EIEPD Sizing Criteria

Standards, Codes and References

1.Heat exchangers

Shell and tube heat exchangers, double pipe heat exchangers and waste heat boilers	TEMA Class R/ API-660
Surface Condensers	HEI/ ASME Sec III Div.1
Air-cooled heat exchangers	API-661
Plate exchangers	API-662
2.Pressure vessels	
Separators	GPSA/API-521 /Svercheck
Distillation Column	Koch-Glitch Criteria
3.Storage tanks	API-620/ API-650
4.Rotary machinery	
Axial and centrifugal compressors	API-617
Reciprocating compressors	API-618
Rotary-type positive displacement compressors	API-619
Centrifugal pumps	API-610
Reciprocating pumps	API-674
Steam turbines	API-611/API-612
5.Piping	ASTM
6.Instrumentation	EIEPD Criteria

Units of Measurement	
Temperature	[C]
Pressure	[barg]-[mmWG]
Volume	[m^3]-[l]
Length/Diameter	[m]-[mm]
Mass or Weight	[kg]-[ton]
Mass flowrate	[kg/hr.]-[ton/hr.]
Volumetric flowrate	[m^3/hr.]-[Nm^3/hr.]
Velocity	[m/s]
Energy	[MJ]-[KJ]
Power	[MW]-[kW]
Heat capacity	[kcal/kg.C]
Thermal conductivity	[kcal/h.m.C]
Density	[kg/m^3]
Sound	[dBA]
Nominal pipe diameter	[inch]
Nozzle size	[inch]

Site Condition-Middle East

Temperature

Maximum recorded temperature	52C
Maximum dry bulb temperature(winter)	5C
Max wet bulb temperature	33C
Max dry bulb temperature	48C
Dry bulb temperature for design of air coolers	50C
Max temperature for mechanical, civil and structural design	55C
Max temperature for equipment exposed to sunlight-design	85C

Humidity

Maximum in summer	76%
Minimum in winter	74%

Barometric pressure

	990
Min. mbar	1100
Max. mbar	

Wind

Maximum wind velocity (up to 10m elevation):	
	16m/s
Flare thermal radiation	

Emission

NO_x, vol ppm, (dry, 3%O_2) max.	100
CO, vol ppm, (dry, 3%O_2) max.	20

Noise

Maximum dB(A) at 1m from equipment	85

Utility Characteristic

HHPS

Parameter	Units	Min.	Norm.	Max.	Mechanical Design
Pressure	barg	92	98	103	112
Temperature	C	-	454	-	490

HPS

Parameter	Units	Min.	Norm.	Max.	Mechanical Design
Pressure	barg	38	43	47	52
Temperature	C	400	410	430	470

Min steam quality

Conductivity	< 1 us/cm
CO_2	< 2 wet-ppm
SiO_2	<0.02 wet-ppm
Fe	<0.02 wet-ppm
Cu	<0.03 wet-ppm
Na+K	<0.02 wet-ppm

LPS

Parameter	Units	Min.	Norm.	Max.	Mechanical Design
Pressure	barg	6.5	7	8	9.5
Temperature	C		215		340

Nitrogen

Parameter	Units	Min.	Norm.	Max.	Mechanical Design
Pressure	barg	6	6	8	10.5
Temperature	C		Ambient		75

Nitrogen Quality

Nitrogen, vol%, min	99.9
Oxygen, ppm (vol), max	2
CO, ppm (vol), max	10
CO_2, ppm (vol), max	10

Demineralized Water

Parameter	Units	Min.	Norm.	Max.	Mechanical Design
Pressure	barg		5		7
Temperature	C		Ambient		65

DMW quality

PH	6.5-7.5
Iron	<0.02 mg/kg as Fe
Silica	<0.02 mg/kg as SiO_2
Conductivity	<0.15 us/cm

Cooling Water

Parameter	Units	Min.	Norm.	Max.	Mechanical Design
Pressure	barg		1.5	4.5	7.5
Temperature	C	38	Max.48		100

CW quality

PH	7.5
Chloride as Cl	10

Instrument Air for control valves

Parameter	Units	Min.	Norm.	Max.	Mechanical Design
Pressure	barg	6	7	7.5	10.5
Temperature	C		Ambient		75

IA quality

Free from oil, dust, water droplets

Plant Air

Parameter	Units	Min.	Norm.	Max.	Mechanical Design
Pressure	barg	7	7.5	8	10.5
Temperature	C		Ambient		75

PA quality

Free from oil, dust, water droplets

Design Pressures

The design pressure is the maximum and/or minimum pressure for which the mechanical calculation shall be performed. The set pressure of the relief valve must be lower than or equal to the design pressure of equipment. For vacuum rating designation, pressure shall be shown as external. The maximum operating pressure is defined as the maximum pressure which occurs during normal modes of operation, including start-up and shutdown, and should take full account of any hydrostatic head, and other pressure drop across the item.

Maximum operating pressure (barg)	Minimum design pressure (barg)
< 1	2 or 3.5 (*) minimum
1 -10	MOP + 1 bar (**)
> 10	MOP + 10%

(*) 2.0 barg for PSV discharging to atmosphere, 3.5 barg for PSV discharging to flare network.
(**) 2 or 3.5 barg as minimum design pressure considering the criteria in Part (*).

Notes:

1. Vapor pressure at design temperature should be considered as design pressure except when safety relief valves are provided.

2. Equipment that operates at pressure below atmospheric pressure shall also be designed for full vacuum.

- Equipment that could face vacuum under abnormal conditions such as:
- Vacuum conditions during start-up, shut down and/or regeneration purges
- Normally operated full of liquid but can be blocked in and cooled down
- Containing condensable vapor but can be blocked in and cooled down (especially Equipment which is subjected to steam out).
- Could undergo a vacuum condition through the loss of heat input
- Loss of artificial gas blanketing on vessels containing liquids in a vessel containing liquids with a vapor pressure less than atmospheric at the minimum storage temperature
- Product storage tanks and vessels where net output is possible (e.g., Unloading).

They shall be treated on a case-by-case basis and be designed for full vacuum unless fully reliable protection devices are provided (vacuum breaker, pressurization gas, low pressure switch etc.)

3. In Atmospheric storage tanks:

- Without gas blanketing, the design pressure shall be the hydrostatic pressure considering the tank full of liquid.
- gas blanketed and with a seal pressure lower than 100 mm of H2O, the design pressure shall be the hydrostatic pressure considering the tank full of liquid plus 150 mm H2O.
- gas blanketed and with a seal pressure not higher than 400 mm of H2O, design pressure shall be the hydrostatic pressure considering the tank full of liquid plus 500 mm of H2O.

4. For Welded Steel Tanks for Oil Storage, unless otherwise specified by the purchaser, the internal design pressure shall not exceed the weight of the roof. In no case shall the maximum design pressure exceeds 9 inches water column. When the design pressure for a tank with an aluminum dome roof is being calculated, the weight of the roof, including structure, shall be added to the weight of the shell. Vents shall be sized so that the venting requirements can be handled without exceeding the internal design pressure.

5. For Large, Welded, Low-Pressure Storage Tanks, design pressure, in pounds per square inch gauge, shall be at least equal to the total pressure on the wall of the tank at the level where the cover plate is located or shall be 15 pounds per square inch gauge, whichever is greater. The design pressure for the gas vapor space of the tank shall not exceed 2 pounds per square inch gauge.

6. As with jacketed vessels, some tanks such as double wall tanks will be subject to an external design pressure, because the external pressure in the annulus between the walls may exceed the internal pressure, even when the internal pressure is at or above gauge pressure. Open vents or other means of relieving the annulus pressure is often employed to limit this external pressure.

7. If a control or block valve is installed downstream the heat exchanger, the design pressure shall be the same of the upstream equipment or the actual shut-off pressure of the upstream purchased pump. If a control or block valve is installed upstream the heat exchanger, the design pressure shall be calculated as the design pressure of the downstream equipment at the inlet point plus 1.20 times the pressure drop of the circuit between the heat exchanger inlet and the inlet points of the downstream equipment plus static head (if any).

8. For S&T heat exchangers, design pressure of one side shall not be less than operating pressure of the other side.

9. For lines and equipment located on discharge side of rotating machineries (pumps, compressors, …) and are not protected by pressure relief valve, design pressure shall be:

- Maximum shut-off
- Blocked-in pressure plus static head (if any)
- Above mentioned pressure whichever is greater.

10. OVHD condenser and reflux drum: design pressure will be calculated based on the column top operating pressure.
Bottom reboiler: design pressure will be calculated based on the maximum column bottom operating pressure plus static head.

11. For equipment in equilibrium with ('riding on the') flare, the design pressure of the equipment is at least the maximum flare back pressure at any point of the flare system or the flare design pressure, whichever is higher.

12. Hydraulic pressure due to the relative elevation between equipment and also the PSV's location shall be considered.

13.Special equipment – it should be noted that some items of equipment, e.g. glass lined vessels, carbon block exchangers etc., may have design difference between the two sides of the unit, rather than maximum system design pressure.

14.Particular Cases: The Design Pressure (DP) of the Equipment is as follows:

Compressors

At the reciprocating compressor discharge:

DP = MOP + 2 bar for MOP ≤ 20 bar g,

DP = MOP + 10% for MOP > 20 bar g.

PSVs are required.

At the discharge of the centrifugal compressor:

DP = MOP + 1 bar for MOP ≤ 10 bar g,

DP = MOP + 10% for MOP > 10 bar g.

Generally, surge pressure is above design pressure and PSVs are required.
Consideration shall be given to compressor arrangement to determine the settle-out pressure of the isolated system. The settle-out pressure is the equilibrium pressure reached between the suction and discharge isolating valves of the compressor system when the compressor is stopped or shut down.

Generally, the design pressure of the equipment and piping at compressor suction shall be above this settle-out pressure in order to avoid unnecessary lifting of PSVs. For variable speed compressors, the maximum discharge pressure shall be calculated from the performance curve at the maximum trip speed setting prior to arriving at design pressure considerations.

Pumps

a- Centrifugal pumps

- Generally, no PSVs are provided at the discharge of centrifugal pumps and the design pressure shall be the discharge pressure of the pumps at no flow with the maximum suction pressure and the maximum specific gravity

- When the discharge pressure of the pumps at no flow is not available, this pressure can be estimated:

$$P_d = P_{s\max} + \frac{1.2 \cdot head \cdot d_{\max}}{10.2}$$

P_d = design pressure at pump discharge (bar g)

$P_{s\ max}$. = design pressure of suction drum + static head at d_{max} and at High Liquid Alarm Level (barg)

head = head of the pump at design point (m)

d_{max} = maximum specific gravity of liquid pumped under normal operating conditions

b- Positive displacement pumps

At discharge of positive displacement pumps:

DP = MOP + 1 bar	for MOP ≤ 10 bar g,
DP = MOP + 10%	for MOP > 10 bar g.

PSVs are required.

In case of two pumps in series, the maximum differential head shall be the sum of the maximum differential head of each pump if there is no pressure relief valve between the pumps.

Heat exchangers design pressure

Maximum Operating Pressure (barg)	Minimum Design Pressure (barg)
0 < MOP ≤ 1	3.5
1 < MOP ≤ 3.5	5
3.5 < MOP ≤ 17	MOP + 2
17 < MOP ≤ 70	MOP x 1.1
70 < MOP ≤ 140	MOP + 7
140 < MOP	MOP x 1.05

Loss of containment of the low-pressure side to atmosphere, is unlikely to result from a tube rupture where the pressure in the low-pressure side (including upstream and downstream systems) during the tube rupture does not exceed the corrected hydrotest pressure.” It should also be noted that:

“Pressure relief for tube rupture is not required where the low-pressure exchanger side (Including upstream and downstream systems) does not exceed the criteria noted above. “The corrected hydrotest pressure is defined as:

“Hydrostatic test pressure multiplied by the ratio of stress value at design temperature to stress value at test temperature.”

The recommended practice consists of oversetting, if necessary, the design pressure of the low-pressure side of heat exchanger:

- In all cases up to limit of 150#
- After analysis, case by case, for higher pressure

This practice applies only to the heat exchanger itself and does not concern relevant piping and valving. Since double pipe type heat exchangers are considered a piping item, they are excluded.

As an alternative to relief valve installation the design should consider the capacity of the shell side piping and downstream unit to accept the tube rupture case.

Full vacuum conditions shall be added to design conditions since vacuum can happen during cooling of such equipment (when not connected to atmosphere) unless fully reliable protective devices are provided (vacuum breaker, pressurization gas, low pressure switch).

Columns

For columns, the same design pressure shall be selected for the top of a fractionation tower and associated condenser, reflux drum and inter connecting piping. The design pressure at the bottom of a column (vapor phase) is determined by adding the column pressure drop to the column overhead design pressure.

Liquid density and maximum liquid height in the bottom shall be specified on the process data sheet to allow the vessel designer to calculate the bottom thickness. Special attention shall be paid to the case when the hydrostatic test is to be done in the vertical position, e.g. a field test, as the tower will be filled with water. A water column equal to column height shall be considered when calculating vessel thickness.

Design Temperatures

The design temperature is the value used for the mechanical design of equipment. In all cases, design temperatures of all equipment shall be quoted as Maximum design temperature /Minimum design temperature.

Equipment operating above 0°C

Max. design temperature = max. operating temperature + 15°C or maximum exceptional operating temperature, whichever is the greater.

Note: exceptional operating temperature shall be considered for operations exceeding a total of 100 hours per year.

Maximum design temperature for equipment exposed to solar radiation shall be at least 85°C.

This value should be examined case by case for equipment on which dilatation problems can occur (such as double wall tank, fixed tube sheet, plate heat exchanger) and for insulated high pressure vessels (not to increase wall thickness).
For those equipment items not exposed to solar radiation the maximum design temperature for all equipment shall be at least 55°C. This is the maximum estimated temperature that can be achieved in insulated equipment and equipment shaded from the sun after prolonged shutdown.

Equipment operating below 0°C

As a general rule the minimum design temperature shall be:

TD = TSM - 5°C, or minimum ambient temperature, whichever is lower.

Where:

TD: Minimum Design temperature (°C)
TSM: Minimum continuous operating temperature (°C), however see Note (1) below.

Notes:

- When applicable, the exceptional temperature generated by depressurization of equipment or interconnected items system shall be indicated as well as the related residual pressure. Depending upon the depressurization philosophy of the plant, dynamic simulations of equipment have to be performed using commercial or in-house software so as to determine the relevant pressure and temperature of depressuring conditions

- Temperature associated with a gas blow by from one equipment item shall be considered for the buried drum (belonging to the drainage system) design temperature.

- When applicable an exceptional 'hot' design conditions set (e.g., temperature and related design pressure) may be added to the 'cold' design conditions set for equipment operating at low temperature. (An exceptional condition may be steam out etc.).

Emergency Depressurising

The minimum design temperature must take into account any depressurization and re-pressurisation (depending on material selection) of the equipment / piping that may occur either during an emergency or shutdown situation or gas blow-by from one equipment item to another equipment item and to the possible consequence of a change of material. The emergency depressurizing shall impact the material selection as follows:

Piping material

Piping material shall be selected taking into account the minimum temperature encountered during depressurization. Piping re-pressurisation shall be considered as to be performed with the minimum depressurization temperature.

Line Sizing Criteria

This paragraph shall not be applied to the flare lines. The pressure drop and velocity guidelines provided may be used for the preliminary sizing of lines. However, the final sizing shall also take into account other factors, such as pump NPSH requirements, pressure drops available, and specific process requirements.

Where specific maximum velocity limits are given, these shall not be exceeded.

Vapour and steam lines	ρv^2 max. ($kg.m^{-1}.s^{-2}$)	Max. Velocity (m/s)	DP (bar/km)	
			Normal	Maxi
- Continuous operation				
P <= 20 bar g	6000		)	
20 < P <= 50 bar g	7500		)	
50 < P < =80 bar g	10000		) Pressure drop must be	
80 < P <= 120 bar g	15000		) considered compatible	
P > 120 bar g	20000		) with corresponding service	
- Compressor suction	Compatible with above		0.2	0.7
- Compressor discharge	Compatible with above		0.45	1.15
- Discontinuous operation				
P <= 50 bar g	10000		)	
50 < P <= 80 bar g	15000		) Pressure drop must be	
P > 80 bar g	25000		) considered compatible	
- Column overhead	15000 (high pressure columns)		) with corresponding service	
- Stripper vapor return			0.2	0.45
- Kettle vapor return			0.2	0.4
Steam lines				
- P <= 10 bar g				
Short line (L <= 200 m)	15000		0.5	1.0
Long line (L > 200 m)	15000		0.15	0.25
- 10 < P <= 30 bar g				
Short line (L <= 200 m)	15000	42	1.2	2.3
Long line (L > 200 m)	15000	42	0.25	1.0
- P > 30 bar g				
Short line (L <= 200 m)	15000	30	1.2	2.3
Long line (L > 200 m)	15000	30	0.35	1.0
Vacuum (<0.2 bara)			0.001	0.002

Liquid line type	ΔP (bar/km)		Max. Velocity. (m/s) (2)			
	Norm.	Max.	To 2"	3" to 6"	8" to 18"	from 20"
Pump suction						
- Liquid at bubble point with dissolved gas	0.6	0.9	0.6	0.9	1.2	1.5
- Non boiling liquid	2.3	3.5	0.9	1.2	1.5	1.8
Unit lines						
- Liquid at bubble point with dissolved gas	0.6	1.0	0.6	1.0	1.4	1.8
- Non boiling liquid	2.3	3.5	0.9	1.2	1.8	2.4
Pump discharge (1)						
- Disch. pres. <= 50 bar g	3.5	4.5	1.5 to 4.5 m/s			6.0
- Disch. pres. > 50 bar g	7.0	9.0	1.5 to 4.5 m/s			6.0
Column outlet	0.6	0.9	0.6	0.9	0.9	0.9
Gravity flow	0.25	0.45	0.6	0.6	0.6	0.6
Water lines (CS)(3)						
- Cooling water & service water (4)						
Large feeders between pumps and units	1.5		1.5 to 3.0 m/s			
Unit lines (long)		1.5	1.5	2.5	3.0	3.0
Unit lines (short)		3.5	1.5	2.5	3.0	3.0
- Boiler feed						
Pres. <= 50 bar g	3.5	4.5	1.5 to 4.5 m/s			6.0
Pres. > 50 bar g	7.0	9.0	1.5 to 4.5 m/s			6.0
-Sea water lines			2.5 to 3.5 m/s (2 m/s mini)			
- Steam cond. return			1 to 1.5 m/s			
- Reboiler feed (for indication)	0.2	0.4				

Notes:

1) 3.0 m/s maximum (2 m/s average) at storage tank inlet or in loading.
2) Vendor and/or Licensor requirements could supersede maximum velocity values upon COMPANY approval.
3) Special considerations can be applied for copper-nickel or glass reinforced plastic piping Upon COMPANY approval.
4) Velocities below 1 m/s shall not be used for cooling water service to avoid solids deposition.
5) For amine service velocity should not exceed 1 m/s to avoid corrosion/erosion.
6) For lines containing mixtures of hydrocarbon and water, velocity should be limited to 1 m/s to

avoid generation of static.
7) 60 to 98% sulphuric acid lines velocity should not exceed 1.2 m/s to avoid corrosion.

Line sizing criteria for two phase flow

For preliminary mixed phase fluid line size calculations, the average density method shall be used while considering the following criteria:

- V_m : 10 to 23 m/s
- $\rho_m V_m{}^2$: 5000-10000 Pa
- $\rho_m V_m{}^3$: 100000-150000 kg/s^3

Where:

- $\rho_m = W/((W_L/\rho_L) + (W_V/\rho_V))$ in kg/m^3
- $W = W_L + W_V$ = Total rate in kg/h ρ_L = liquid density in kg/m^3
- W_L = liquid flow rate in kg/hr. ρ_V = Vapor density in kg/m^3
- W_V = vapor flow rate in kg/hr.

And the apparent velocity V_m expressed as:

- $V_m = 4W/((3600)\ \rho_m \pi D^2)$ in m/s

  D = internal diameter of the line in m

In general, continuous flow patterns should be ensured such as:

- Stratified, annular, bubble, wavy flow patterns, etc. For horizontal lines or slightly sloped.
- Annular or bubble flow, etc. For the vertical lines
- For horizontal lines in slug and plug flow regimes and for vertical line in slug flow regimes reinforced anchoring shall be specified.

Line sizing criteria for offsite line

The following criteria are typical and shall have to be supported by economic appraisal

LINE TYPE	DP (bar/100m)		Max. velocity (m/s)
	Normal	Maximum	
Long Carbon steel water line	0.058	0.116	-
Bonna concrete pipe	-	-	2.5 to 3
Steam condensate (mixture)	0.02 to 0.03	-	-

Corrosion/Erosion Criteria

Corrosion

For corrosion resistant material (SS, Special alloys…), no limitation of flowing velocity up to 100 m/s and no requirement for corrosion allowance.

For non-corrosion resistant material, in corrosive fluid service, a corrosion allowance for the design service life and corrosion inhibitor injection are required. The flowing velocity is limited by the inhibitor film integrity. The process designer shall consult the project material and corrosion specialist who shall be responsible for implementing COMPANY approved guidelines.

Erosion

For Duplex, SS or alloy material, the flowing velocity shall be limited to :

- 100 m/s in single phase vapor lines and multiphase lines in stratified flow regimes (65 m/s for 13 % Cr material),
- 20 m/s in single phase liquid lines and multiphase lines in annular, bubble or hydrodynamic slug flow regime,
- 70 m/s in multiphase lines in mist flow regimes

For Carbon Steel material:

- In case of continuous injection of corrosion inhibitor, the inhibitor film ensures a lubricating effect which drifts the erosion velocity limit. The corrosion inhibitor erosion velocity limit shall be calculated taking into account the inhibitor film wall shear stress.

- In case of uninhibited fluid, the API RP 14 E recommendation shall apply: the flowing velocity must be maintained below the erosional limit:

$$V_e = C/ (\rho_m)^{0.5}$$

With: Ve erosional velocity in m/s
ρ_m gas / liquid mixture density at flowing conditions in kg/m3 the empirical constant 'C' is equal to 183 to 207. C values of up to 245 can be considered on peak flow rates only in case of absence of abrasive (solid) particles such as sand. When solid and/or corrosive contaminants are present C values shall not be higher than 122 in SI units.

Absolute Roughness

Values for absolute roughness for commonly used materials, which are used in liquid and vapor line sizing calculations, are as follows:

Material	Roughness mm (Inches)
Carbon Steel	0.05(0.0018)
Corroded Carbon Steel (For Flare Lines)	0.5(0.018)
Stainless Steel, Duplex Steel (New, Seamless, Cold Drawn)	0.03 (0.0012)
Stainless Steel (Hot Rolled, Longitudinally Welded)	0.05-0.1 (0.0019-0.0039)
Titanium (New, Seamless, Cold Drawn)	0.03 (0.0012)
Titanium (Cold Rolled, Longitudinally Welded)	0.05-0.1 (0.0019-0.0039)
Galvanized Carbon Steel	0.15 (0.0059)
GRP	0.02 (0.0008)
Epoxy Lined Pipe	0.15 (0.0059)

EQUIPMENT DESIGN CRITERIA

The minimum margin between the normal and rated flow for a pump shall be as below:

- Reflux pump = +20% of normal flow
- Other process pump = +10% of normal flow
- Utility pump = +10% of normal flow
- Export pump from storage to pipeline (continuous operation) = +15% of normal flow
- Loading Pump (to road and rail tankers or marine vessels) = +0% of nominated loading rate.
- Boiler feed water pump = See applicable codes but not less than +10% of normal flow

To be noted that:

- Normal and rated flow shall be identical in such instances as:

    1. Intermittent service pumps: e.g. sump pump.
    2. When the pump has been overrated to allow for a centrifugal type and if overrating is ≥ 10%.
    3. Re-circulation flow such as for product loading lines or through amine filtration system.

- Pump automatic start shall generally be done through the Flow Switch Low Low (FSLL) (if flow transmitter already exists) but shall need to be examined on a case-by-case basis. The determination of automatic start shall be based on consideration of the following guidelines and applicability:

    1. Personnel safety: for example, flare knockout drum pump shall be started in order to avoid liquid in flare tips. In that case, considering the discontinuous operation of flare drum pumps, the start of the spared pump can be performed by Level Switch High (LSH) or by Distributed Control System (DCS) logic.
    2. Equipment safety: for example, Boiler Feed Water (BFW) pump shall be started in order to protect the steam drum and the steam coil.
    3. Severe process upset: pumps that can generate a process unit trip or that can generate an off-spec product shall have spares that can be started automatically.
    4. Flaring: automatic start shall not be considered to minimize the flaring, for example reflux pumps, unless a severe process upset is faced.

Suction Calculation

This calculation yields the system pressure available at the pump centerline of horizontal pumps or at the centerline of the suction inlet nozzle for vertical shaft pumps. It involves the summation of the feed vessel's normal operating pressure, the static head loss, the pressure drop in the suction piping resulting from friction, inlet-exit, and other losses.

The static head for vertical vessels is calculated from the bottom tangent line while for horizontal vessels, the bottom invert line is used. Usually, no credit is taken for the head contributed by liquid operating levels in a vessel. This should be reviewed on a case-by-case basis.

a) Suction line equivalent length (Le)

Equivalent length may be calculated in two ways for the suction lines, either the user inputs straight line length and fitting factor and the Le is calculated by multiplying the two, or the Le is estimated from the pipe diameter d (inches) as follows:

Pumping temperature < 150° C Le = (8d+30) m

Pumping temperature >= 150° C Le = (12d+30) m

NB: the estimation excludes an allowance for suction strainer. This shall be included as an additional loss

b) Centerline elevations of horizontal pumps

The pump centerline elevation is selected from the table below. If the flow exceeds 4540 m3/h the Mechanical group shall be consulted.

The suction pipe for fluids at or near their bubble point shall be adequately sized if the pressure drop is in the range of 0.01 to 0.06 bar/100m.

m^3/hr.	m
Up to 45.4	0.76
45.4-227.1	0.91
227.1-2271	1.07
2271-4542	1.37

Net Positive Suction Head Available (NPSHA)

NPSHA is calculated by deducting the vapor pressure of the fluid at pumping conditions from the Suction Pressure and converting it to pressure head in terms of liquid column.

Process engineers shall include a Safety Margin of 1.0 m in the NPSH calculated for:

- All boiling point fluids either single or multi-component.
- Fluids that contain dissolved gas.
- Foaming fluids.

In the case of boiler feedwater pumps, a margin of 2.0 m shall be used.
The static head used in calculating the NPSH shall be taken from either the tangent line or bottom invert line in the suction vessel to one of the following:

- The center line of a horizontal or rotary pump.
- The suction impeller on a vertical centrifugal pump.
- The design of suction lines from storage tanks shall be based on the NPSH taken from the lowest specified level in the tank at which rated pump capacity is required.
- Suction line sizing for reciprocating pumps shall take into account acceleration head.

Discharge Calculations

For pump discharge lines when fittings and valve count are not available, a reasonable estimate of the total equivalent length can be made by multiplying the approximate run of actual pipe by the multiplying factor. Details of applicable factors are given below.

Equivalent Line Length Calculation

The total equivalent length (Le) can be calculated using a factor multiplied by the straight length of pipe or by adding up the equivalent length of pipe fittings and the straight length of pipe. This method shall be used when pipe routing has not been finalized / defined.

TABLE OF FITTING FACTORS

Line sizes, diameter	**Approximate line length , ft**		
	100	200	500
	Multiplying Factor		
3in or less	1.9	1.6	1.2
4in	2.2	1.8	1.3
6in	2.7	2.1	1.4
8in or over	3.4	2.4	1.6

Shutoff Pressure

The shutoff pressure of a typical centrifugal pump is approximately equal to the sum of the maximum suction pressure and 120% of the net differential pressure generated by the pump, based on the maximum anticipated fluid density. Other pumps with steep Head-Flow curves such as turbine, multistage and mixed flow pumps, however, shall have higher shutoff pressures. The process engineer specifying these types of pumps shall consult with the Rotating Equipment Group to determine this value since it may influence the design pressure of downstream equipment.

The maximum discharge pressure sets the design pressure of a pump casing. This is the sum of the maximum suction pressure and maximum differential pressure, which usually occurs at zero flow. In cases where the feed vessel is protected by a safety relief valve, the maximum suction pressure shall be equal to the sum of the safety valve set pressure and the maximum static head.

Equipment Pressure Drops

The following typical pressure drops shall be used in line size calculation when the actual pressure drop data are not available:

TYPICAL EQUIPMENT PRESSURE DROPS (bar)	
Coalescer	0.7
Dessicant Drier	1.0
Desalter	1.7-2.7
Exchangers: S&T, Double-pipe & Air Coolers Box Coolers	 0.35-0.7 3.5
Fixed Bed Reactors	1.4-3.5
Flow Orifice	0.14
Orifice Mixer	0.35/plate
Pump Suction Strainer	0.07
Rotary & Turbine Flow Meters	0.4

For systems involving multiple heat exchangers in series, consult with the Heat Exchanger Group for pressure drop estimation.

Control Valve Pressure Drop

The control valve normal pressure drop is calculated in three ways:

- 33% of frictional pressure drop or,
- 10% of operating pressure or
- The value corresponding to a control valve pressure drop of 0.7 bar at maximum flow.

The maximum of these three values is inputted into the calculation for the net design discharge pressure.

For systems operating above 69 barg, the control valve may take less than 10% of the operating pressure, depending on process and control considerations.

The pressure drop of a control valve on the discharge of a pump should be a minimum of 20% of the system dynamic pressure loss at normal flowrate, or 0.7 bar, whichever is greater. (This criteria do not apply to loading pumps).

Pump Efficiency

The efficiency of centrifugal pumps varies from about 20% for low-capacity pumps (less than 6.3 m3/h) to a high of almost 90% for certain large capacity pumps. Low head pumps using open type impellers are less efficient than closed impellers.

Compressors, Fans & Blowers

International Standards are utilised to identify tolerances for rotating equipment, such as the API 600series. In addition, the following criteria shall be applied.

- Normally no margin is taken if the flow is constant, a 10% margin can be used if the flow is directly coming from a production separator to take into account slugging regime.

- The variations of gas compositions, molecular weight, specific heat ratio etc., and the operating conditions (mainly suction pressure and temperature) shall be taken into account to determine the sizing case, and shall be listed on the Process Data Sheet

Compressor Process Specifications

Operating Case

If more than one case exists, all these alternative cases shall be included in the specification so that the compressor vendor is able to evaluate the most stringent case for design.

Capacity

The volumetric flowrate capacity shall be determined by the compressor manufacturer from the data sheet provided. The process engineer shall determine the mass flowrate based on minimum, normal and maximum flow conditions.

Suction Temperature

Suction temperature is to be accurately specified since it is directly related to the volume of gas at suction conditions, the discharge temperature, and the horsepower requirements. It is important for the vendor to know the minimum and maximum temperatures for proper compressor design and selection of correct driver rating.

Suction Pressure

Suction pressure is the pressure at the suction flange of the compressor and not before filters, pulsation dampers, etc. The suction pressure shall be accurately specified.

Molecular Weight

Molecular weight is an important consideration in the design of a centrifugal compressor. When this or any type of compressor is to be used in multiple services, the vendor is to be supplied with data on the molecular weight of the gases in each of these services.

Specific Heat Ratio

The specific heat ratio is also an important consideration in the design of centrifugal and reciprocating compressor as it affects both power and efficiency of the machines. It shall be clearly documented what the basis for the stated specific heat ratio e.g. ideal or polytropic etc.

Compressor Power Estimation

Compressor power estimates shall include gear losses. When a compressor is to be used in vacuum or refrigeration service, peak driver load may be required during start-up and a footnote to this effect is to be added to the specification form. The final determination of compressor power requirements and discharge gas temperatures is part of the vendor's responsibility.

Gas Composition

This is to be supplied by the process engineer and is to be expressed on a wet basis if the gas contains moisture.

Discharge Temperature (maximum allowable)

This is to be supplied by the process engineer when a known process limitation exists. Discharge temperatures are limited by gas reactions, eg. polymerization or in the case of air compressors with the lube oil, safe lubrication temperatures. Some compressors are limited by mechanical considerations and these shall be defined by the Mechanical Equipment Group and the compressor vendor.

Corrosive Compounds

Corrosive compounds in the gas (such as sulphur oxides, hydrogen sulphides, acidic compounds, chlorides, etc.), shall be specified by the process engineer as these may determine the selection of materials by materials group or the compressor manufacturer.

Start-up considerations

Start-up methods shall be considered by the process engineer since items such as anti-surge control systems, bypass lines, valve lifters and pockets on reciprocators, etc., are involved. In addition, compressors generally require a running-in period during which time an alternative feed gas may be used. If air is to be used for running-in, then suitable vents, etc. may be an additional requirement.

Compressor Selection and Comparison

Centrifugal compressors are the preferred type for the majority of applications. Reciprocating compressors shall be considered for conditions of low flow, high differential pressures, intermittent loads, varying gas densities, and varying discharge pressures, combined with moderate temperatures. Screw compressors shall be employed for applications involving relatively low flows and differential pressures. Their selection shall be referred to the rotating equipment specialists.

Safety Considerations

The following potential hazards shall be considered for compressor installations.

a) At high pressures, many reactions proceed at higher rates, e.g. the reaction between a hydrocarbon lube oil and oxygen or air. The discharge temperature of air from reciprocating compressors is generally limited to about 149-166°C. Compressor circuits frequently have automatic shutdown instrumentation, which operates on high gas discharge temperature.

b) Excessive discharge pressures from positive displacement machines can be attained if a discharge valve is inadvertently closed. Therefore, safety valves are mandatory for this class of compressors.

c) Adequate ventilation of the compressor house shall be provided when compressing toxic or flammable gases. This is frequently accomplished by omitting the siding from a portion of the compressor house.

d) Adequate inlet KO drums shall be provided where necessary to prevent liquid slugs from damaging compressors. Providing demisters in the KO drum can reduce entrainment.

e) Rotating compressors and their drivers have speed limitations. Trip-outs are indicated and these are usually supplied by the vendor and specified by the Mechanical Equipment Section.

Heater and Boiler

The design margins to be applied are as follows:

- Fired heaters and furnaces: 10% on design duty
- Boilers: 10% on design flow rate

Vessel

Overdesign Factor

- First separation equipment (plant inlet): 10% on inlet gas flow rate
- Other drums: 0% unless specific requirements
- Fractionation column: 0% unless specific requirements

Diameter Calculation

Use the following equation and K-values and derating value from the tables to calculate terminal velocity

$$U_T = K\sqrt{\left(\frac{\rho l - \rho v}{\rho v}\right)}$$

K-Values

Device	Typical Souders-Brown K Value* m/s
Mesh Vertical Flow to Mesh	0.11
Mesh Horizontal Flow to Mesh	0.13
Vane (simple profile) — Vertical Flow to Vane	0.15
Vane (simple profile) — Horizontal Flow to Vane	0.20
Vanes with single or double pockets — Vertical and Horizontal Flow to Vane	0.20 to 0.30
Vertical Flow To Axial cyclone	0.15 to 0.24
Combination Vane / Mesh Vertical Flow	0.15
Combination Vane / Mesh Horizontal Flow	0.20
Axial cyclone Combinations Vertical Flow	0.15 to 0.24

De-rating factor to K-value for pressure

Pressure, kPa (ga)	De-rating For Mesh Demisters At Elevated Pressure
Atmospheric	1.00
1034	0.90
2068	0.85
4137	0.80
7929	0.75

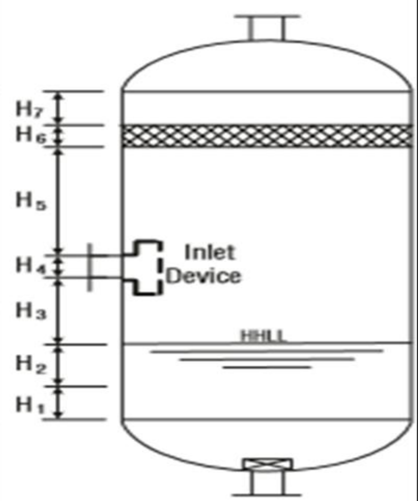
Finally, by having Q_V and U_V, diameter is calculated.

$$ID = \sqrt{\left(\frac{4Qv}{\pi Uv}\right)}$$

If a mesh pad is used, then $ID_{selected} = ID_{calculated} + 150$ mm

Height Calculation

Dim	Section	Distance
H_1	Bottom Tangent to LLLL	300–450 mm, can be lower depending on instrument mount
H_2	LLLL to HHLL	Per required surge time or retention time
H_3	HHLL to Feed Nozzle Bottom	300–600 mm for diffuser 0.25 D for all other inlet devices, with 600 mm minimum
H_4	Nozzle Diameter	Larger of piping size or velocity head criteria
H_5	Nozzle Top to Mist Eliminator Bottom	300–900 mm for diffuser 0.5D for all other inlet devices
H_6	Mist Eliminator	100-150 mm typical
H_7	Mist Eliminator to Top Tangent	150 mm minimum or per



Manholes

- Size of manholes = 24”

- Location of manholes

  At the opposite side of the utility connection for horizontal vessel
- Number of manholes

1. For vessel length/height less than 6 m a single manhole shall be provided. For other vessel (length/height > 6m), two manholes to be provided at least ; one manhole each 6 m for longer /higher vessel. If vessel is equipped with internals (baffles etc.) , one manhole to be provided on each compartment.
2. For Trayed column, Manhole shall be provided at the top, below the bottom tray, at the feed tray, at any other tray at which removable internals are located, and at intermediate points so that the maximum spacing of manholes does not exceed 15 trays. Tray spacing with manholes in the internal shall be at least 900 mm.

Handhole

Handhole size = 8”.

Vortex Breaker

Vortex breaker to be installed for the following services:

- Pump suction
- Outlet to thermosiphon or kettle reboilers
- Letdown to a low-pressure system

Drains and Vents Connections

- Location

The drain of the vessel shall always be at the lowest point of a vessel. For vertical vessels they shall be connected to the bottom outlet line at the low point. For horizontal vessels the drain point shall be directly on the bottom of the drum at the lowest point ensured through vessel slope (1:100).

- Vent and drain diameter shall be defined as follows:

Volume or diameter of vessel (m^3 or mm)	Vent diameter (minimum)	Drain diameter (minimum)
$V \leq 15$ or $D \leq 2500$	2"	2"
$15 < V \leq 75$ or $2500 < D \leq 4500$	2"	3"
$75 < V \leq 220$ or $4500 < D \leq 6000$	3"	4"
$220 < V \leq 420$ or $D > 6000$	4"	4"
$V > 420$	6"	4"

Elevation of Equipment

As a general rule for a vessel containing a liquid at its boiling point, a minimum elevation of 5000 mm shall be specified when supplying a centrifugal pump. The elevation shall be updated when NPSH requirements are defined with rotating equipment specialist. If there is no process requirement regarding the elevation, a note on PID shall be indicated “Minimum for piping”.

Nozzle Sizing

The following criteria for vessel and column nozzles design shall be used:

- Inlet line:

  1. $\rho * V^2$ max = 1500 if no inlet device is foreseen
  2. $\rho * V^2$ max = 3000 if half pipe or baffle inlet device is foreseen
  3. $\rho * V^2$ max = 6000 if other vane pack inlet device is foreseen

- Outlet line:

The same criteria which are used for line sizing shall be used.

Notes

Size of Inlet, Gas Outlet and Liquid Outlet Nozzles

Inlet

- Size based on normal volumetric flow + 10% (liquid + vapor flow)
- Limit inlet velocity to 7-13 m/s
- Round nozzle diameter up or down to nearest standard size

Gas outlet

- Size on normal flow
- Velocity limit 15-30 m/s

Liquid outlet

- Normal flow + 10%
- Velocity limit 1-3 m/s HC
- 2-4 m/s water

Columns and Trays

Towers shall be sized based on flows that are 110% of the respective material balance figures to allow for any vagaries in the equations of state, operational control around the material balance duty point and effects of fouling etc. Tray loadings used for sizing should be the vapor to the respective tray and the liquid leaving it.

Towers Recommended Minimum Tray Spacing and Oversizing

TRAY DIAMETER	TRAY SPACING
1300 mm ID or less	450 mm
1300 to 3000 mm ID	550 mm
3000 mm ID and larger	600 mm

Valves

- Butterfly Valve: This type shall be used in services with large volume flow and low-pressure drop (less than 5 bar). High duty or triple offset butterfly valves, e.g. fire-safe in fuel gas services, shall be used for tight shut-off when these are more cost-effective than ball valves.

- Ball Valves: This type shall generally be used as block valves. Characterized balls shall be used as control valves when the fluid tends to crystalize, or where a high C_v is required. Ball valves shall be trunion type suitable for bi-direction shut-off, unless otherwise specified.

- Angle Valve: This type shall be considered when the pressure drop is very high, where there is a risk of accumulation of solids, or where the fluid velocity is extreme.

- Globe Valve: For standard applications!

General Guideline for Valves and PSVs Body

1. Cast Carbon Steel, A216 Gr WCB/WCC or forged carbon steel, A105 is used in non-corrosive service from -28C to 427C. Low temperature carbon steel, A352 Gr LCB/LCC can be used down to -46C (stainless steel may be considered as an alternative)
2. Alloy Steel, A217 Gr WC1, WC6, WC9 is used for temperatures above 427C. WC9 may also be used for flashing services.
3. Stainless Steel, A351 CF8 is used in flashing services, corrosive service and for temperatures below -28C.

4. Monel is used in pure oxygen services.

Valve Trim

1. As standard the material shall be AISI 316, unless otherwise specified.
2. Erosion-resistant trim with hardened or hard-faced surfaces are required when the pressure drop across the valve exceeds 10 bar, the temperature is above 315C, the pressure drop across the valve exceeds 5 bar in steam service, or when there is a risk of flashing /incipient cavitation.
3. Cobalt-based alloys must not be used for hard-facing in boiler feed water and amine service.
4. Anti-cavitation trim is selected for high-pressure drop applications to prevent the onset of cavitation.
5. Anti-noise trim is selected for reducing the noise generated by the fluid.
6. Trim material for butterfly and gate valves may be the same as the body material.

Packing

1. The packing design for linear motion valves shall include a packing flange.
2. PTFE shall be used as standard packing material for bonnet temperature below 230C and graphite for higher temperatures. Higher temperatures can be accepted for PTFE if the bonnet is extended. Packing design and material shall be selected carefully for minimum stem friction and live-loading packing boxes shall be considered for PTFE packing.
3. Vacuum service and special services like oxygen, require special packing materials and should be given special consideration.

FLARE AND COLD VENT SYSTEMS

Type of Flare Tip

For flare and cold vents, the tip can be conventional or sonic depending on the required back pressure and noise limitation.
When possible, a sonic tip shall be preferred. Sonic tip with Coanda effect and/or with variables slots are prohibited. The flares shall be smokeless. Suitable media (Steam, Air, Fuel Gas) shall be considered for smokeless operation of Flares.

Radiation Levels Criteria

The radiation levels criteria shall follow the Basic Engineering Design Data. The minimum relative humidity stated on the basis of design shall be applied.

Emissivity Coefficient

When the radiation calculations are performed by a flare vendor it is necessary to check carefully the emissivity coefficient used. The emissivity coefficient used by vendors does not take into account the liquid carry over, they consider an ideal gas/liquid separation. The droplets size for the flare drum sizing and the expected liquid carry over shall be clearly indicated in the flare tip process data sheet.

RECOMMENDED EMISSIVITY COEFFICIENT

For pipe flare:

- Natural gas molecular weight of 18 : 0.21
- Natural gas molecular weight of 21 : 0.23
- Ethane : 0.25
- Propane : 0.30
- See also API RP 521

For sonic flare:

The minimum emissivity coefficient = 0.13 for all gases without liquid carry over, and 0.15 with liquid carryover not exceeding 5% weight.

Lines upstream relieving devices-PSVs

For the line sizing, the maximum capacity of the PSV (recalculated with the selected orifice), shall be considered even if this figure exceeds the actual maximum flow rate due to process limitations. ΔP between the protected equipment and the PSV < 3% of PSV set pressure (API RP 520 Part II)

Inlet line diameter ≥ PSV inlet diameter

- ρV2 ≤ 25 000 kg/m/s2 for ∅ of line ≤ 2”
- ρV2 ≤ 30 000 kg/m/s2 for P ≤ 50 bar g
- ρV2 ≤ 50 000 kg/m/s2 for P > 50 bar g

DEPRESSURISATION DEVICE

- Minimum line size 2”
- ρV2 criteria are the same as for PSV’s

Line downstream relieving devices

Flare and cold vent headers and sub-headers:

- Minimum line size 2”
- Back pressure to be compatible with the protected equipment

Flare Drum Sizing

For flare drum and cold vent drum, the sizing shall follow API RP 521 method with the following droplets size in microns:

- Remote flare or cold vent offshore: 600 μm
- Vertical flare or cold vent onshore: 600 μm

Header Sizing

The major criteria governing the sizing of the header are the backpressure and gas velocity. Flare headers must be large enough to prevent excessive back pressure on the plant safety valves and to limit gas velocity and noise to acceptable levels.

Flowmeter Selection

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