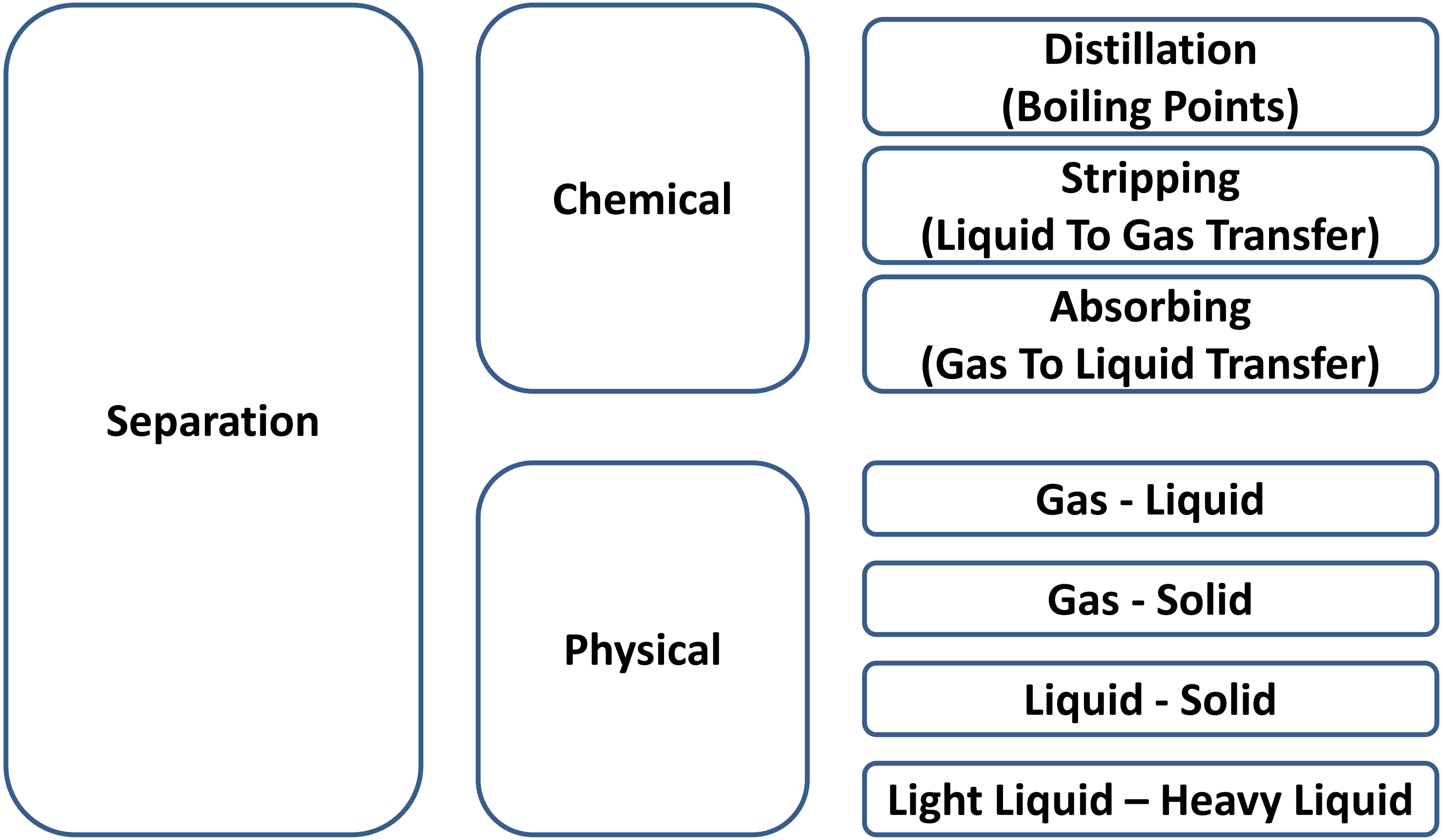
Process Applications

Accumulation	Surge	Feed
		Reflux
	Storage	Holding
		Storage
Mixing	Homogeneity	Dispersion
		Diffusion
	Suspension	Liquid - Liquid
		Liquid - Solid
Reaction	Static	Fixed Bed
		Plug Flow
	Dynamic	Fluid Bed
		Stirred

Process Applications



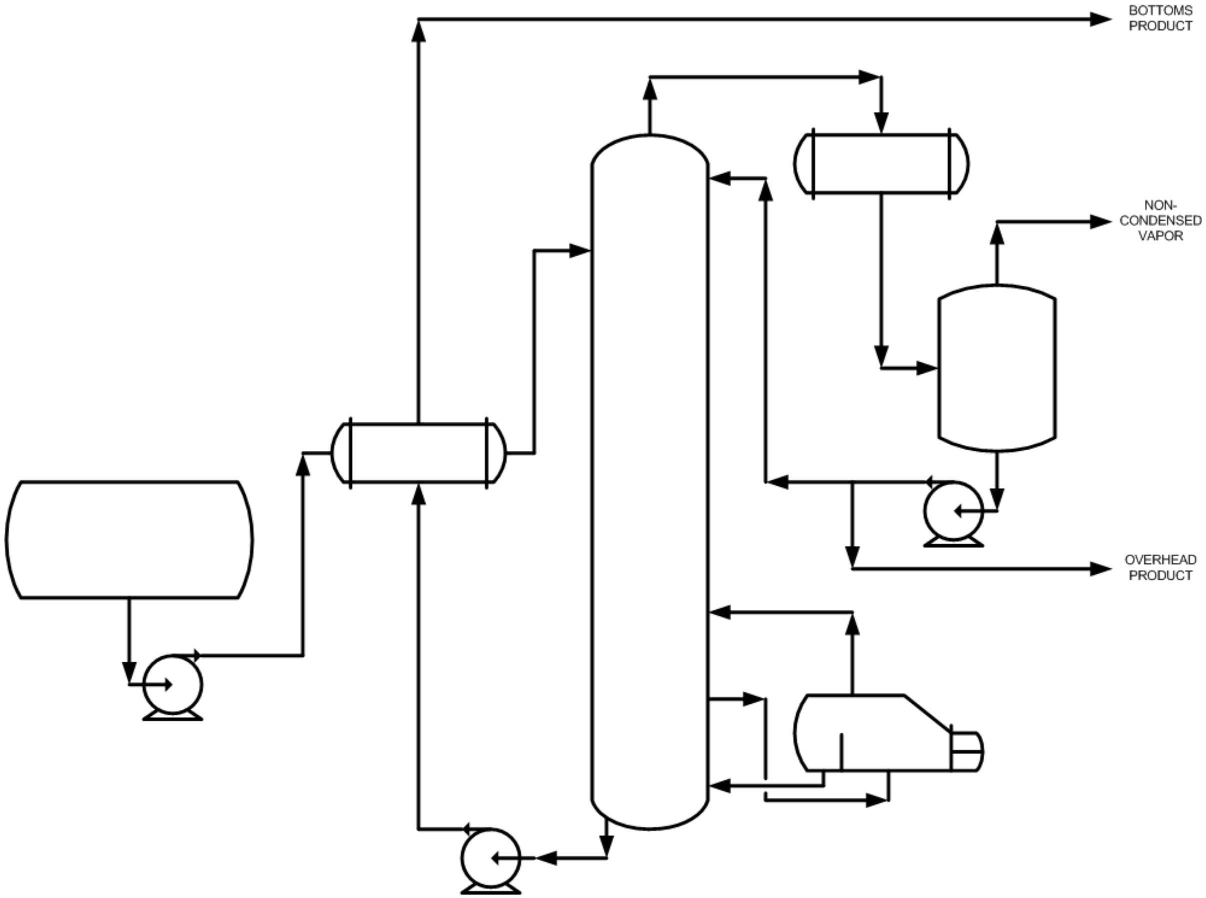
Process Uses For Pressure Vessels

Service	Equipment Type
Accumulation Or Mixing Of Materials	Accumulator Drum
Reaction Chamber For Chemical Change Of Materials	Reactor
Separation By Chemical Means	Column Tower
Separation By Physical Means	Filter Separator

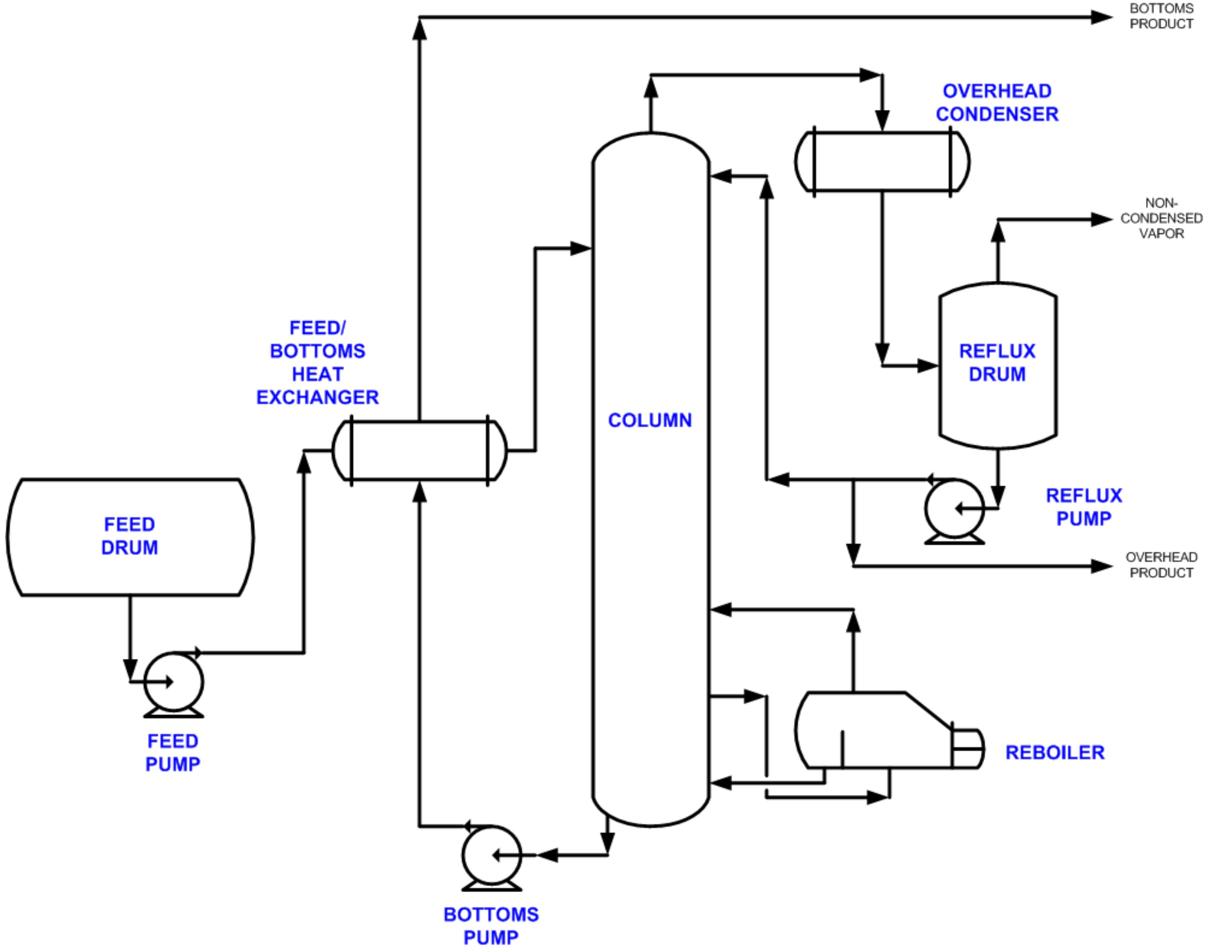
Orientation

VERTICAL	HORIZONTAL
Columns	Liquid – Liquid Separators
Vapor – Liquid Separators	Pressurized Storage
Vessels With Mechanical Agitation	Plug Flow Reactors
Fixed Bed Reactors	

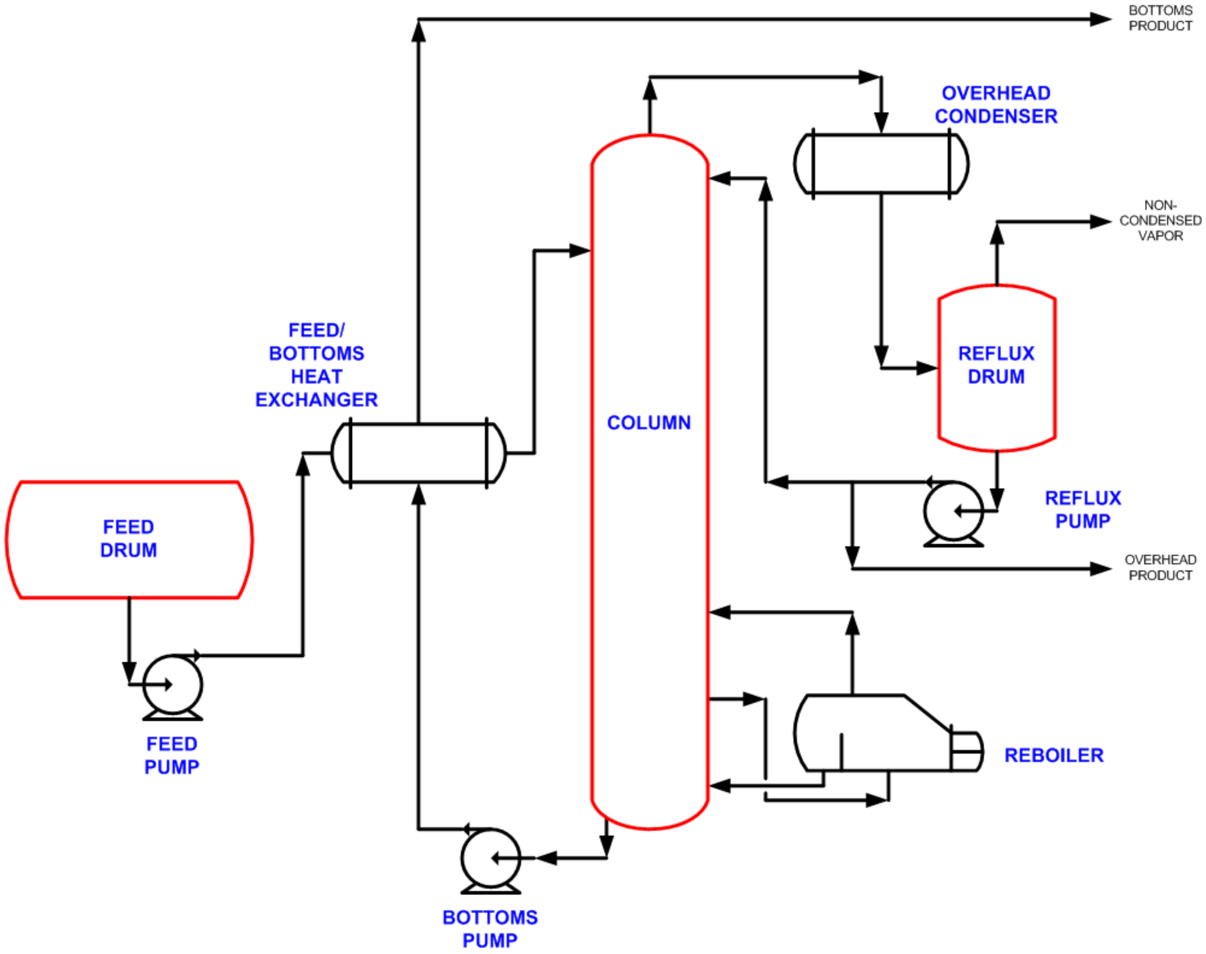
Distillation System



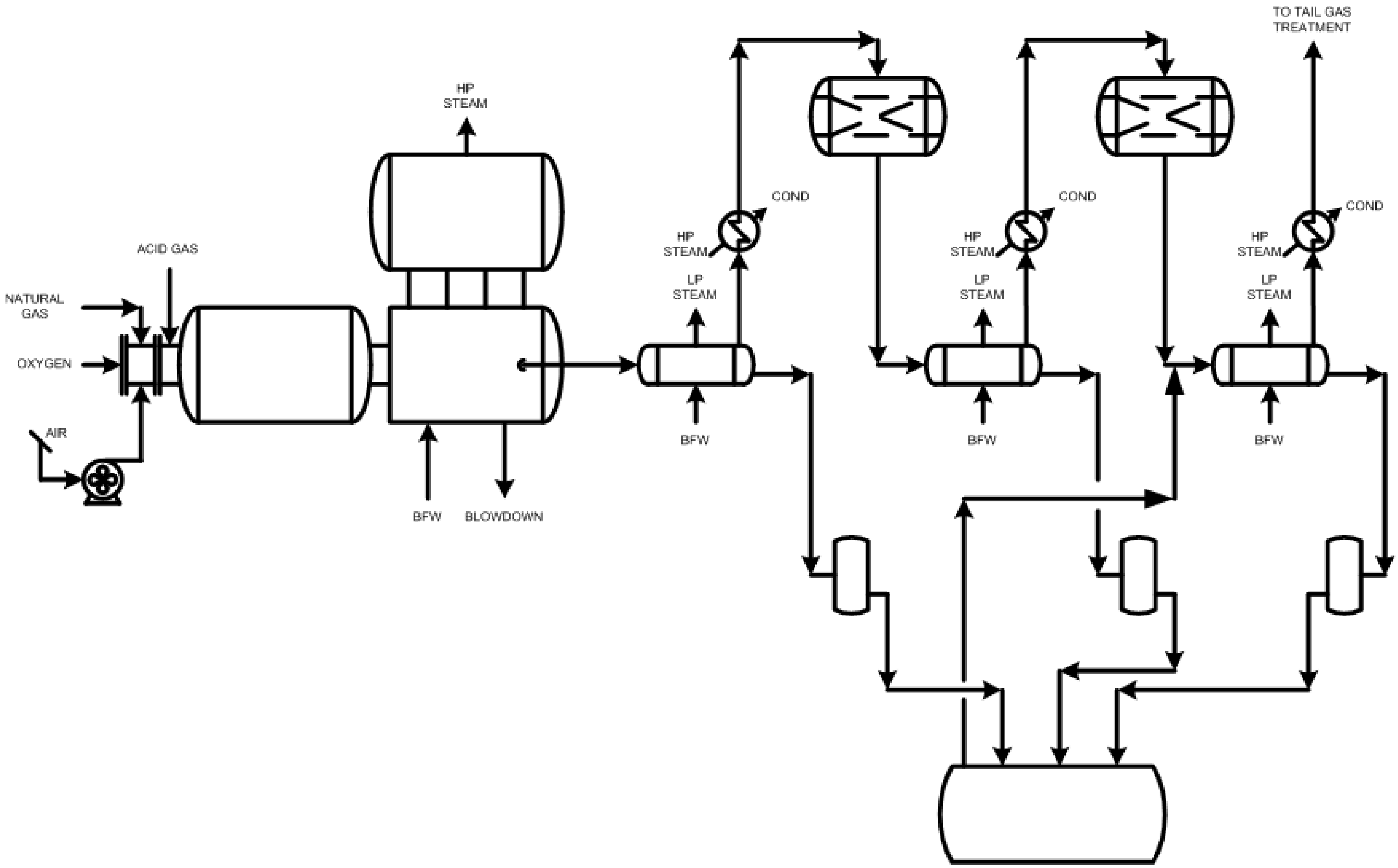
Distillation System



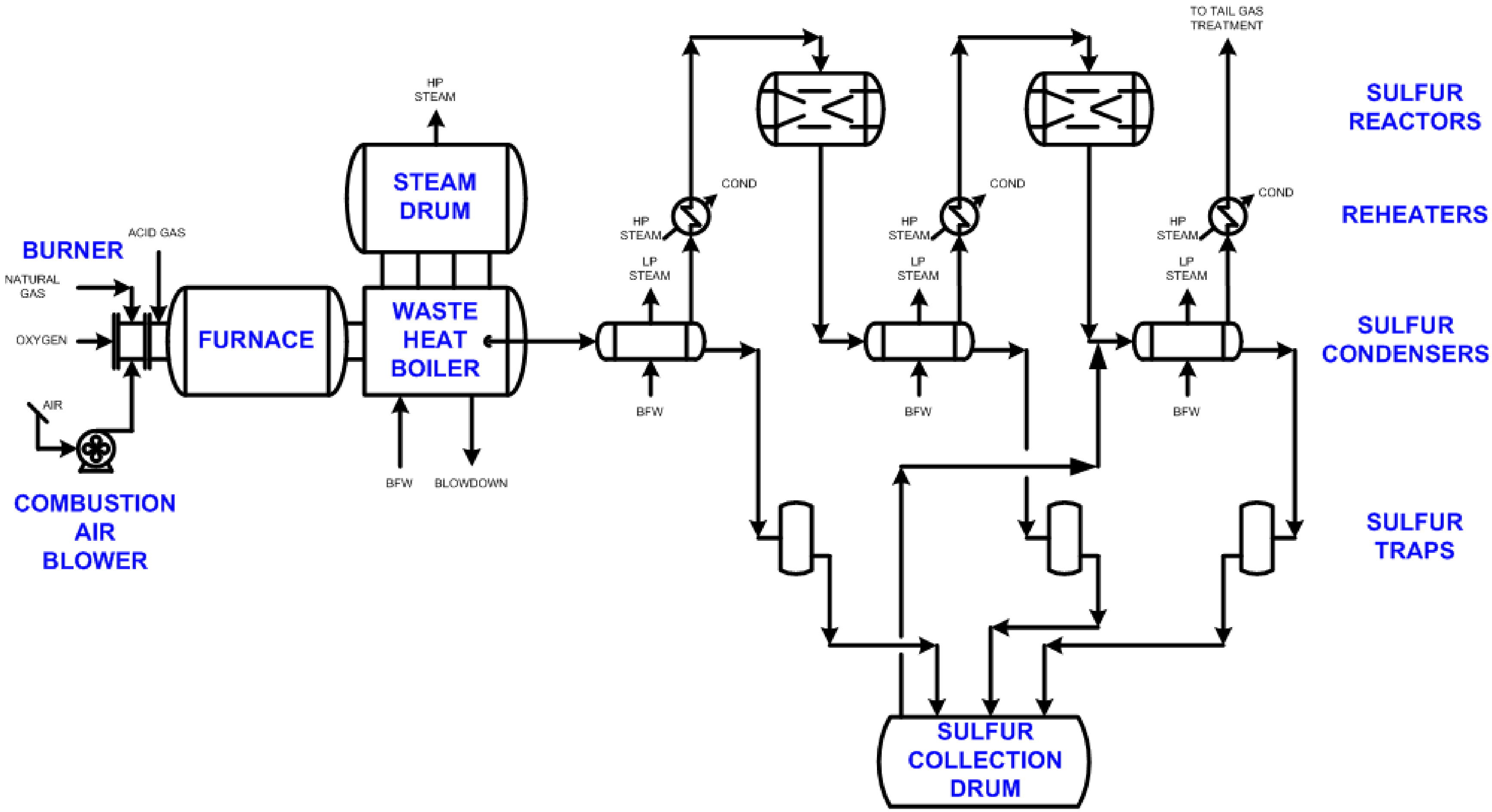
Distillation System



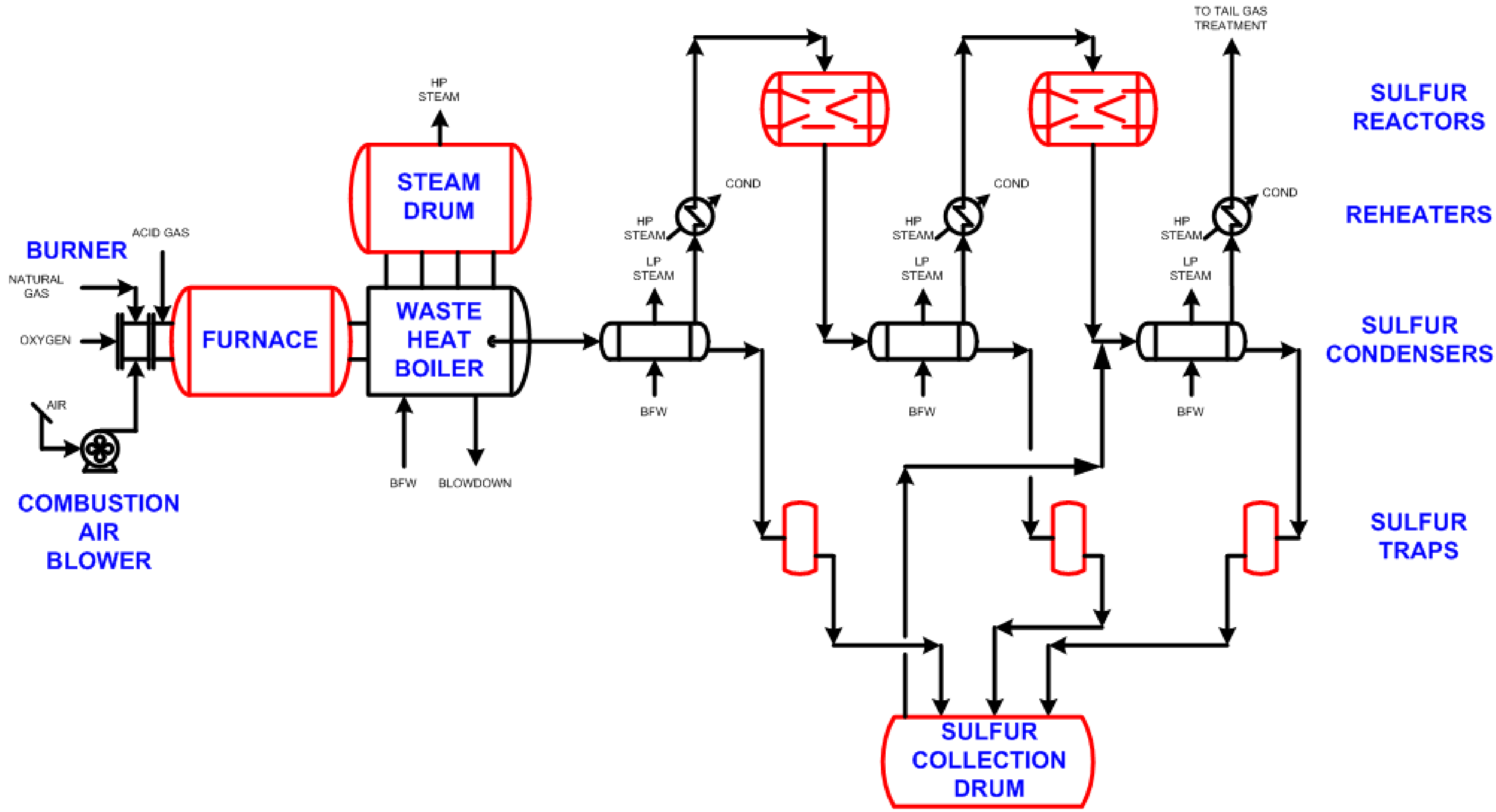
Sulfur Recovery Unit



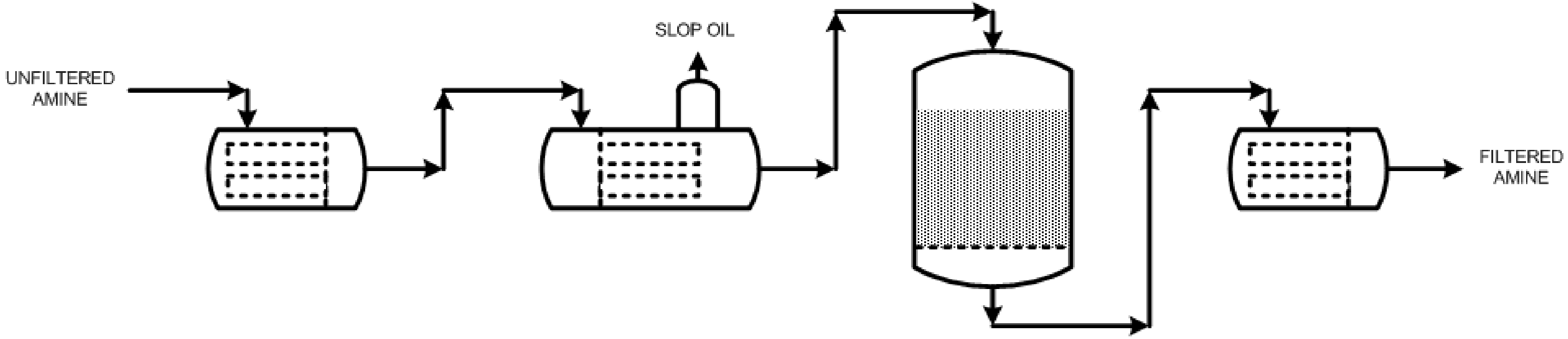
Sulfur Recovery Unit



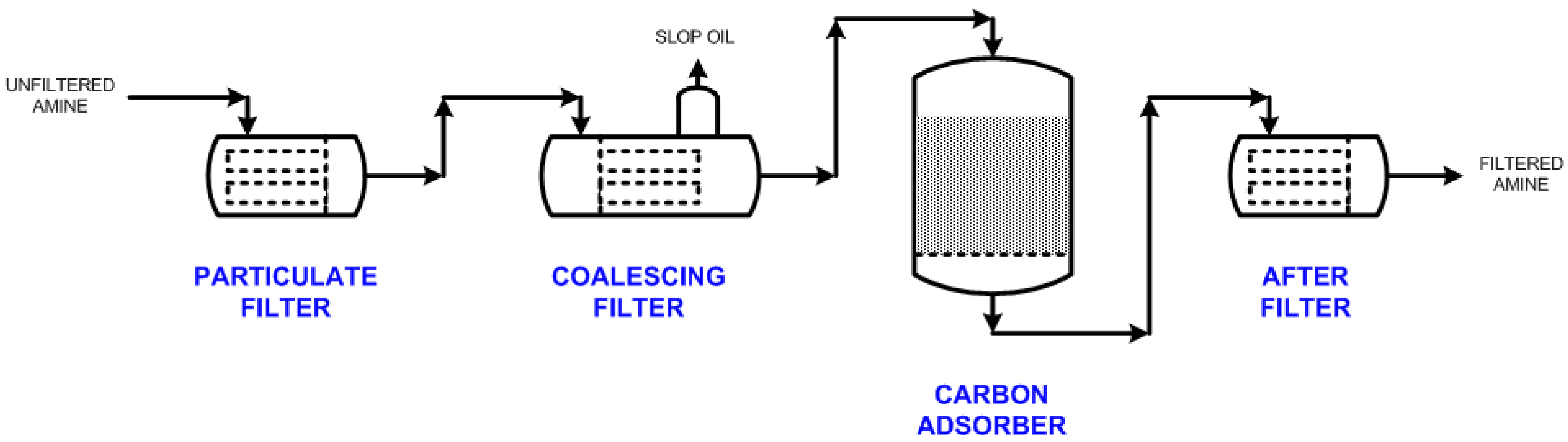
Sulfur Recovery Unit



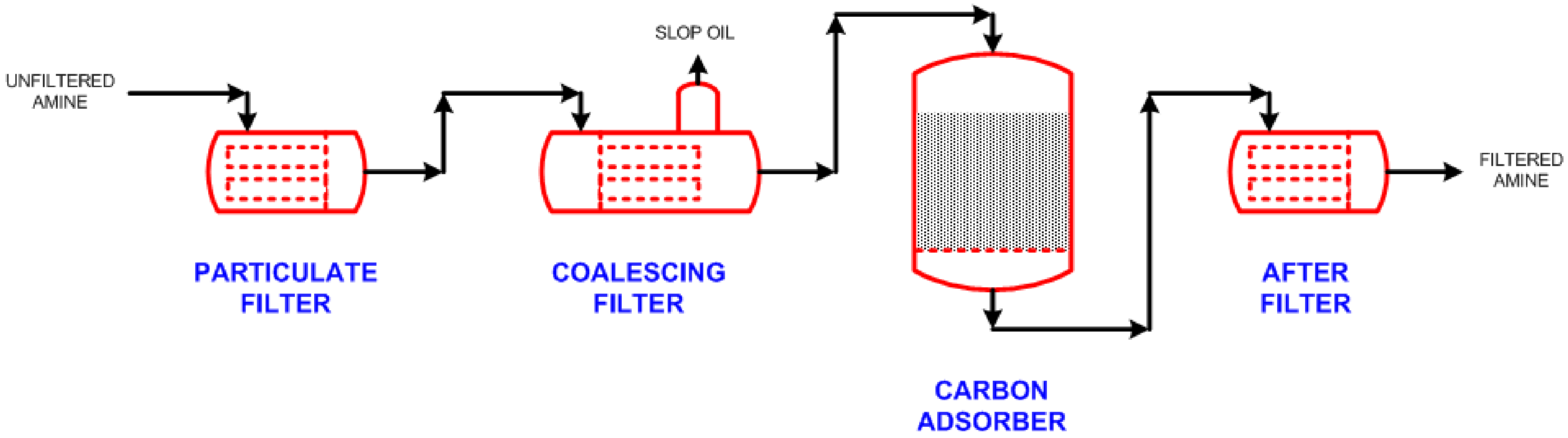
Filtration System



Filtration System

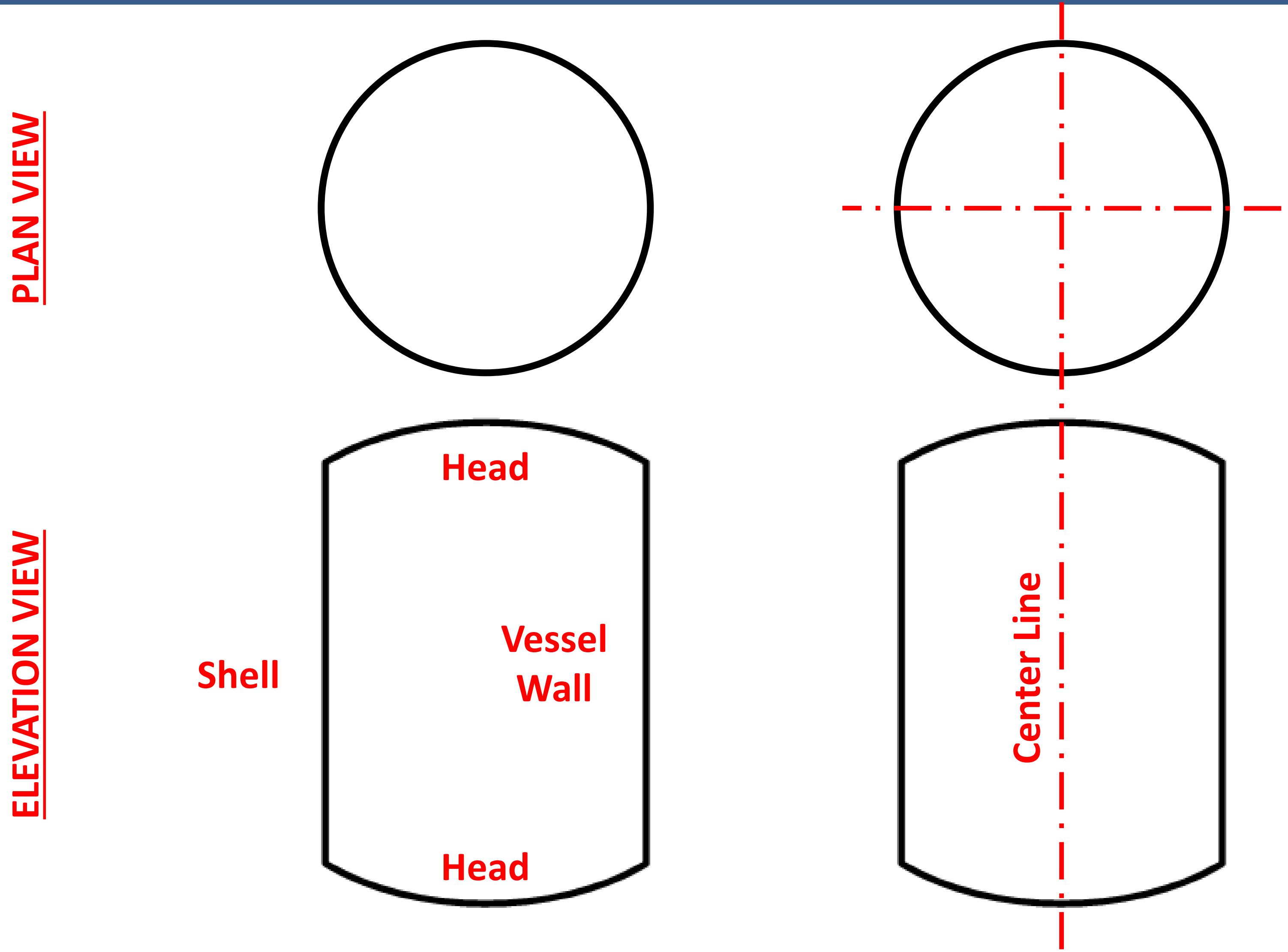


Filtration System



Mechanical Overview

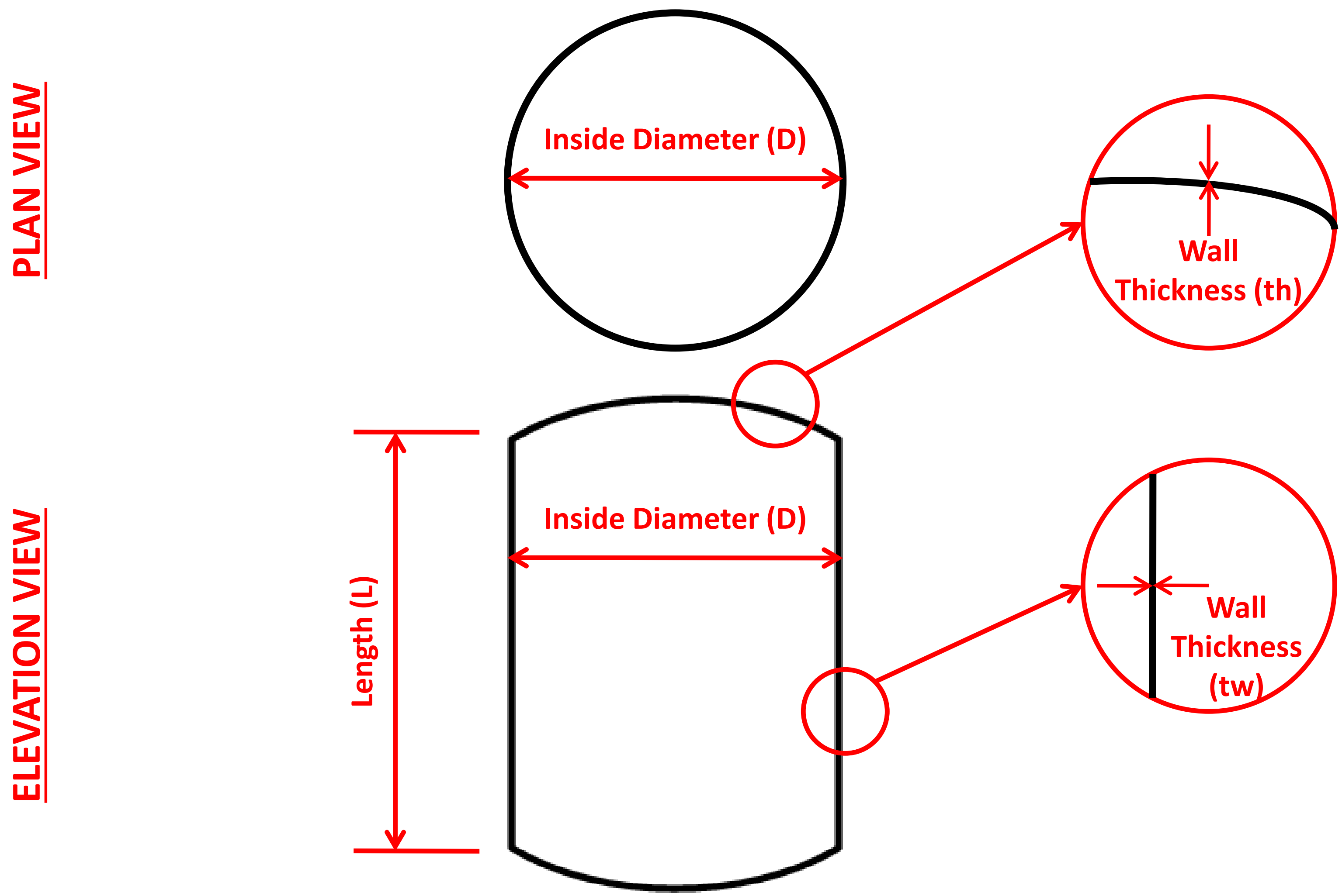
Pressure Vessel Components



Pressure Vessel Dimensions

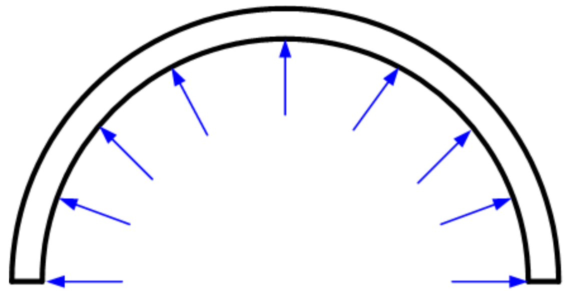
- **Inside Diameter (D)** – Inside Diameter Of Vessel
- **Outside Diameter (OD)** – Outside Diameter Of Vessel (Inside Diameter Plus Twice Wall Thickness)
- **Length (L)** – Measured From Tangent Line Of Bottom Head To Tangent Line Of Top Head (Length of Shell)
- **Wall Thickness (t)** – Varies Based On Design Pressure

Pressure Vessel Dimensions

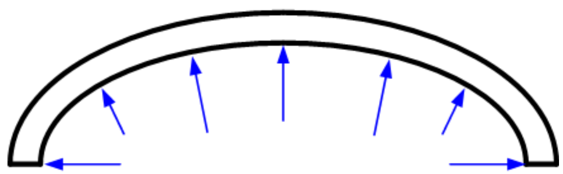


Head Profile Vs Design Pressure

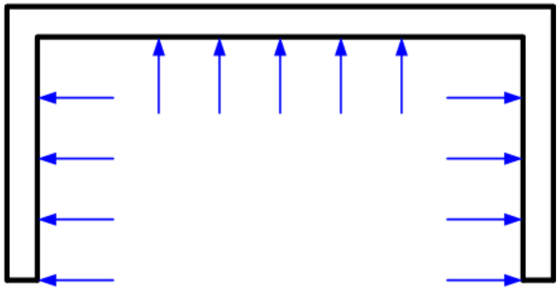
HEMISPHERICAL



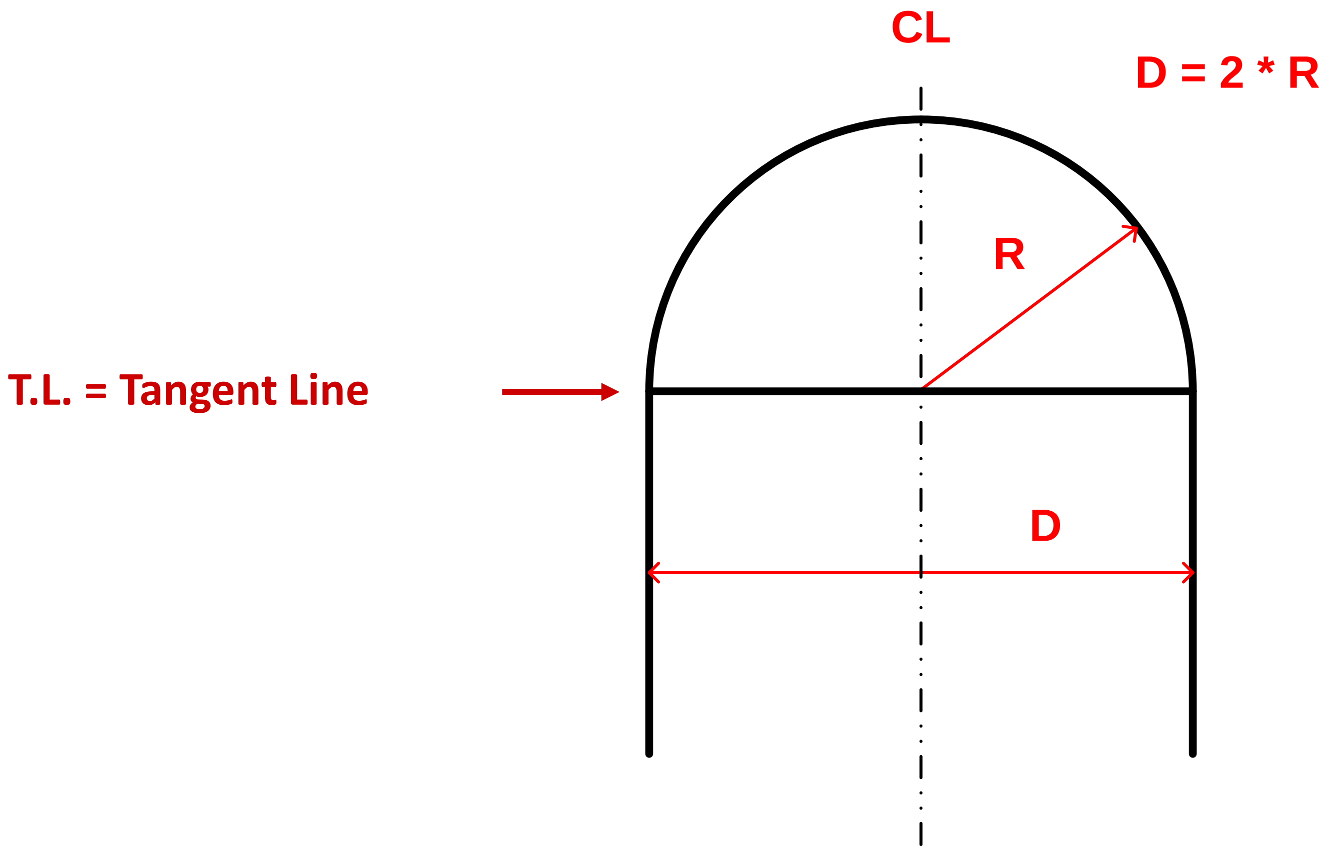
ELLIPTICAL / DISHED



FLAT



Hemispherical Head

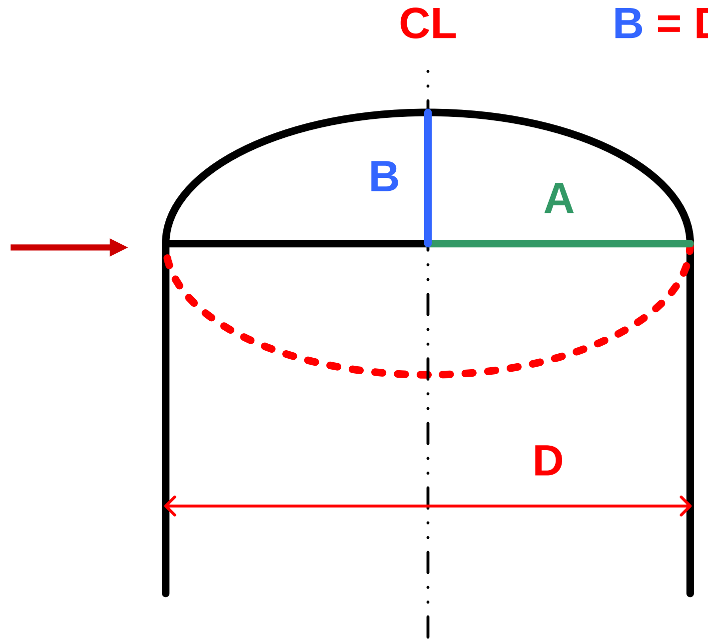


2:1 Semi-Elliptical Head

A = D/2

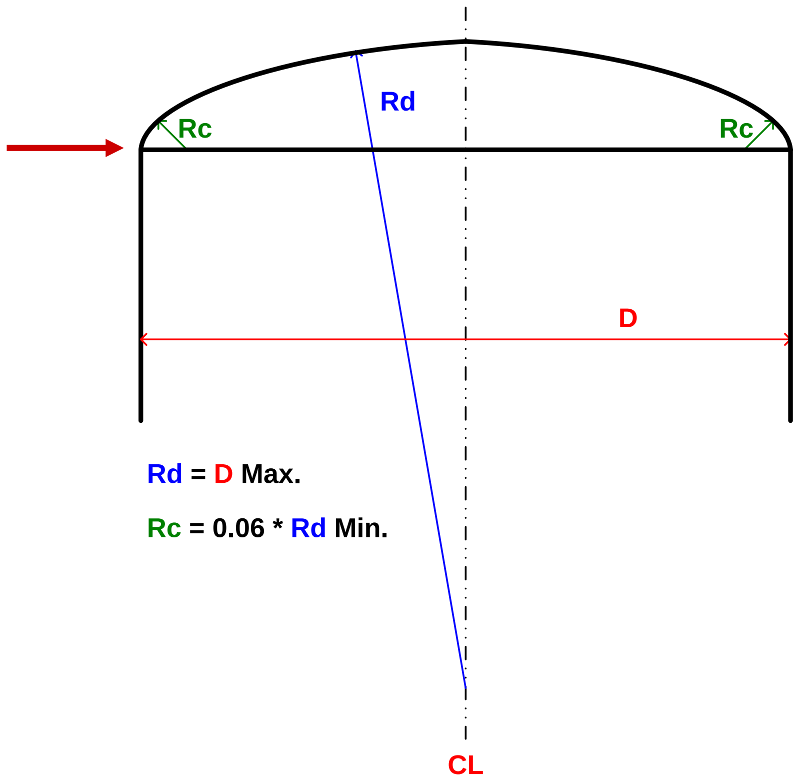
B = D/4

T.L. = Tangent Line



ASME Flanged & Dished Head

T.L. = Tangent Line



Pressure Vessel Design

Pressure Vessel Design Criteria

- Correct Size For Process Use
- Ability To Contain Fluid Under All Expected Operating Conditions
- Proper Selection And Design Of Internals / Attachments For Process And Operational Use
- Provide Necessary Interface With Surrounding Process And Facility

Diameter

Length

Pressure

Temperature

Material Selection

Corrosion Allowance

Nozzles

Supports

Access

Internals

- Baffles To Aid Mixing Or Separation
- Catalyst With Support Grids For Reaction
- Cartridges or Media For Filtration
- Piping To Aid Gas or Liquid Distribution / Collection
- Trays or Packing To Aid Gas-Liquid Contact For Absorption, Distillation, or Stripping
- Ladder Rungs To Facilitate Access
- Baffle / Tray Manways To Provide Personnel Paths

Attachments

<u>Process</u>

- Agitators To Aid Mixing
- Jackets For Heat Transfer

<u>Supports</u>

- Skirt / Legs / Lugs
- Insulation Clips / Rings
- Pipe Clips

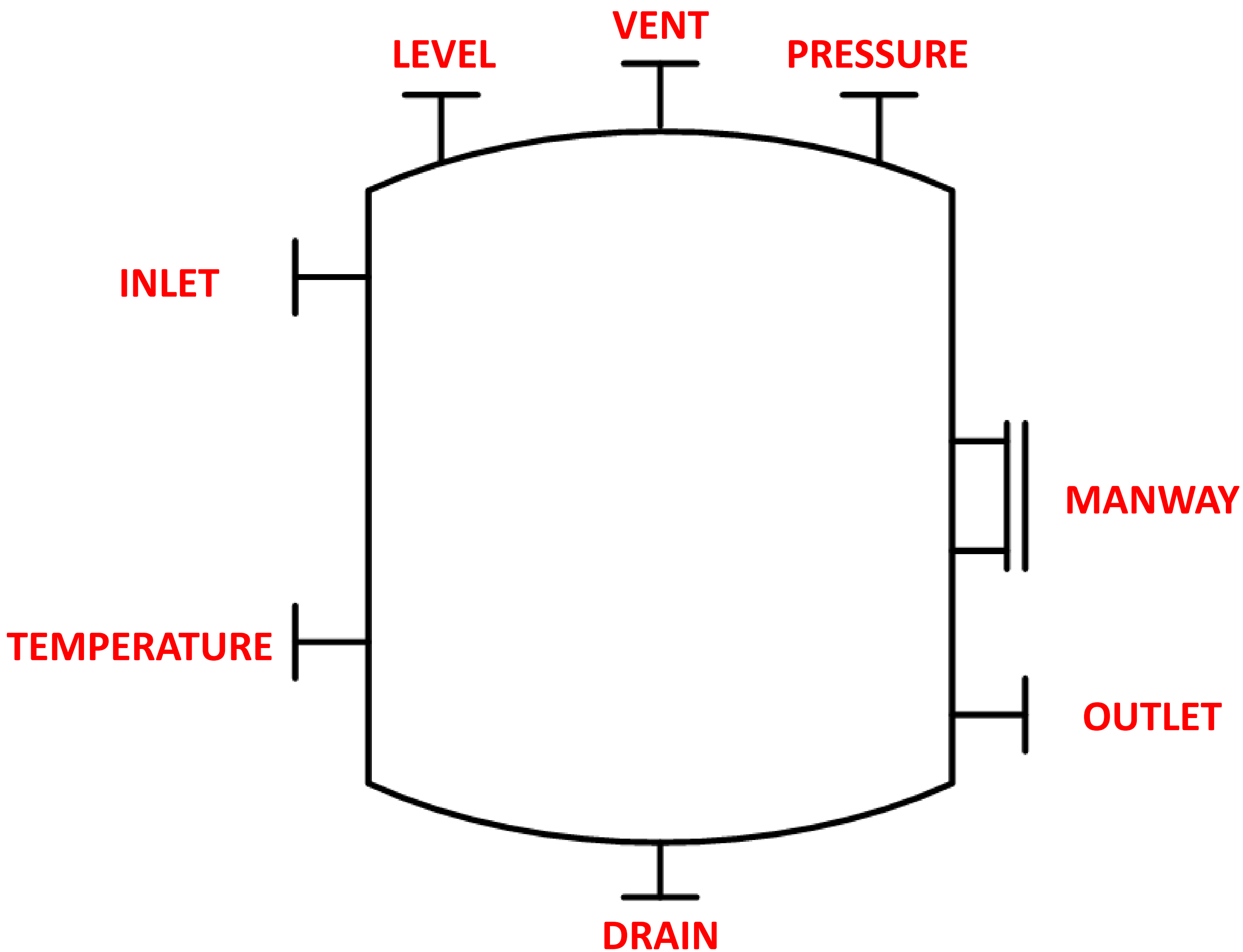
<u>Access</u>

- Ladders / Stairs
- Platforms
- Handrails

Nozzles

- Process Connections
- Operational Connections
- Instrument Connections
- Maintenance Access

Nozzles

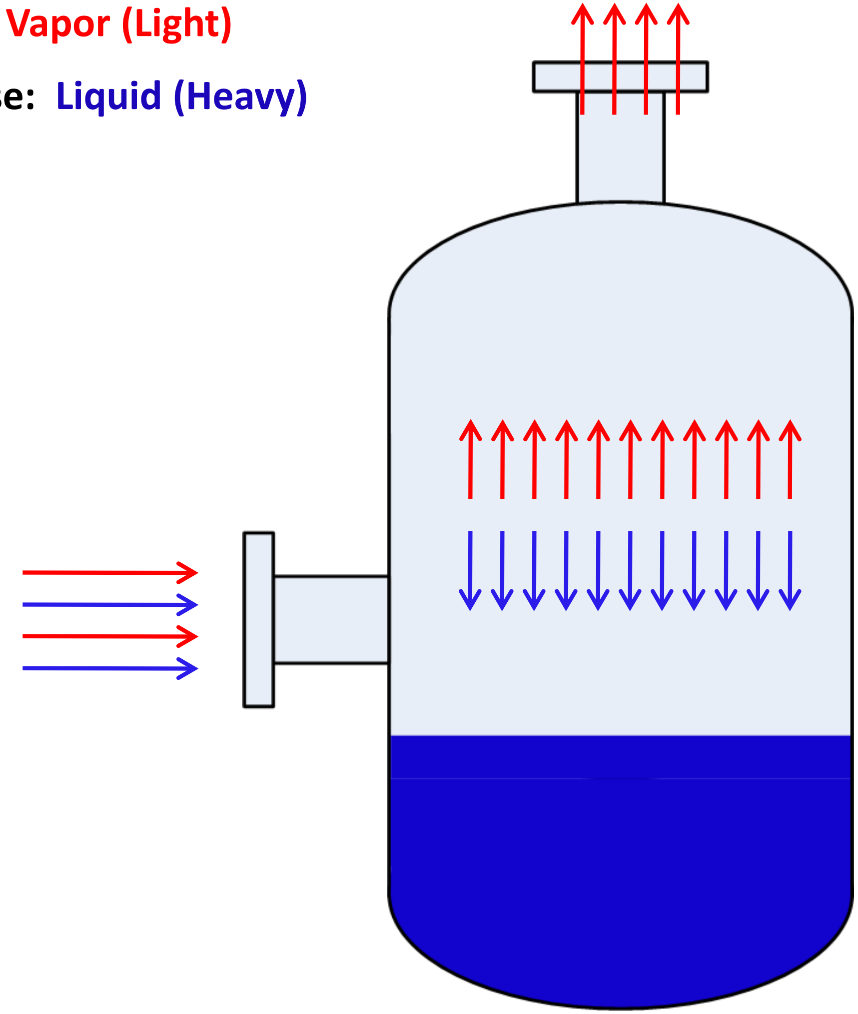

VENT
LEVEL
PRESSURE
INLET
MANWAY
TEMPERATURE
OUTLET
DRAIN

Separator Design

Vertical Drum: Vapor-Liquid

Continuous Phase: Vapor (Light)

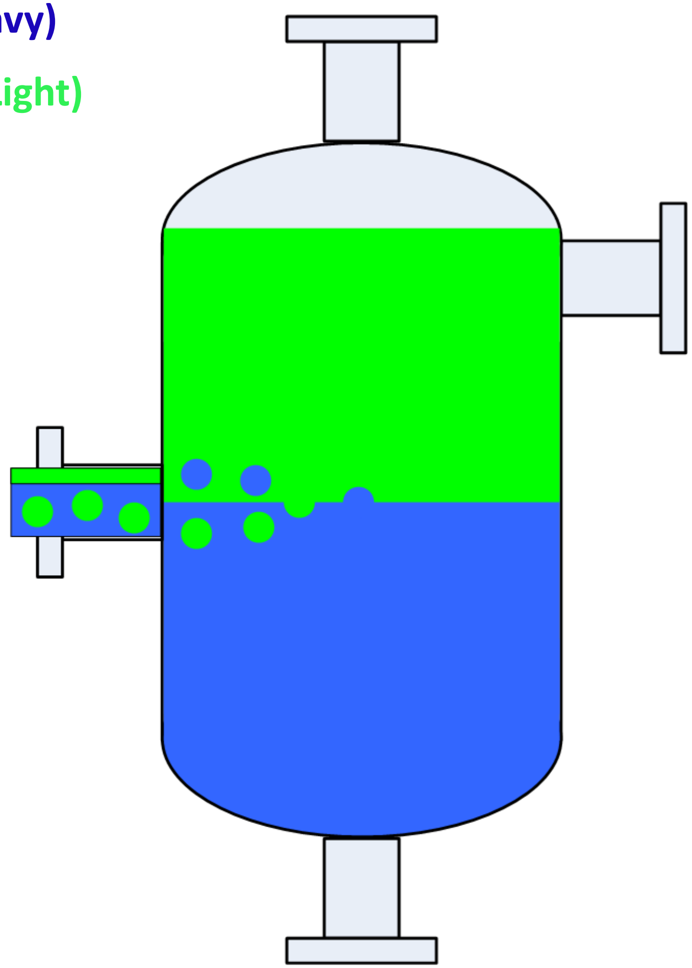
Discontinuous Phase: Liquid (Heavy)



Vertical Drum: Liquid-Liquid

Continuous Phase: Liquid (Heavy)

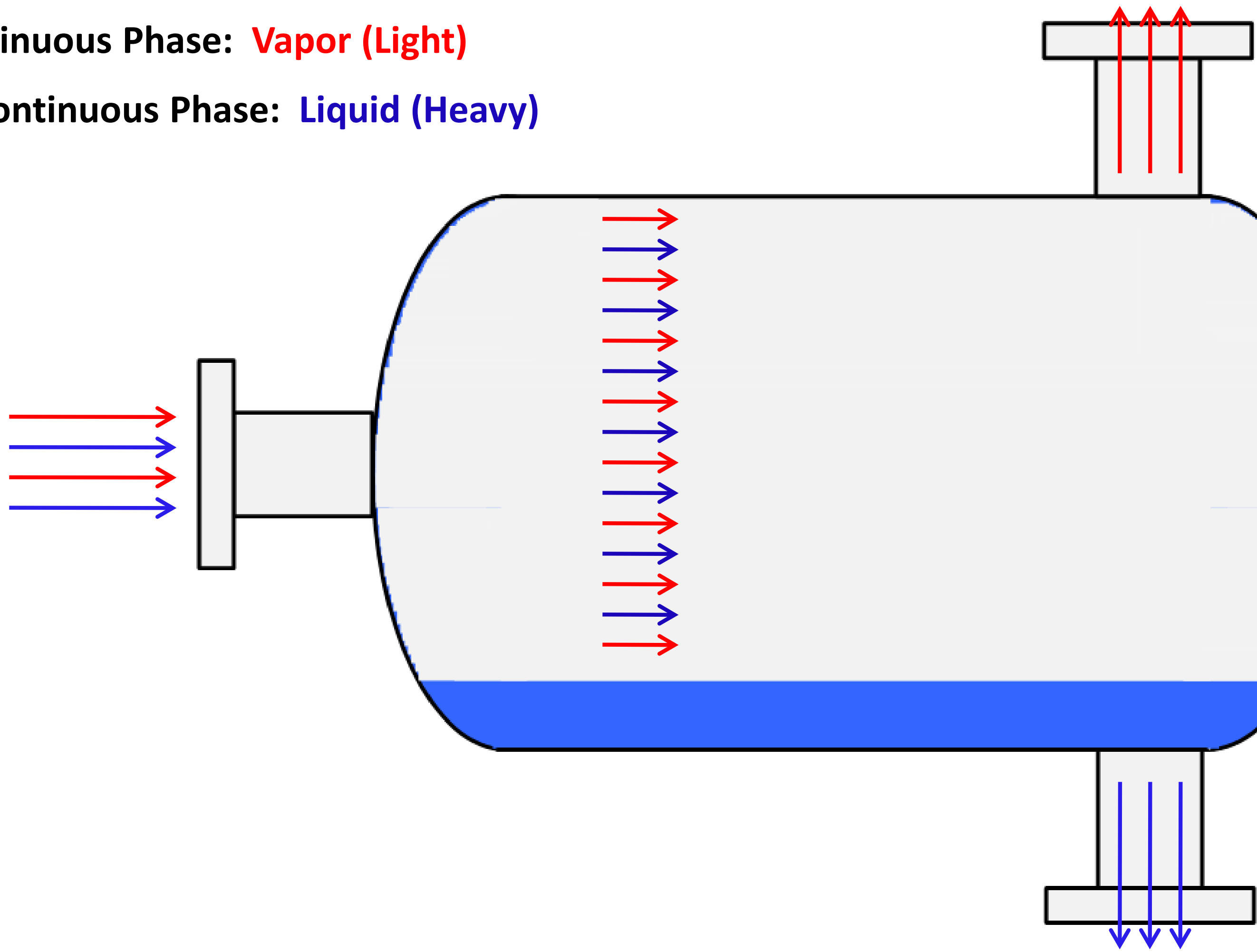
Discontinuous Phase: Liquid (Light)



Horizontal Drum: Liquid-Vapor

Continuous Phase: Vapor (Light)

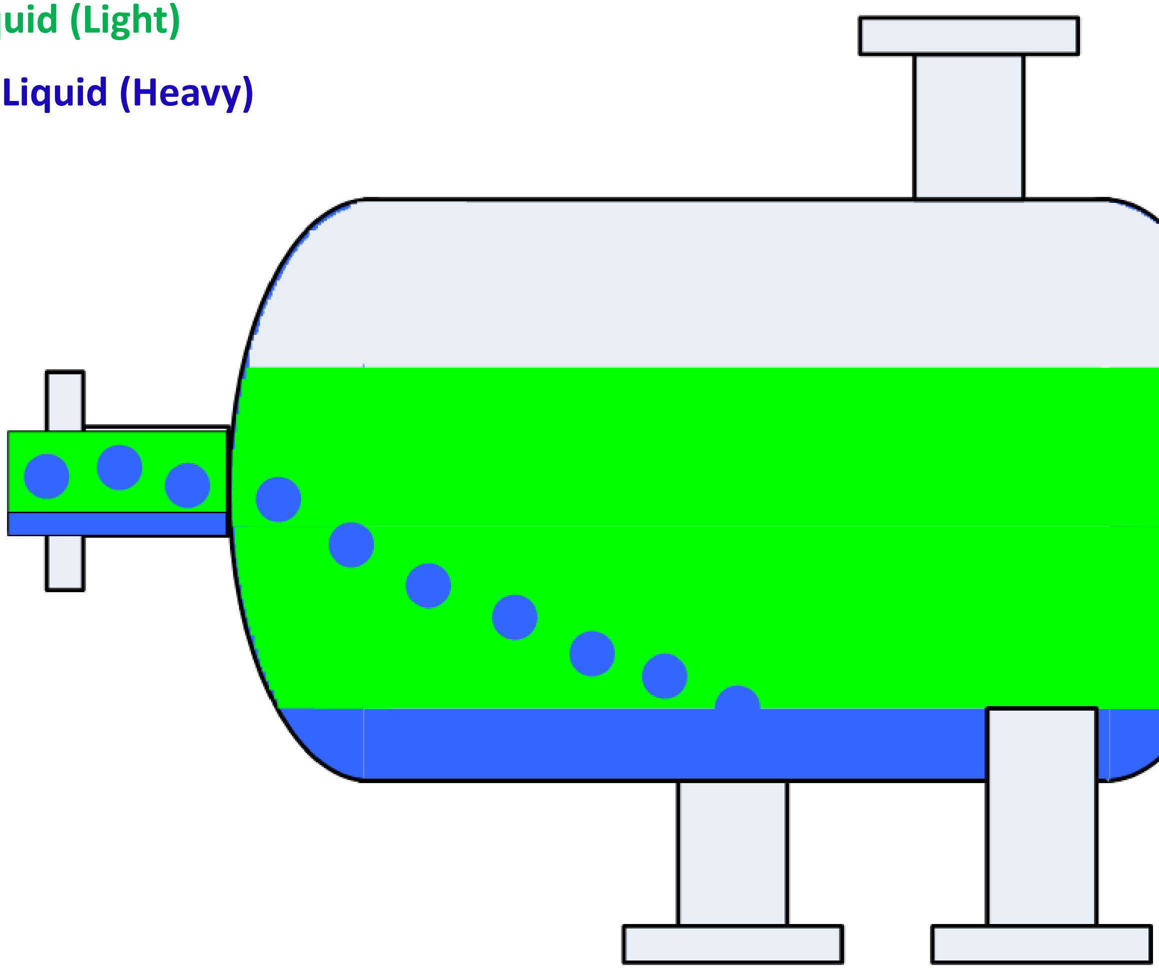
Discontinuous Phase: Liquid (Heavy)



Horizontal Drum: Liquid-Liquid

Continuous Phase: Liquid (Light)

Discontinuous Phase: Liquid (Heavy)



Separator Design

- Select Correct Orientation For Process Purpose
- Determine Appropriate Sizing Method
- Calculate Vessel Dimensions To Achieve Target Separation

Orientation

Orientation	Application	Example
Vertical	Liquid Droplet Separation From Vapor	Compressor Suction Knockout Drum Fuel Gas Knockout Drum
Horizontal	Liquid – Liquid Separation (Light – Heavy Phases)	Hydrocarbon – Water Separator Overhead Accumulator (Reflux Drum)

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Separator Sizing Methods

- Stokes (Vertical) - Rigorous
- Sauders-Brown (Vertical) - Simplified

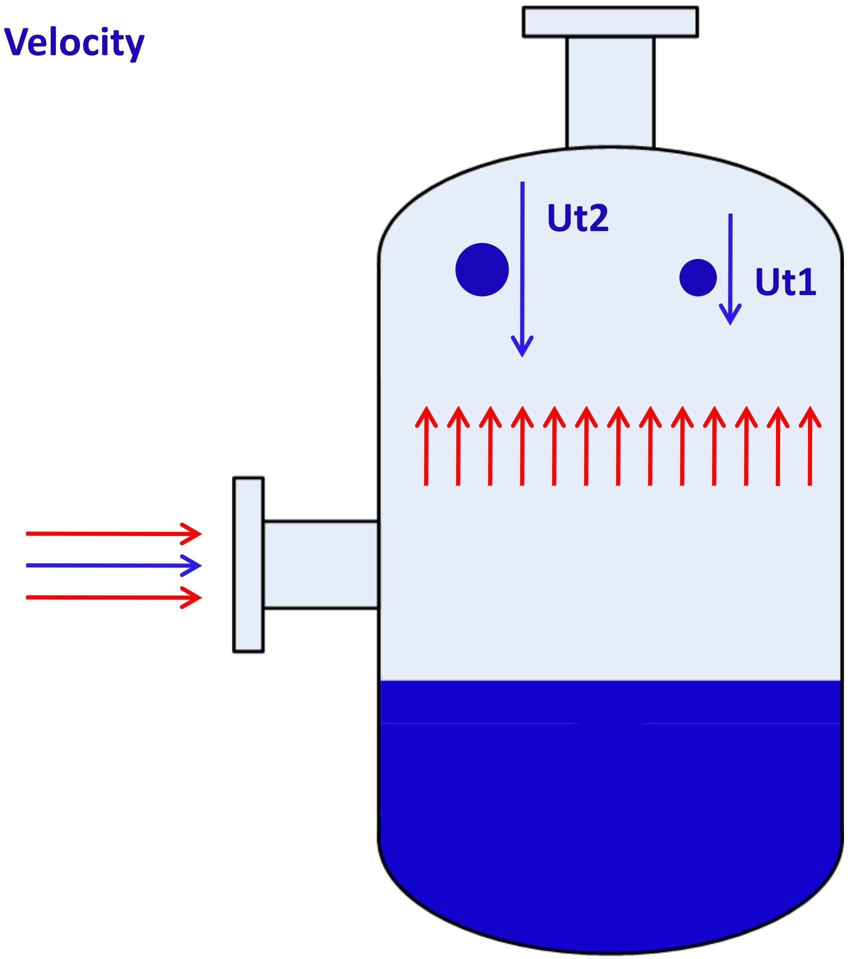
DIAMETER

- Disengagement Length (Horizontal)
- Residence Time (Horizontal)

LENGTH

Vertical Liquid-Vapor Separator

Ut = Terminal Velocity



Stokes Equation

Stokes Equation

Ut = Kc * (Dnl - Dnv) / Dnv)^0.5

Ut = Terminal Velocity (ft/s)

Kc = Sizing Coefficient

Dnl = Liquid Density (lb/ft^3)

Dnv = Vapor Density (lb/ft^3)

Sizing Coefficient

Kc = (4 / 3 * 32.2 * Dp / Cd) ^ 0.5

Kc = Sizing Coefficient

Dp = Particle Diameter (ft)

Cd = Drag Coefficient

Particle Reynolds Number

Re = 95,000,000 * Dnv * Dp^3 * (Dnl - Dnv) / Viv^2

Re = Reynolds Number (Particle)

Dnv = Vapor Density (lb/ft^3)

Dp = Particle Diameter (ft)

Dnl = Liquid Density (lb/ft^3)

Viv = Vapor Viscosity (cP)

Drag Coefficient Vs Particle Re

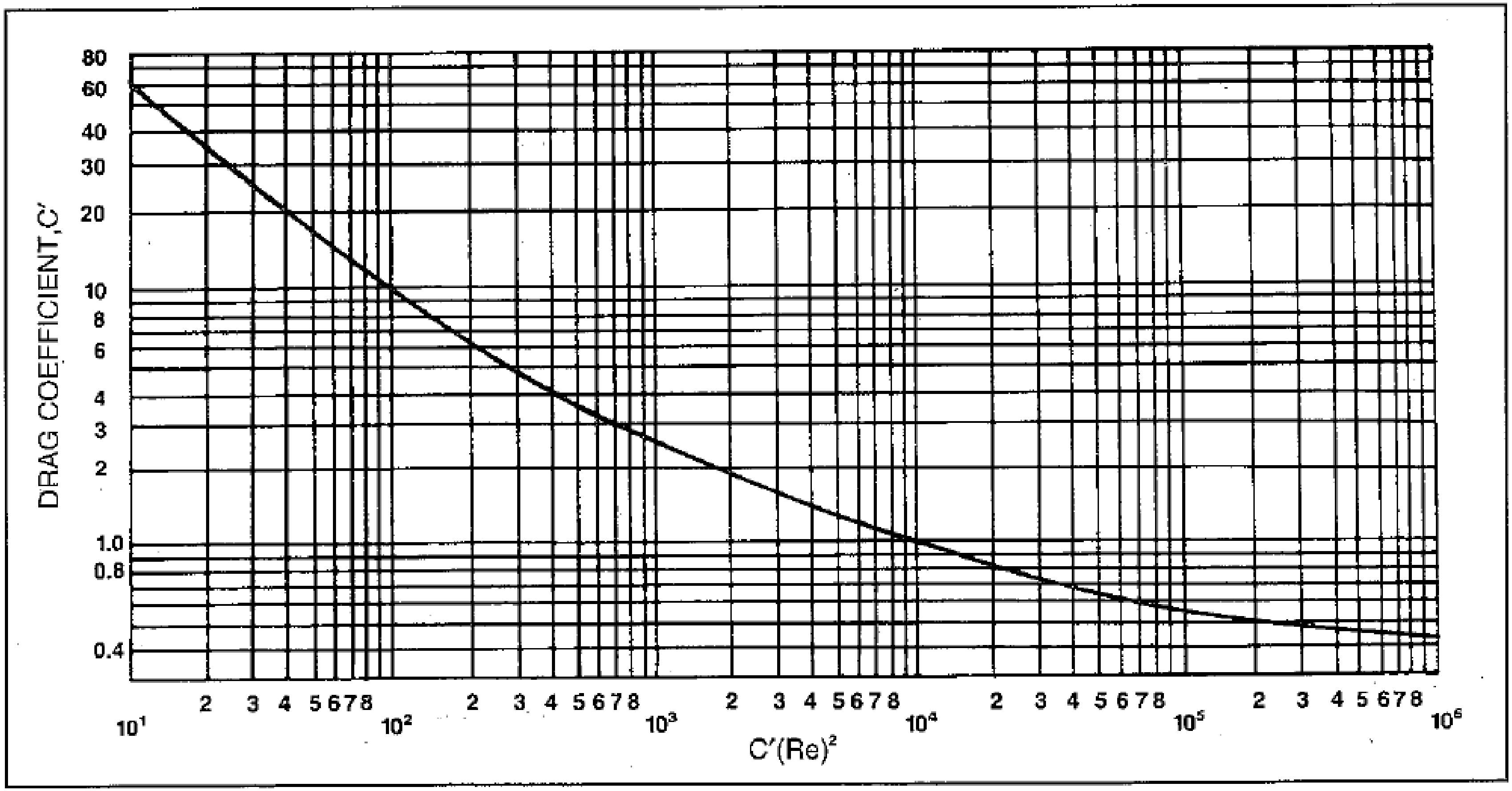


Figure 7-3, GPSA Engineering Data Book - 11th Ed.

Drag Coefficient Correlation

Cd = exp (Y)

Y = 8.411 - 2.243 * X + 0.273 * X^2 - 0.01865 * X^3 + 0.0005201 * X^4

X = ln (Re)

Cd = Drag Coefficient

Re = Reynolds Number (Particle)

Design Two-Phase Separators Within The Right Limits – CEP 10-1993

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Drag Coefficient Comparison

Re	X	Y	Cd (Calc)	Cd (Figure 7-3)
10	2.30	4.48	88.29	60.00
20	3.00	3.68	39.73	35.00
40	3.69	3.01	20.33	20.00
70	4.25	2.55	12.79	14.00
100	4.61	2.28	9.81	10.00
200	5.30	1.83	6.21	0.42
400	5.99	1.43	4.18	0.46
700	6.55	1.15	3.15	3.00
1,000	6.91	0.98	2.67	2.70
2,000	7.60	0.68	1.98	2.00
4,000	8.29	0.41	1.50	1.50
7,000	8.85	0.20	1.23	1.20
10,000	9.21	0.08	1.09	1.00
20,000	9.90	-0.14	0.87	0.80
40,000	10.60	-0.34	0.71	0.68
70,000	11.16	-0.47	0.62	0.60
100,000	11.51	-0.55	0.58	0.55
200,000	12.21	-0.66	0.51	0.50
400,000	12.90	-0.73	0.48	0.48
700,000	13.46	-0.73	0.48	0.44
1,000,000	13.82	-0.70	0.50	0.42

Reynolds Number	Re=95,000,000*Dnv*Dp^3*(Dnl-Dnv)/Viv^2
Drag Coefficient Factor No. 1	X=@ln(Re)
Drag Coefficient Factor No. 2	Y=8.411-2.243*X+0.273*X^2-0.01865*X^3+0.0005201*X^4
Drag Coefficient	Cd=@exp(Y)

Particle Size Vs Terminal Velocity

Liquid		Water	SG = 0.99		
Vapor		Air	MW = 29	Viv = 0.019	cP
Temperature		100 °F			
Pressure	Particle Diameter	Particle Reynolds No.	Drag Coefficient	Sizing Coefficient	Terminal Velocity
psig	microns				fps
100	32	10	84.49	0.007	0.077
100	100	316	4.76	0.054	0.57
100	500	39,512	0.72	0.31	3.3
100	1,000	316,093	0.49	0.54	5.6
100	1,450	963,650	0.49	0.64	6.8
500	20	11	78.52	0.006	0.029
500	100	1,374	2.31	0.078	0.38
500	300	37,094	0.73	0.24	1.2
500	600	296,753	0.49	0.41	2.0
500	890	968,528	0.49	0.50	2.5
1,500	14	10	86.19	0.005	0.013
1,500	100	3,715	1.55	0.095	0.26
1,500	200	29,722	0.78	0.19	0.52
1,500	400	237,774	0.50	0.33	0.92
1,500	640	973,922	0.49	0.43	1.2

Particle Size Vs Terminal Velocity

Liquid		Hydrocarbon	SG = 0.80		
Vapor		Methane	MW = 16	Viv = 0.013	cP
Temperature		100	°F		
Pressure	**Particle Diameter**	**Particle Reynolds No.**	**Drag Coefficient**	**Sizing Coefficient**	**Terminal Velocity**
psig	**microns**				**fps**
100	32	10	89.96	0.007	0.090
100	100	301	4.89	0.054	0.68
100	500	37,584	0.73	0.31	4.0
100	1,000	300,673	0.49	0.54	6.8
100	1,450	916,638	0.49	0.65	8.2
500	20	11	82.47	0.006	0.035
500	100	1,320	2.36	0.077	0.46
500	300	35,647	0.74	0.24	1.4
500	600	285,173	0.49	0.41	2.5
500	900	962,460	0.49	0.51	3.0
1,500	14	10	87.45	0.005	0.016
1,500	100	3,672	1.55	0.095	0.32
1,500	200	29,377	0.78	0.19	0.64
1,500	400	235,016	0.50	0.33	1.1
1,500	640	962,627	0.49	0.43	1.4

Simplified Sizing Coefficients

$$Ud = Ks * ((Dnl - Dnv) / Dnv)^{0.5}$$

Ud = Ks * (Dnl - Dnv) / Dnv)^0.5

Sauders-Brown Equation

Ud	**=**	**Design Velocity (ft/s)**
Ks	**=**	**Sizing Coefficient (Simplified)**
Dnl	**=**	**Liquid Density (lb/ft^3)**
Dnv	**=**	**Vapor Density (lb/ft^3)**

Service	Without Mesh	With Mesh	Maximum Allowable
Compressor Suction (Centrifugal)	0.17	0.25	0.35
Compressor Suction (Reciprocating)	0.17	0.20	0.35
Turbine Feed	0.08	0.15	0.25
Vapor/Liquid Separator (Vertical)	0.17	0.25	0.35
Vapor/Liquid Separator (Horizontal)	0.07	0.25	0.35
Overhead Accumulators	0.07	0.25	0.30
Flare Drum	0.30	Not Used	0.35
Steam Drum	0.07	0.20	0.25

Without Mesh – **No** Mist Eliminator (Coalescing Pad)

With Mesh – **Includes** Mist Eliminator (Coalescing Pad)

Simplified Sizing Coefficients

With Mesh	
Pressure	Sizing Coefficient
psia	fps
0.5	0.17
1	0.18
2	0.22
3	0.24
5	0.27
7	0.29
10	0.32
14.7	0.35
30	0.35
50	0.34
70	0.33
100	0.32
500	0.28
1,000	0.27

Service	Multiply Ks By
Without Mist Eliminator (Or Use Rigorous Stokes Equation)	0.5
Amine Solution Handling Glycol Solution Handling	0.6 to 0.8
Compressor Suction Scrubbers Expander Inlet Separators	0.7 to 0.8
Vapors Under Vacuum	Ks = 0.20 Maximum
Wet Steam	Ks = 0.25 Maximum

Simplified Sizing Coefficients

Lower	Upper	Correlation
psia	psia	
1	15	K = 0.1821 + 0.0029*P + 0.0460 * ln(P)
15	40	K = 0.35
40	5,500	K = 0.43 - 0.023 *ln(P)

With Mesh			Without Mesh
Pressure	Suggested Ks	Calculated Ks	Calculated Ks
psia	fps	fps	
0.5	0.17	0.15	0.08
1	0.18	0.19	0.09
2	0.22	0.22	0.11
3	0.24	0.24	0.12
5	0.27	0.27	0.14
7	0.29	0.29	0.15
10	0.32	0.32	0.16
14.7	0.35	0.35	0.17
30	0.35	0.35	0.18
50	0.34	0.34	0.17
70	0.33	0.33	0.17
100	0.32	0.32	0.16
500	0.28	0.29	0.14
1,000	0.27	0.27	0.14
1,500		0.26	0.13
3,500		0.24	0.12
5,500		0.23	0.12

Design Two-Phase Separators Within The Right Limits – CEP 10-1993

Sizing Coefficient Comparison

With Mesh			Without Mesh
Pressure	Suggested Ks	Calculated Ks	Calculated Ks
psia	fps	fps	
100	0.32	0.32	0.16
500	0.28	0.29	0.14
1,500		0.26	0.13

Liquid		Water	SG = 0.99		
Vapor		Air	MW = 29	Viv = 0.019	cP
Temperature		100	°F		
Pressure	**Particle Diameter**	**Particle Reynolds No.**	**Drag Coefficient**	**Sizing Coefficient**	**Maximum Velocity**
psig	**microns**				**fps**
100	250	4,939	1.42	0.16	1.4
500	170	6,750	1.24	0.14	0.58
1,500	135	9,141	1.12	0.13	0.30

Liquid		Hydrocarbon	SG = 0.80		
Vapor		Methane	MW = 16	Viv = 0.013	cP
Temperature		100	°F		
Pressure	**Particle Diameter**	**Particle Reynolds No.**	**Drag Coefficient**	**Sizing Coefficient**	**Maximum Velocity**
psig	**microns**				**fps**
100	250	4,698	1.42	0.16	1.7
500	170	6,486	1.26	0.14	0.70
1,500	135	9,035	1.12	0.13	0.37

Recommended Particle Size

Reference	Particle Size (microns)
GPSA (General Separator Sizing)	150
API 521 (Flare Knockout Drum)	300 to 600

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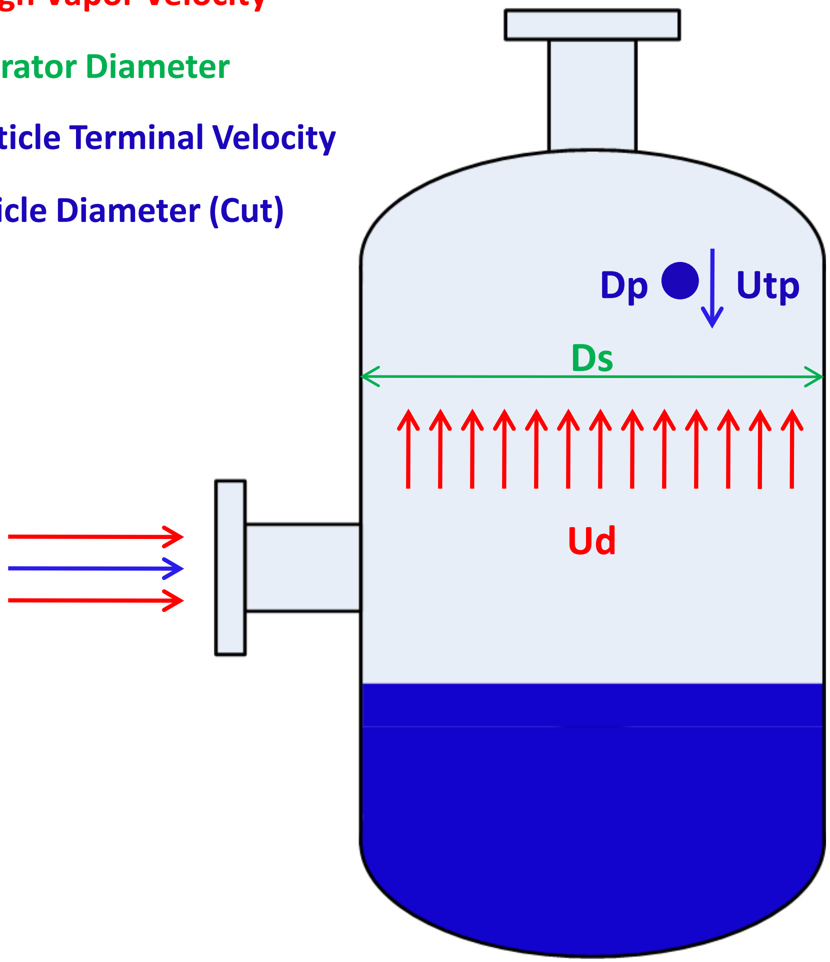
Minimum Separator Diameter

Ud = Design Vapor Velocity

Ds = Separator Diameter

Utp = Particle Terminal Velocity

Dp = Particle Diameter (Cut)



Ks = 0.07 to 0.35

Uvmx = Fv * Ut

Uvmx = Maximum Vapor Velocity (Design) (ft/s)

Fv = Sizing Coefficient

Ut = Terminal Velocity (ft/s)

Fv Range: 0.70 to 0.90

Ud = Ks * (Dnl - Dnv) / Dnv)^0.5

Ud = Design Velocity (ft/s)

Ks = Sizing Coefficient (Simplified)

Dnl = Liquid Density (lb/ft^3)

Dnv = Vapor Density (lb/ft^3)

Ud = Uvmx

Ds=((Qv / 60 / Ud)/ 0.785)^0.5

Ds = Minimum Separator Diameter (ft)

Qv = Vapor Volumetric Flow Rate (acfm)

Ud = Design Velocity (ft/s)

Summary

- Identify Process Use Of Drums
- Determine Mechanical Design Of Drum That Best Fits Process Use
  - Safety
  - Environment
  - Cost Effectiveness
- Determine Key Elements Of Drum Design
  - Volume / Dimensions
  - Pressure / Temperature
  - Nozzles / Internals