Educational Institute for

Equipment & Process Design

EIEPD

Design Criteria

CONTENTS

Heat exchangers

Shell and tube exchangers and double pipe heat exchangers and process gas waste Heat Boilers	ASME Sec. II, V, VIII Div. 1 or 2, and TEMA Class R, API 660
Surface condensers	ASME Sec. VIII Div.1 / HEI (Heat Exchanger Institute)
Air cooled exchangers	API 661, ASME Sec. VIII
Plate exchangers	API 662, ASME Sec. VIII Div. 1
Welded type heat exchanger	Vendor's standards and / or ASME Sec. VIII Div. 1

Pressure vessels, reactors and columns

Pressure vessels	ASME Sec. VIII Div.1 or 2

Storage tanks

Design and construction of large, welded, low-pressure storage tanks	API 620
Welded steel tanks for oil storage	API 650
Pressurized and spherical storage tanks	ASME Section VIII, Div. 1 or Div. 2

Rotating machinery for process

Compressors	
- Axial and centrifugal compressors and expander-compressors	API 617
- Reciprocating compressors	API 618
- Rotary-type positive displacement compressors	API 619
- Packaged, integrally geared centrifugal air compressors	API 672
Pumps	
- Centrifugal pumps	API 610, except for slurry pumps or any other particular pumps which cannot be covered by API, well known International standard to be specified.
- Positive displacement pumps – reciprocating	API 674
- Positive displacement pumps – controlled volume	API 675
- Positive displacement pumps – rotary	API 676
- Sealless centrifugal pumps	API 685
Fan	
- Centrifugal fans	API 673
Liquid ring vacuum pumps and compressors	API 681
Steam turbines	
- General purpose steam turbine	API 611
- Special – purpose applications steam turbines	API 612

Gear	
- General – purpose gear units	API 677
- Special purpose gear units	API 613
Lubrication, shaft-sealing and control-oil systems and auxiliaries	API 614
Pumps-shaft sealing systems for centrifugal rotary pumps	API 682
Machinery protection systems	API 670
Gas turbines	API 616
Chemical injection units	VENDOR'S standard
Ancillary items	VENDOR'S standard

1.10.6 Boiler (except for process gas waste heat boilers)

ABMA, Press. parts ASME Sec.1, others vendor's standard or equivalent European standard.

1.10.7 Piping

Process piping: ASTM

Electrical

General	IEC, NEC,NEMA, ISO,ANSI, API,EN,CENELEC,BS
Bearing of motors	ISO R281 or equivalent
Illumination level	API 540
Fire alarm system	NFPA, IEC, BS or equivalent
Air craft warning system	IEC 529, ICAO or equivalent
Cathodic protection system	NACE, IEC, NEC or equivalent
Area classification	API RP 505 HTAS suggest to use IEC 60079-10 and IP 15 from the Energy Institute of London- HOLD
Classification of equipment for hazardous areas:	IEC,EN,CENELEC,BS,NFPA,ANSI,API or equivalent (as per licensee approval)
Ex-type electrical equipment selection	IEC 79

Instrumentation

General	ISO, ISA, API, IEC, NFPA
Orifice	ISO 5167
Thermocouple	IEC-60584

Units of measurements

The following units of measurements must be applied:

Temperature	[°C]
Pressure	[bar g[4]], [mm WG]
Volume	[m^3], [l]
Length/diameter	[m], [mm]
Mass or weight	[kg], [MT], [ton]
Volume (gases)	[Nm^3], [kmol]
Flow rate:	
- volume	[m^3/h], [Nm^3/h], [kmol/h]
- mass	[kg/h], [ton/h]
Velocity	[m/s]
Energy	[MJ], [kJ]
Power	[kW], [MW]
Work	[kWh]
Heat capacity	[kcal/kg °C]
Thermal conductivity	[kcal/h m °C]
Heat transfer coefficient	[kj/h m^2 °C]
Absolute viscosity	[cP],
Density	[kg/m^3]
Sound	[dBA]
Electric current	[A]
Voltage	[V]
Frequency	[Hz]
Rotational frequency	[RPM]
Nominal pipe diameter	[inch]
Nozzle size	[inch]

Site conditions

Temperature

Maximum recorded temperature :	52 °C
Minimum dry bulb temperature (*winter*)	5 °C
Winterizing temperature	Not to be considered
Max. wet bulb temperature (*summer*):	33 °C
Max. dry bulb temperature (*summer*):	48 °C
Dry bulb temperature for design of air coolers:	50 °C
Max temperature for mechanical, civil and structural design:	55 °C
Max temperature for equipment exposed to sunlight (design):	85 °C
Design temperature for electrical equipment	
Max. outdoor	48 °C
Max. indoor	45 °C

Humidity

Relative humidity for design	
Ambient Air Relative Humidity	
Maximum in summer	76%
Minimum in winter	74%
Design relative humidity :	
At max. temp. (summer)	65%
At min. temp. (winter)	100%
Electrical equipment	80%

Barometric pressure

Min., mbar	990
Max., mbar	1100

Wind

Shape factor, please refer to building standards as per contractual codes & standards.

Note: Wind design criteria to be based on the UBC. code.

Maximum wind velocity (up to 10m elevation):

Structure calculation:	125 km/h
Flare thermal radiation:	16 m/sec

Prevailing wing direction from NW to SE for mechanical & civil design purpose is to be considered from all directions

Precipitation and snow level

3 min, mm	17
10 min, mm	24
60 min, mm	40
Maximum daily precipitation (24 h)	70

Snow load

Design snow load:	25 kg/m^2

Earthquake

The area has to be classified as a zone 4 as per the uniform building code.

Emissions

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

Noise

Maximum dB(A) at 1 m from equipment	85

Utility Characteristics

Existing utility characteristics are shown below.

Steam

HHP superheated steam

Parameter	Units	Min.	Norm.	Max.	Mech. design
Pressure	bar g	-	98	-	112
Temperature	°C	-	454	-	490

Min fouling factor for heat exchanger design, m²°C/W 0.00020

HP superheated steam import/export

HP super heated steam must be available for start up and shut down.

Min. steam quality:

		Pure Steam
Conductivity µS/cm (after cationic exchanger, and CO_2 removal)		<1
Ammonia wt-ppm (water treatment in deaerator by amine (morpholine))	Natural Gas	<1
Volatile alkalizing Amines, wt-ppm		<15
Methanol, wt-ppm		<4
CO_2, wt-ppm		<2
SiO_2, wt-ppm		<0.02
Fe, wt-ppm		<0.02
Cu, wt-ppm		<0.03
Na+K, wt-ppm		<0.02

Battery limit conditions:

Parameter	Units	Min.	Norm.	Max.	Mech. design
Pressure	bar g	38	43	47	52
Temperature	°C	400	410	430	470

Min fouling factor for heat exchanger design, m²°C/W 0.00025

LP steam

Parameter	Units	Min.	Norm.	Max.	Mech. design
Pressure	bar g	6.5	7	8	9.5
Temperature	°C	-	217[3]		340

Nitrogen

Nitrogen for process
Quality:

Nitrogen, vol %, min.	99.9
Oxygen, ppm (vol), max	2
CO, ppm (vol), max.	10
CO_2, ppm (vol), max.	10
Water, ppm (vol), max.	1
Sulphur, ppm (wt), max.	0.2
Oil	Nil

Battery limit conditions:

Parameter	Units	Min.	Norm.	Max.	Mech. design
Pressure	bar g	6	6	8	10.5
Temperature	°C		Ambient		75

Demineralised water

Quality:

Parameters	Unit	Quantity
pH	-	6.5-7.5
Total hardness	mg/kg as $CaCO_3$	Absent
Chloride as Cl	mg/kg as Cl	<0.1
Iron	mg/kg as Fe	<0.02
Silica	mg/kg as SiO_2	<0.02
Total dissolved solid	mg/kg	<0.1
Copper	mg/kg as Cu	<0.003
Conductivity	µS/cm	<0.15
Sulphur (as SO_4^{2-})	mg/kg	<0.2
Sodium (Na)	mg/kg	<0.01
$KMnO_4$ consumpt. Mn(VII)□Mn(II), as $KMnO_4$	mg/kg	<3
Oil, grease	mg/kg	<1

Min fouling factor for heat exchanger design, m²°C/W 0.00020

Battery limit conditions:

Parameter	Units	Min.	Norm.	Max.	Mech. design
Pressure	bar g		5		7
Temperature	°C		Ambient		65

1.5.5 Cooling water

Closed loop water as cooling media:

Quality

pH 7.5

Chloride, as Cl, mol ppm 10

Min. fouling factor for heat exchanger design, m²°C/W 0.00030

Battery limit conditions:

Parameter	Units	Supply	Return	Mech. design
Pressure	bar g	4.5	1.5	7.5
Temperature	°C	38	Max. 48	100

Turbine steam condenser will be cooled by closed loop cooling water.

Instrument air

Dew point, at 9 bar g -40
Quality Free from oil, dust and water droplets

Battery limit conditions:

Parameter	Units	Min.	Norm.	Max.	Mech. design
Pressure	bar g	6	7	7.5	10.5
Temperature	°C		Ambient		75

Plant air

Quality Free from oil, dust and water droplets

Battery limit conditions:

Parameter	Units	Min.	Norm.	Max.	Mech. design
Pressure	bar g	7	7.5	8	10.5
Temperature	°C		Ambient		75

Electricity

Electricity is to be generally supplied at 20000 V, 3 phases, 3 wires 50HZ. The standard voltage ratings for various utilization loads are as follows:

Item No.		AC/DC	Rated Voltage	Phase/Wire
1.	Motors			
	2500 KW and above	AC	11000/20000	3/3
	Above 150KW	AC	6000V	3/3
	0.2KW and including 150KW	AC	400V	3/3
	below 0.2KW	AC	230V	1/2
2.	Construction & Maintenance	AC	230/400V	1/2 3/4
3.	Lighting Fixtures	AC	230V	1/2
4.	Emergency Lighting Fixtures	AC	230V	1/2
5.	Instruments	AC	110V	1/2
6.	Controls for H.T. Boards	DC	110V	-
7.	Controls for L.T. Boards	AC	230V	1/2
8.	Expected short circuit level	500 MVA at 20 KV supply		

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 exceed 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:

(1) 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 (see Section 12, Software).

(2) 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.

(3) 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 repressurisation(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 repressurisation shall be considered as to be performed with the minimum depressurization temperature.

Vessel material

The minimum temperature due to the blowdown conditions shall be associated with design pressure. Although depressurization of any section of the plant cannot be performed unless the section is isolated and permission is obtained, repressurisation may take place by operator’s error or a valve failure, therefore the minimum temperature shall be associated with design pressure. Credit for special devices to ensure that the plant shall remain isolated and depressurised shall not be considered.

In addition, the above criteria shall ensure safe operation in case of residual piping stress being present (in particular for small diameter nozzle/piping).

Heat exchanger and air cooler

The following conditions mentioned hereafter shall be applied generally up to the next piece of process equipment:

- Consideration for design temperature definition shall be given to cooling medium failure when coolers are used. Downstream of an air cooler, the design temperature is determined considering that 20% of the duty is provided by natural draft. Where possible detailed thermal analysis of natural convection cooling under the worst design ambient conditions shall be performed to arrive at the maximum cooler outlet temperature.
- For the bypassed air cooler, the design temperature of the downstream equipment, if any, shall be the maximum upstream operating temperature of the bypassed exchanger.
- Downstream of other coolers, the design temperature shall be the upstream maximum operating temperature.
- Fixed tubesheet exchangers shall not be used and other designs shall be considered if the difference between the average shell metal temperature and the average tube metal temperature in any tube pass exceeds 28°C.

Cleaning and steam out

The steam-out conditions for vessels are 150°C @ atmospheric pressure. For equipment subjected to steam-out operations, full vacuum condition shall be specified at 150°C.

The accidental temperature which may occur in emergency situations, such as loss of utilities, valve closure, air cooler failure or any abnormal operation lasting for a short duration, is not to be taken into account as long as the temperature increase does not exceed the code’s limits (investigation has to be undertaken with specialists on a case-by-case basis)

However, equipment containing parts which can be damaged by an abnormally high temperature shall be designed for this temperature. This mainly concerns equipment internals.

Material Selection

The following section is provided as a general guideline. Final material selection shall be determined by the materials department.

Material selection used for vessel

Design temperature °C (1)	Steel type
$-196 \leq T < -101$	SS 304 L
$-101 \leq T < -46$	31/2 Ni / SS 304 L
$-46 \leq T < 0$	LTCS
$0 \leq T < 343$	CS

(1) Design temperature corresponding to operating conditions. For temperature due to depressurization, LTCS might be suitable to use at lower temperature (<-45°C) provided that the vessel shall naturally reheat before repressurisation. This limit should be determined by the Mechanical Department, depending on vessel wall thickness.

Material selection used for piping

Design temperature °C	Steel type
$-196 \leq T < -101$	SS 304 L
$-101 \leq T < -46$	SS 304 L
$-46 \leq T < -29$	LTCS
$-29 \leq T < 343$	CS

General considerations

H_2S and CO_2 corrosion results in metal loss and in metal embrittlement (cracking). Sulphide Stress Corrosion Cracking (SSCC) can be limited by using materials listed in the NACE MR0175 / ISO15156. Hydrogen Induced Cracking (HIC) corrosion is directly linked to the material quality, specifically the presence of elongated inclusions and microsegregations. Therefore, HIC control is a matter of material specification.

Post-weld heat treatment

For caustic soda and amine service of any concentration, a post weld treatment for stress relief shall be specified to avoid corrosion cracking.

No post weld heat treatment shall be performed on Austenitic Stainless-Steel materials.

Corrosion allowance

	Corrosion allowance on Carbon Steel and low alloy steel (mm)	Corrosion allowance on Stainless Steel, high alloy steel or cladded steel (mm)
Wet H_2S service	3 min. (1)	0
Corrosive process service (except wet H_2S service) (2)	3 min.	0
Non corrosive process services (3) (4)	3 min.	0
Utility (3) (4)	3 min.	0

However, minimum corrosion allowance should be for carbon steel (including 0.5 Mo alloy steels)

Pressure vessels and other applicable equipment	3 mm
Storage tanks	1.5 mm
Piping	1.5 mm
Removable parts or internals (on each side in contact with operating fluid)	0.75 mm
For stainless steel/titanium / aluminum / alloy	0 mm
Carbon steel with epoxy resin coating	3 mm

Notes:

1) Minimum corrosion allowance depending on corrosion control philosophy

2) e.g. amine systems, sulphur recovery units

3) The corrosion allowance applies for pressure vessels, shell and tube type and air fin type Heat exchangers

4) For piping, refer to piping classes

5) For storage tanks, corrosion allowance shall be:

- For fixed roof tank: 1.5 mm for shell and roof except tank bottom where wall thickness is generally imposed by other constraints
- For floating roof type tank: 0 mm

Protective painting shall be applied on roof and shell (above overflow) where condensation may occur and bottom part of shell where water may accumulate.

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:

• When a non-automatically controlled minimum flow protection has been installed, the permanent recirculation flow (if required) must be added to the net process flow.

• 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 minimise the flaring, for example reflux pumps, unless a severe process upset is faced.

9.1.1 Physical Properties

Physical characteristics of the fluid being pumped are based on the heat material balance verified during the FEED study.

9.1.2 Capacity

Design margins as set out in Section 9.1 shall be applied when setting pump design capacities. For flows less than about 3.4 m3/h, a larger pump is usually purchased and a fixed recycle is added to provide for recirculation of excess pumped fluid to the suction supply. An orifice plate is frequently included in the bypass line and this can be supplied by the pump vendor, who shall size the orifice for a minimum flow requirement. The pump requisition sheet shall specify a capacity equal to the desired flow (including extra capacity) plus the amount bypassed.

9.1.3 Suction Calculation

This calculation yields the system pressure available at the pump centreline of horizontal pumps or at the centreline 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 inthe 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: -

a) All boiling point fluids either single or multi-component.

b) Fluids that contain dissolved gas.

c) 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 centre 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.

9.1.5 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 in section 10.3.6.

9.1.6 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.

9.1.7 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.

9.1.8 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 Cooling Water Requirement

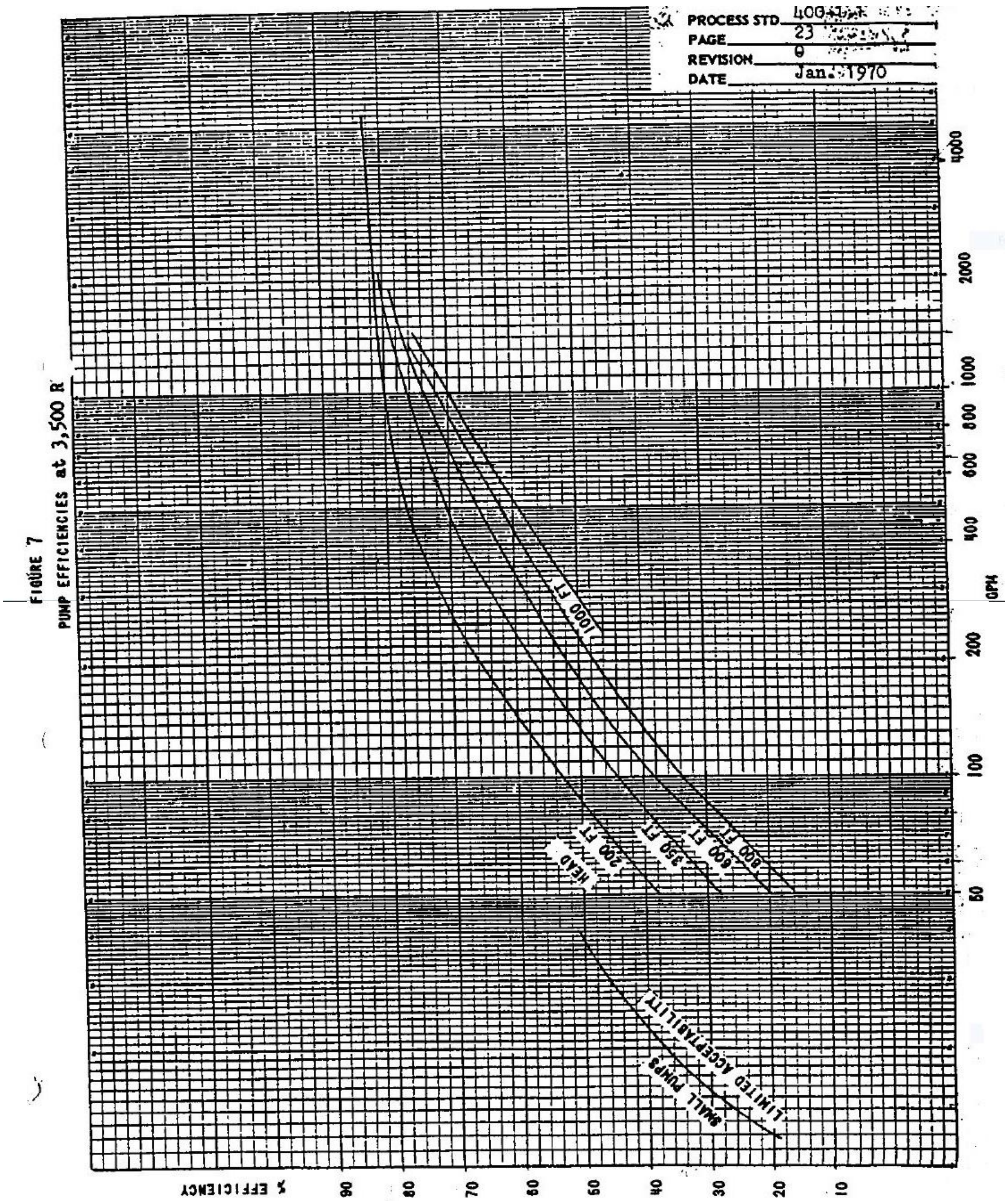
Cooling water, preferably fresh, is used to cool bearings, stuffing boxes, pedestals and glands to safe temperature levels.

The coolant rate varies with temperature and to some extent with pump size. For design purposes, the following rates shall be used:

Casing Design Temp (°C)	m^3/h
120	0.25-0.75
120-250	0.75-1.5
250+	1.5-2.5

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.


PROCESS STD.
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REVISION 0
DATE Jan. 1970
FIGURE 7
PUMP EFFICIENCIES at 3,500 R
GPM
4000
2000
1000
800
600
400
200
100
50
% EFFICIENCY
90
80
70
60
50
40
30
20
10
1000 FT
800 FT
600 FT
350 FT
200 FT
HEAD
LIMITED ACCEPTABILITY
SMALL PUMPS

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

9.2.1.1 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.

9.2.1.2 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. Design margins are as set out in Section 9.2.

9.2.1.3 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.

9.2.1.4 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.

9.2.1.5 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.

9.2.1.6 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.

9.2.1.7 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.

9.2.1.8 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.

9.2.1.9 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. polymerisation 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.

9.2.1.10 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.

9.2.1.11 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.

9.2.1.12 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.

9.2.1.13 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.

9.2.1.14 Bearing and Seal Losses

The polytropic horsepower absorbed by the gas compression phase does not include additional power,which is required for bearing and seal losses.

The combined losses shall be estimated from the table below and shall be added to the polytropic power requirement.

Polytropic Power, kW	Power Loss, kW
Up to 4500	19
Above 4500	38

Gear Losses

The mechanical efficiency of gears used to transmit power from a driver to a compressor varies as follows:

Type of Gear	Mech. Efficiency	% Gear Loss
Single Reduction	98-98.5	2 – 1.5 %

Double Reduction	97-97.5	3 – 2.5 %
Triple Reduction	96-96.5	4 – 3.5 %

9.3 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

9.4.1 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

9.4.2 Vapour Area Sizing

The following excludes the flare/vent drums, desalters and electrostatic dehydrators.

- If internals are installed, the common vapour internal shall be a wire mesh but for some services a vane pack can be used with COMPANY approval.
- The use of other vapour internals such as cyclones, etc. Requires COMPANY approval.
- The basis of sizing is the critical velocity Vc (m/s)

$$V_C = 0.048\left(\frac{\rho_l - \rho_g}{\rho_g}\right)^{0.5}$$

ρl = liquid density in kg/m3

ρg = vapour density in kg/m3

Vc = critical velocity in m/sec

The maximum gas velocity is K*Vc

K is a coefficient depending on the service, and the use or the absence of wire mesh. Recommended K values are given hereafter for different services.

Service	Without wire mesh	With wire mesh
Production separator	1.7	2.2
Fuel gas drum	0.8	1.7
Compressor suction drum	0.8	1.7
Glycol or amine contactor inlet drum	0.8	1.7
Reflux drum	1.7	2.2
Steam drum	-	1.3

• If a vane pack internal is used, the recommended K value is 3.3. This shall be confirmed with the vendor.

• For horizontal vessels without vapor internal (wire mesh, vane pack,), the minimum distance between the top of the vessel and the LSHH (level switch high high alarm) set point is the largest of 300 mm or 0.2 internal diameter.

• Vessels handling paraffinic oil shall not be equipped with gas internals

• The above separation criteria do not apply to slug-catchers which are not vessels and are indeed, a coarse Vapour-Liquid Separator.

A high efficiency inlet distributor can be considered to improve gas/liquid separation provided that EPCC Contractor verify pressure drop through distributor and dimensions between inlet distributor/mesh and inlet distributor/High Liquid (HLA-high liquid alarm point).

Hold-up and Residence Time of Liquids

• If the vessel is sized to receive a slug, that slug volume shall be taken between Normal Liquid Level and High Liquid Level.

• The residence time corresponds to half of the holdup time, the Normal Liquid Level (NLL) being set at 50% of the High and Low Liquid Level range. Exceptions shall be specified on data sheet.

• The minimum liquid hold up time between Low Level Alarm and High Level Alarm are as follows:

SERVICES	TIME (MINUTES)
Feed Surge Drum	
A. to heater	5
B. to others	3 without pump
	5 with pump
Reflux Drum	5
Fractionation tower bottom : the largest of	
A. product to next process	5
B. product to other column	5
C. product to storage tank	3 without pump
	5 with pump
Steam flash drum (process units)	5
Steam drum (utility generation and sulphur recovery unit)	10
Desalter	15
Deaerator (note 1)	15
Atmospheric degassing drum	15
Others Drums	3 without pump
	5 with pump

Note 1: Liquid hold up time is based on one deaerator shutdown associated with the normal liquid flowrate.

Note 2: The above criteria apply generally to all vessels (horizontal or vertical) where the liquid volume is one of the controlling cases for sizing.

• Two phase separators

ISA SYMBOL	CORRESPONDING DATA SHEET SYMBOL	VERTICAL DRUM	HORIZONTAL DRUM
LAHH/LSHH	HHLA/HHLS (HHL)		
		At least 1 to 2 min. with 150 mm minimum To verify : minimum 10% of control range (1) If only HHL:HLA-HHL: 10% of control range.	At least 1 to 2 min with 100 mm minimum To verify : minimum 10% of control range (1) If only HHL:HLA-HHL: 10% of control range.
LAH	HLA		
		Liquid hold up time to be considered with 300 mm minimum	Liquid hold up time to be considered with 300 mm minimum
LAL	LLA		
		At least 1 to 2 min. with 200 mm minimum To verify: minimum 10% of control range (1) If only LLL:LLA-LLL: 10% of control range.	At least 1 to 2 min. with 100 mm minimum To verify : minimum 10% of control range (1) If only LLL:LLA-LLL: 10% of control range.
LALL/LSLL	LLLA/LLLS (LLL)		
		300 mm minimum, but to be compatible with time required to close a Shutdown valve (SDV)	150 mm minimum, but to be compatible with time required to close a Shutdown valve (SDV)
Tangent line (Vertical Drum) Bottom (Horizontal Drum)			

Control range is the vertical distance between the high level alarm (HLA) and the low level alarm (LLA) with the normal control liquid level set point (NLL) set usually at 50% of the HHL-LLL distance

• Three phase separators

ISA SYMBOL	DATA SHEET SYMBOL	VERTICAL DRUM	HORIZONTAL DRUM
LAHH/LSHH	HHLA/HHLS (HHL)		
		At least 1 to 2 min. with 150 mm minimum To verify : minimum 10% of control range (1) If only HHL:HLA-HHL: 10% of control range.	At least 1 to 2 min with 100 mm minimum To verify : minimum 10% of control range (1) If only HHL:HLA-HHL: 10% of control range.
LAH	HLA		
		Lightest density liquid hold up time to be considered with 200 mm minimum	Lightest density liquid hold up time to be considered with 200 mm minimum
LAL	LLA		
		At least 1 to 2 min. with 200 mm minimum To verify : minimum 10% of control range (1) If only LLL:LLA-LLL: 10% of control range.	At least 1 to 2 min. with 100 mm minimum To verify : minimum 10% of control range (1) If only LLL:LLA-LLL: 10% of control range.
LALL/LSLL	LLLA/LLLS (LLL)	450 mm minimum	450 mm minimum
LDAHH	HHIA (HIL)		
		At least 1 to 2 min. with 150 mm minimum To verify : minimum 10% of control range (1) If only HHL:HLA-HHL: 10% of control range.	At least 1 to 2 min. with 100 mm minimum To verify : minimum 10% of control range (1) If only HHL:HLA-HHL: 10% of control range.
LDAH	HIA		
		Highest density liquid hold up time to be considered with 200 mm minimum	Highest density liquid hold up time to be considered with 200 mm minimum
LDAL	LIA		
		At least 1 to 2 min. with 200 mm minimum To verify : minimum 10% of control range (1) If only LLL:LLA-LLL: 10% of control range.	At least 1 to 2 min. with 100 mm minimum To verify : minimum 10% of control range (1) If only LLL:LLA-LLL: 10% of control range.
LDALL	LLIA(LLIS)		
		300 mm minimum, but to be compatible with time required to close a Shutdown Valve (SDV)	150 mm minimum, but to be compatible with time required to close a Shutdown Valve (SDV)
Tangent line (Vertical Drum) / Bottom of Vessel (Horizontal Drum) (2)			

1) Control range is the vertical distance between the high level alarm (HLA) and the low level alarm (LLA) with the normal control liquid level set point (NLL) set usually at 50% of the HHL-LLL distance. This definition also applies to each discrete and separated liquid phase for three phase separators.

2) Exception is made for vertical vessel with negligible liquid on clean service with manual or on/off liquid outlet valve; in that case volume of the hemi-spherical head can be used : Low Low Liquid Level (LLL) (or LLLA/LLLS) location to be still compatible with Shutdown Valve (SDV) or control valve closing time.

3) When applicable, the hold up time below the low low liquid level (LLLA or ILLLA) has to be compatible with the time required to close a Shutdown Valve (SDV) or to trip the pump(s) taking suction from the vessel.

4) Stand pipe shall be installed on clean service when at least 3 level instruments are required to be installed (independently from level instrument required for safety actions) e.g.: one level transmitter with two level gauges.

5) Minimum size for stand pipe: 3”

6) Particular case: slug catcher: stand pipe shall be installed.

7) Gauge glasses and level controller shall cover the full range of level transmitters and alarm switches.

8) Connections for level instruments generating a trip function shall be independent from control function.

General notes for Three Phase Separator:

For three-phase separators, the retention time for the two liquid phases shall be considered.

1. The effective retention volume in a vessel is that portion of the vessel in which the two liquid

phases remain in contact with one another. As far as the two liquid phases' separation is concerned, once either substance leaves the primary liquid section, although it may remain in the vessel in a separate compartment, it cannot be considered as a part of the retention volume.

2. The highest density liquid retention volume is taken between the bottom for horizontal vessels and bottom tangent line (for vertical vessels) and the normal interface liquid level (INLL).

3. The lightest density liquid retention volume is taken between the INLL and the normal liquid level (NLL)

9.4.4 Diameter

• As a general rule, inside diameter shall be specified on process data sheets (in mm)

• If the required inside diameter for a vessel is lower than 800 mm, a note shall be added specifying that a piping element is acceptable.

• For vessels less than 1000 mm ID, flanged heads *may* be specified.

• Recommended L/D ratio for horizontal vessel:

PRESSURE (barg)	L/D
Lower than 17	3
17 up to 34	4
Higher than 34	5

Manholes

Size of manholes

• For vessel diameter < 1000 mm

• Flanged vessel shall be considered if equipment contains internals

• Otherwise, size of manholes = 18”

• For vessel diameter ≥ 1000 mm

• Toxic service size of manholes = 24”

• Non-toxic service size of manholes = 20” (or up to 24” if internals need to be removable through manhole.)

Location of manholes

• At the opposite side of the utility connection for horizontal vessel

Number of manholes

• Vessel

• 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.

• 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”. Handhole to be installed on vessel with diameter less than 800 mm or on vessel where severe fouling of internals is expected.

9.4.7 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

A vortex breaker in fouled/dirty service shall have a standoff of 150 mm from vessel wall /bottom.

9.4.8 Drains, Vents and Overflow 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”

Drain number:

For horizontal drums having a length greater than 6 m TL to TL, additional drain connections shall be considered. An additional drain is also required on each compartment of a vessel. On toxic service, an open drain connection (washing out) is to be provided with a blind flange. Size of open drain connection shall be of the same diameter as drain connection.

• **Overflow:**

For vessels equipped with overflow connections, the overflow nozzle line size shall be at least one size greater than the inlet/outlet nozzle, whichever is greater.

Utilities Connections (steam out, purging)

Utility connections (2” minimum) shall be sized as follows:

• Drums and heat exchangers (when applicable): 2”

• For large vertical drums, two 2” connections shall be provided for diameter >= 4.5m

• For horizontal vessel with a length >= 6m and operating in toxic service, two 2” connections shall be provided.

• If vessel is equipped with internals (baffle), one 2” connection shall be provided on each compartment

• Columns: as follows with regard to column diameter, D (m)

1. $D \leq 4$	:	2”
2. $4 < D \leq 5.5$	:	3”
3. $D > 5.5$	:	4”

Utility connections, when specifically required, are not necessarily located on vessels (advantage may be taken to use connection on drain to steam out / nitrogen purge the vessel) but should remain operational even when the vessel is isolated.

No hard piping connection for steam out / nitrogen purge shall be provided.

9.4.10 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".

9.4.11 Nozzle Sizing

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

Inlet line:

• ρ*v2 max = 1500 if no inlet device is foreseen

• ρ*v2 max = 3000 if half pipe or baffle inlet device is foreseen

• ρ*v2 max = 6000 if Schoepentoeter or other vane pack inlet device is foreseen

Outlet line:

The same criteria which are used for line sizing (see below paragraph 10.3) shall be used.

Size of Inlet, Gas Outlet and Liquid Outlet Nozzles

- Inlet

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

- Gas outlet
a) Size on normal flow
b) Velocity limit 15-30 m/s

- Liquid outlet
a) Normal flow + 10%
b) Velocity limit 1-3 m/s HC
2-4 m/s water
c) Min. diameter = 2″ (avoid plugging

Towers Recommended Minimum Tray Spacing and Oversizing

Factor in Tray Towers

3-8-1) Minimum Tray Spacing

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

* ABOVE FIGURES SHALL BE USED JUST AS A FIRST ESTIMATION. FOR PRECISE FIGURES CONFIRMATION OF VENDOR IS NEEDED.

Tray spacing shall be greater than the minimum where required for access to column internals, man way location, vapor disengaging, nozzle interference or other reasons.

Minimum distance from top tray to top tangent line shall be 750mm or as required to accommodate man way, internals or nozzles. Minimum hole diameter for perforated trays shall be 1/2 inch. Minimum trayed column size shall be 750mm internal diameter.

3-8-2) Design Oversizing Factor:

- Flooding factor for fractionating trays: 78% maximum
- Flooding factor for pumparound trays: 83% maximum
- Flooding factor for steam stripping trays and side cuts strippers regardless of Stripping medium: 75% maximum
- Down comer back-up: 50% maximum of the tray spacing.

- Type of internals: structured packing may be applied, provided that they are compatible with coke formation tendency of the service. Random packing can be used in columns less than 750 mm in diameter

Heat Exchangers and Air Coolers

9.5.1 Oversizing

• Shell and tube heat exchangers and air coolers: 10% on surface based on design duty.

9.5.2 Fouling Factors

The following gives some indicative fouling factors for process and utility fluids which can be reviewed case by case. They can be applied to items such as electric motor cooling and used to check vendor’s data.

▪ Process fluids	$m^2.°C/W$
Acid gas	0.00020
Sour natural gas from slug catcher	0.00035
Sour natural gas downstream unit 100	0.00017
Sweet gas	0.00017
Liquid LPG	0.00020
Raw Feed Condensate from slug catcher	0.00052
Raw Feed Condensate	0.00035
Stabilised Condensate	0.00020
Process water	0.00035
Stripped water	0.00030
Glycol	0.00040
Refrigerant (propane)	0.00015
▪ Licensed units fluids	by Licensor
▪ Utilities	
Sea Water	0.00050
Chilled water	0.00020
Potable water	0.00020
Saturated steam/LP condensate	0.00017
BFW/Demineralised water	0.00017
Nitrogen	0.00017
Instruments air	0.00017
Fuel gas	0.00017
Diesel	Light:0.00030 Heavy 0.00035

Fouling Factors for Plate Exchangers

For Plate Frame Heat Exchangers, a general fouling factor of 0.00005 m2 °C/W shall be taken for all fluids (or Process Licensor recommendation).

For Plate Fin Heat Exchangers, no fouling factor shall be applied but an extra surface of 15% to be added on calculated area.

Temperature Approach for Heat Exchangers

The temperature approach shall be optimised for heat exchangers but it shall not be smaller than:

- 5°C for TEMA type heat exchangers (shell and tube)
- 10°C for air coolers
- For plate type heat exchangers (PHE) and printed circuit heat exchangers (PCHE) the vendor shall confirm and specify the requirement on a case by case basis.
- 3°C for kettle type

9.5.5 Specific Requirements for Heat Exchangers

TEMA R shall be generally used for all shell and tubes and air fin type heat exchangers. Fixed tube sheet exchangers are acceptable for non fouling service on the shell side. In this case Licensor or EPCC Contractor shall define all exceptional operating conditions (start-up, shutdown) to check the necessity to provide an expansion bellow on the shell.

9.5.6 Air Cooler Type

The air cooler shall be of an induced type when the air cooler is installed on pipe rack. Forced draft type shall be considered:

- If air cooler is installed at grade

• If inlet process temperature is above 175°C or calculated air outlet temperature is over 93°C

• Several sections stacked (in the case of multiple service exchangers).

When control of process side temperature is required then the control method shall be defined on a case-by-case basis.

In all cases design margins for air cooler fans shall be specified.

9.5.7 Allowable Pressure Drop- Shell and Tubes

Typical allowable pressure drops are given below:

9.5.7.1 Liquids

Total Pressure Drop (bar)
-Shells in series

	Total Pressure Drop (bar) -Shells in series-		
Viscosity (cp). (at average temperature)	One	Two	Three
Less than 1.0	0.35 to 0.7	0.35 to 0.7	0.7 to 1.0
1.0 –5.0	0.7	1.0	1.0 to 1.4
5 – 10	1.0	1.0 to 1.4	1.4
Above 10	1.4	1.4 to 2.0	2.0

Notes:
1) Under the following circumstances, ΔP's approaching the higher recommended values shall be employed: when the ΔT is small (28°C or less) or when the temperature range is large, (above111°C).

2) Calculated tube side pressure drop values are subject to greater variation than shell side values, because of the nature of tube bundle construction.

3) It must be realised that little can be gained by specifying increased pressure drop for one fluid in an exchanger when the other fluid has a significantly lower film coefficient.

4) For gravity flow, the pressure drop is usually limited from 0.07 to 0.14 bar.

Gases

Operating Pressure (barg)	Pressure Drop (bar)
0 – 0.7	0.035 – 0.07
Above 0.7	0.14 – 0.35

Condensers

Types	Pressure Drop (bar)
Partial	0.14 – 0.35
Total	Negligible

Reboilers

Types	Pressure Drop (bar)
Kettle	Negligible (shell side)
Thermosyphon:	
- Horizontal	0.02 – 0.035
- Vertical	Equivalent to approx. 3 – 5m tube length

Allowable Pressure Drop- Air Fin Exchangers

Suggested pressure drop for various services are given below. However, care should be taken to ensure that the selected pressure drop results in the most economic overall installation.

The allowable pressure drop for product cooling and non-critical services shall not control the size of the exchanger, as this may result in an uneconomic design which could be avoided by reconsidering the hydraulics of the process circuit. Special consideration is required for wide temperature range cooling of viscous liquids, low pressure gases or condensation of vapours at very low pressures. In these services, pressure drop is a critical requirement, which greatly influences the size of the heat transfer surface.

ALLOWABLE PRESSURE DROP		
Service	**Allowable pressure drop (bar)**	
Liquid Cooling	0.7	Note 1
Gas Cooling:		
Operating pressure 1.0 to 3.5 barg	0.2	
Operating pressure 3.5 to 17.5 barg	0.35 to 0.7	
Condensing: (atmospheric pressure and above)		Note 2
Total condensation	0.035 min	Note 3
Partial condensation	0.14 to 0.35	Note 3

Notes:

1) Not valid for viscous fluids.

2) For vacuum service the selection of an allowable pressure drop should be from the results of

an economic study. Pressure drops are usually in the range of 3-5 mmHg.

3) For multi-pass air coolers high pressure drops assure proper flow distribution. The higher pressure drop shall also assure proper distribution at lower than design throughput.

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 vapour to the respective tray and the liquid leaving it.

PIPING

10.1 General Design and Hydraulic

The guidelines and process sizing criteria detailed below shall be implemented in conjunction with the latest COMPANY approved Piping Specification, e.g. use of nonstandard pipe sizes.

10.1.1 Line velocity and friction loss for liquid line and gas line

Line size of each line shall be firstly selected based on the mass flow rate and in accordance with the velocity range criteria and then be checked in accordance with the friction loss range criteria as given in paragraph 10.3 Line Sizing Criteria.

10.1.2 Minimum piping sizes

Except for instrument piping, connections to equipment or piping in which minimum flow velocity requirements govern the minimum size shall be:

- 3/4” for pipe when located above ground
- 2” for process line on pipe rack
- 2” for utility lines on pipe rack

• 2” for pipe-on-pipe sleeper

• 2” for underground steel pipe

• 2” for underground nonmetallic piping

Pump suction calculations and NPSHA

For the NPSHA calculation method refer to Section 9.1.4. For the value of NPSHA specified on the process data sheet, the referenced elevation shall be indicated (e.g. grade, pump, centerline, etc.) With pumps in parallel and/or spare pumps, consideration shall be given to ensure that the common suction line leading to the individual pump suctions are sized adequately to cater for the additional flow imposed whether it is for a short or extended duration. When sizing suction lines for reciprocating pumps, acceleration head shall be considered. Pump suction line shall not be smaller than suction nozzle and shall be at least the same diameter as the line. If ball valves are appropriate for the service, then ‘full bore’ (FB) ball valves shall be used for all valves on the suction and marked on the P&ID.

Pump suction valve shall be in the same diameter as the line.

Control valve

Valve Types

Types shall be selected according to the guidelines below and fulfil the requirements of the IPS (Iranian Petroleum Standard):

1) Globe Valves. Single-seated is the standard valve type in sizes below 8" in non-severe service where the pressure drop and shut-off pressure can be handled. Cage-guided globe valves shall be used for more rough service. Balanced trims can be considered for bigger sizes.

Globe valves with shut-off function shall generally be non-balanced.

If suitable, valves with rotating plugs can be used as an alternative to globe valves.

2) Butterfly Valves. 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 service, shall be used for tight shut-off when these are more cost-effective than ball valves.

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

4) Angle Valves. This type shall be considered when the pressure drop is very high, where there is risk of accumulation of solids, or where the fluid velocity is extreme.

Soft-seated butterfly and ball valves for shut-off service shall be tested for fire safety in accordance with ANSI/API STD 607, and metal-seated valves in accordance with API Spec. 6FA.

7.2 Body Materials

Body materials shall be selected in accordance with the process fluid characteristics and the Piping Specification.

Generally, the following materials will apply:

1) Cast Carbon Steel, A216 Gr WCB/WCC or forged carbon steel, A105 is used in non-corrosive service from -28°C to 427°C. Low-temperature carbon steel, A352 Gr LCB/LCC can be used down to -46°C (stainless steel may be considered as an alternative).

2) Alloy Steel, A217 Gr WC1, WC6, WC9 is used for temperatures above 427°C. WC9 may also be used for flashing service.

3) Stainless Steel, A351 CF8 is used in flashing service, corrosive service and for temperatures below -28°C.

4) Monel is used in pure oxygen service.

Connections and Pressure Ratings

As per line specifications, globe valves shall have flanged connections with rating and facing in accordance with the Piping Specification. If welding is specified, butt-welding as per ASME B16.25 is foreseen.

Flanges shall conform to ASME B16.5.

Face-to-face dimensions shall conform to ASME B16.10, ASME 16.34 or API STD 609.

Some valve types, such as eccentric spherical disc valves and butterfly valves shall be wafer-type for installing between flanges. If specified, lug-style butterfly valves shall have free holes in the lugs allowing the use of stud bolts.

1" is the minimum control valve body size. 1¼", 2½" and 5" shall not be used.

7.4 Valve Trim

As standard, the material shall be AISI 316, unless otherwise specified.

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 315°C, the pressure drop across the valve exceeds 5 bar in steam service, or when there is a risk of flashing/incipient cavitation.

Cobalt-based alloys must not be used for hard-facing in boiler feed water and amine service.

Anti-cavitation trim is selected for high-pressure drop applications to prevent the onset of cavitation.

Anti-noise trim is selected for reducing the noise generated by the fluid.

Trim material for butterfly and gate valves may be the same as the body material.

7.5 Bonnets

The bonnets shall be bolted according to ASME B31.3 and material shall be the same as the body material. Requirements for an extended bonnet depend on the fluid temperature and the chosen packing material.

7.6 Valve Characteristic

The valve characteristic shall normally be Equal Percentage.

Valves with linear characteristic are used when the differential pressure is 'constant', such as in pressure-reducing, level control and venting services, and when two valves are used in a '3-way valve' function. Gas compressor recycle valves and 3-way valves for flow-splitting shall also be linear.

7.7 Seat Leakage Classifications

The classifications per ANSI/FCI 70-2 are:

Class II:	0.5% of rated capacity
Class III:	0.1% of rated capacity
Class IV:	0.01% of rated capacity
Class V:	0.03 ml water/min. per 100 mm port diameter per bar differential
Class VI:	See table in ANSI/FCI 70-2

Vent valves that are normally closed shall be very tight to minimise leak losses; class V is the minimum. Block valves in double block-and-bleed arrangement shall be class V-VI (VI in oxygen service). Pump minimum flow valves must be tight, class V to avoid leakage and seat damage

7.8 Packing

The packing design for linear motion valves shall include a packing flange.

PTFE shall be used as standard packing material for bonnet temperatures below 230°C 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.

Vacuum service and special services like oxygen, require special packing materials and should be given special consideration.

7.9 Flow Tendencies

For valves in shut-off service, flow tendency shall comply with the action required to put the plant in a safe condition in the case of power failure. In some cases it is the back-flow scenario that shall be considered.

Generally, it is the flow-to-open tendency that is the most stable type of operation for modulating control valves. This is therefore the preferred flow direction for globe valves. For angle valves, the direction should be flow-tends-to-close. The direction of flow shall be clearly marked on the valve body.

7.10 Actuators

As positioners are normally required, control valves shall be equipped with pneumatic actuators with a spring range from 0.4 – 2 bar g, in order to obtain small and fast actuators.

If feasible, higher ranges may be used for bigger valves, but the maximum range pressure should not exceed the minimum instrument air supply pressure minus 10%.

If not otherwise specified, actuators shall be sized to obtain a stroke time in seconds that does not exceed the valve size in inches. However, higher speeds will be required for anti-surge valves and slower speeds for preventing water hammer. Ball and plug valves used as shutdown valves shall have actuators designed with a safety factor of 2.5 with respect to start friction, as the friction increases if the valves have remained in one position for a long time.

As a rule, actuators shall be diaphragm- or piston-type with springs to provide the necessary failure action.

Double-acting piston actuators with volume tank and lock-up valves that ensure correct failure position are acceptable where high thrust is required. The volume tank shall be of stainless steel and be sized to stroke the valve twice.

• Control Valve pressure drops are defined in section 9.1.8.

• In case of mal-operation, the gas blow-by calculation shall consider the flow rate through the control valve when fully open and also through its by-pass when fully open, where installed. If the calculated flowrate oversizes the flare, the manual by-pass could be removed or a mechanical interlock between the associated manual block valves could be installed.

Piping, Vents and Drains

Pipe Size (ins)	Vent Size (ins)	Drain Size (ins)
¾ to 8"	¾"	¾"
10" and 12"	1½"	1½"
14" and over	2"	2"

Generally, the range of control valve opening should be between 10% for minimum flow rate and 80% for maximum (design) flow rate. At the normal flow rate valve opening percent should be 60%-70%.

- Control valve pressure Drop (ΔPcv) which is utilized to size the control valve should be calculated / specified for routes without and/or with compressor/pump separately as follows:

i) For the routes without comp. /pump, ΔPcv should be calculated according to the following relation: $\Delta Pcv = (Ps – Pe) – \Delta Psh – F$

Where Ps and Pe are operating pressure of equipment in the start and end of the route, ΔPsh is the static head difference between start and end of the route and F is the total frictional press. Drop of the route excluding the control valve which to be calculated at design flow rate through control valve.

ii) For the routes with compressor/pump, ΔPcv should be considered 16 psi or 10-15% of the total pressure drop of the route including pressure drop of control valve, whichever is greater, at the maximum design flow rate. In both cases ΔPcv should be calculated using the mentioned equation at the normal and minimum flow rates through control valve and control valve opening to be checked to make sure that it is not below the lower opening limit.

- Pressure drop at maximum design flow rate (minimum pressure drop of control valve) shall be calculated at the condition of the minimum suction liquid level and maximum discharge liquid level. Minimum liquid level shall be based on low liquid level (LLL).
- Pressure drop at minimum flow rate (maximum pressure drop of control valve) shall be calculated at the maximum suction liquid level.

7.11 Sizing and Available Pressure Drop

30% of the total, dynamic system pressure drop is desirable, in order that the valve achieves good control. However, to minimise the energy absorption in e.g. feed valves, the desired value must be compromised, but not lower than 15%.

Control valves shall be sized in accordance with the calculation method and formula shown in IEC 60534-2-1, and noise prediction shall be based on IEC 60534-8-3/4.

The installed Cv is normally selected 20-40% larger than the calculated Cv for the maximum operational flow conditions for valves with linear characteristic, and 30-60% larger for valves with equal percentage characteristic. An over-sizing factor of 1.3 based on the maximum operational flow is used for both types when selecting the required valve Cv.

Valves in venting service shall not be oversized, but specified for the maximum flow condition.

The actual installed Cv for a linear trim must not differ from the required by more than -10% and +10%.

The actual installed Cv for a Eq% trim must not differ from the required by more than -0% and +30%.

Control valves should preferably be designed to operate within the limits of 10% to 90% of their stroke.

The Cv for normal flow divided by the Cv for the minimum required flow should generally be less than 30-40. If control requires higher rangeability, two valves in parallel can be used.

Butterfly valves for on/off service shall be sized for 90° opening, whilst valves for continuous control shall be sized for a maximum opening angle of 60°. Characterised disc butterfly valves are an exception; these may be sized for a maximum opening angle of 90°C.

Maximum permissible velocity for non flashing liquids at valve outlet is 5-6 m/sec. and for gases it is Mach 0.35 at the outlet of the downstream pipe reducer. No extra noise is generated if velocity is Mach 0.3 or less. Maximum sound pressure level shall be 85 dBA measured one meter downstream from the valve at a distance of one meter from the pipe. The manufacturer shall size vent valves with noise attenuation equipment. The sound pressure level for atmospheric vents shall be measured four meters down from the vent exhaust at a downward of 45°.

Valve-sizing shall be checked for:

- Minimum flow rate conditions
- Flow velocity
- Noise level
- Flashing and/or cavitation
- Maximum shut-off differential pressure across the valve.

7.12 Shutdown Valves

These valves are generally selected in line size. Valve size criteria shall also be considered.

For tight shut-off valves (TSOV) leakage class V, ball valves up to and including 4" or offset disc butterfly valves shall be considered. Line size body and full-size trim shall be used. Soft-seated valves shall be approved fire-safe. Triple offset butterfly valves shall be specified for high shut-off pressures.

Gate valves with electric motors can be used as block valves around the shift converters and for the steam systems if the unpredictable failure action and the relatively large stroking time are acceptable.

Single-seated, unbalanced, line-size and full-size trim globe valves can be used as shutdown valves if desired or if other types are not suitable for the service

The diaphragm- or piston-type actuators for shutdown valves shall generally be spring-to-safe position. Stroking time shall be considered carefully. The valves shall be supplied with 3-way solenoid valves with class H insulation allowing continuous operation in an 85°C ambient temperature. The solenoid valves shall be high-capacity valves ensuring the desired stroking time. When high availability as well as safety is required the solenoid valves are to be in a 2oo2D type configuration.

When shutdown valves are part of a safety function with a SIL requirement, the vendor shall provide failure rates, safe/dangerous failure fractions of the valve, actuator and solenoid valve required to calculate the shutdown valve PFD and spurious trip rate.

Digital valve controllers installed on the shutdown valves monitoring the valve response shall be considered for critical shutdown applications when partial stroke testing is required to fulfil the SIL requirements.

Limit switches shall be hermetically-sealed NAMUR proximity switches. Solenoid valves and limit switches shall have enclosure protection class IP 65 with screw terminals for 2.5 mm^2 wire.

7.13 Positioners and Tubing

Positioners shall be FF/P for Fieldbus communication with full diagnostic possibilities. Positioners shall be vibration-resistant. Output shall match bench-setting of the valve. Positioners shall have output gauges in stainless steel and filter regulators with pressure gauges. Valves in split range shall also have FF AI input; the split is done in the control system.

The positioners shall have sufficient air capacity to stroke the valves as described in clause 8.10.

Air tubes and fittings shall be in stainless steel. Size shall be adequate for the stroking time required. Tubing shall be thin-walled with an OD of not less than 6 mm. Larger valves require tubing with a larger diameter.

7.14 Hand Wheels

These are normally required when no bypass valves are specified. Hand wheels must not be specified for shutdown valves.

8 Pressure-relieving Devices

Pressure-relieving devices protecting pipes, vessels and equipment shall normally be sized in accordance with API RP 520 and/or API RP 521. ASME Code, Section I shall apply to steam drum and super-heater valves. Relieving devices protecting atmospheric or low-pressure storage tanks shall be sized according to API STD 2000.

If applicable, local and national codes shall be respected.

8.1 Percentage Over-pressure, Accumulation and Blow-down

The percentages used in the calculation of orifice sizes of relieving devices shall be as follows:

Over-pressure

3%: Steam service where ASME Power Boiler Code (Section I) applies
10%: Gas or vapour service
10%: For liquids
21%: Fire exposure on unfired pressure vessels
10%: For liquids (non-certified)

Accumulation

6%: Steam service where ASME Power Boiler Code (Section I) applies
10%: Gas, vapour and liquid where ASME Pressure Vessel Code (Section VIII) applies
16%: Gas, vapour and liquid where ASME Pressure Vessel Code (Section VIII) applies and the system is protected by means of multiple valves
21%: Fire exposure on unfired pressure vessels

Blow-down

4%: Maximum for steam service where ASME Power Boiler Code (Section I) applies
5-7%: For vapour, gas and steam service
10-20%: For liquid service

Nomenclatures shall be in accordance with API RP-520.

8.2 Safety and Relief Valves

These valves shall generally be flanged, direct spring-loaded types with high-lift, high-capacity and top-guided discs. Balanced bellow valves shall be furnished for relief into closed flare and blow-down systems if the sum of variable superimposed back-pressure and the built-up back-pressure exceeds the allowable accumulation, or for toxic substances. Bellows shall also be specified for liquid relief valves in case of any variable back-pressure.

Pilot-assisted valves shall be considered under non-fouling conditions where light gases are encountered at high set pressures, and/or where the operating pressure is more than 90% of the set pressure. Pilot malfunction shall not prevent the main valve from discharging its full rated capacity at or below the set pressure.

8.3 Full Nozzle Type Valves

This type of valve shall normally be specified for size 1” and larger. Only the nozzle and parts comprising the disc are exposed to inlet pressure and to corrosive action of the fluid when the valve is closed. The valve shall have an adjustable blow-down ring. If a maximum 4% blow-down is required, the valve shall have two rings.

8.4 Base or Modified Nozzle Type Valves

This type of valve shall be specified for thermal relief service with ¾” inlet and 1” outlet NPT threaded connections for ratings up to and including ASME 900#. Above this rating, flanged valves with 1” inlet and outlet shall be used.

8.5 Rupture Discs

The discs may be used in lieu of or in combination with safety and relief valves where applicable or required. The discs shall be non-fragmenting, reverse-buckling and retained in a stainless steel knife blade holder assembly. Required operating ratio is 90% and bust tolerances ± 5%.

8.6 Tank Vent Valves

Pressure and vacuum relief valves or a combination of both shall normally be the weight-loaded, spring-loaded or pilot-operated type. It shall be observed that the inherent high over-pressure of the weight-/spring-loaded type does not exceed the tank's pressure limits.

8.7 Construction Materials

The materials shall be selected in accordance with API STD 526, the process fluid characteristics and the Vessel and Piping Specifications. Generally, the following will apply:

1) **Cast Carbon Steel,** A216 Gr WCB/WCC or forged carbon steel, A105 is used in non-corrosive service from -28°C to 427°C. Low temperature carbon steel, A352 Gr LCB can be used down to -46°C.

2) **Alloy Steel,** A217 Gr WC1, WC6, WC9 is used for temperatures above 427°C.

3) **Stainless Steel,** A351 CF8 is used in flashing service, corrosive service and for temperatures below -28°C.

4) **Monel** is used in oxygen service.

5) **Nozzle and Disc** shall normally be AISI 316 and hard seating shall be applied as per manufacturer's standard.

6) **Springs** shall be carbon steel for normal process operating temperatures of -28°C to 232°C and tungsten alloy steel or high-temperature alloy steel above 232°C. Stainless steel may be used below -28°C or in corrosive service.

8.8 Bonnets

Bonnets for toxic or inflammable gases and for vapours and liquids shall be plain, closed and pressure-tight and of the same material as the body. Exposed spring bonnets shall be specified for steam and water service above 200°C. Bonnet extension shall be provided in accordance with manufacturer's design. All bellow-type valves shall have bonnet vents separated from the discharge..

8.9 End Connections

The connections shall normally be flanged with facing and rating in accordance with the Piping Specification. However, API STD 526 sizes and ratings shall always govern, where applicable. Centre-to-face dimensions shall be in accordance with API STD 526 where applicable.

8.10 Lifting Levers

The levers shall be provided to lift the seat when the operating pressure is more than 75% of the set pressure for all relief valves in steam, in hot water service above 60°C and on air valves. The lever shall be sealed on closed bonnet valves.

8.11 Test Gags

Test gags shall be provided on all installed safety relief valves. Test gags shall be removed and transferred to owner after testing. All test gags shall be stamped with the valve tag numbers.

Air Coolers

On air coolers one 2" vent shall be located at the highest point in the inlet header and one 2" drain at the lowest point in the outlet header. The exact location of these vents and drains is dependent on the actual cooler design. Connections shall be valved and blanked off.

Pump Casings

For non-operating vents and drains, provide ¾" valved and blanked off vents and drain (not shown on P&ID). EPCC Contractor shall provide drain connections for pump casings, with the drain piped to the edge of the baseplate by the pump vendor.

For non-volatile services, casing vents and pump drains shall be valved and piped to pump baseplate or into a sewer

For volatile services, casing vents and drains shall be piped to relief header and sewers via a sample cooler.

Additional Notes

• Valved / blanked off vent and drain connection shall be furnished on all equipment that is not self-venting or self-draining. Connection shall be located on equipment, if practical, but may be located on connected piping when there are no valves or blocks between the vent or drain connections and the equipment.

- Hydrostatic vents and drains shall be provided by EPCC Contractor, and shall not be shown on P&ID.
- For total condensing service in shell and tube exchangers, EPCC Contractor to provide a flanged 2" vent nozzle on shell at opposite end to shell inlet.
- At relief valves, a ¾" valved blanked off bleed shall be shown between safety valve and any block valve on inlet and discharge side.
- Vents from vessels that may chill and freeze during depressuring shall have double block valves separated by at least 900mm.

10.2 Insulation and Heat Tracing

Thermal insulation for hot or cold services may be required for:

- Heat or cold conservation of equipment and piping,
- Personnel protection of equipment for operating temperatures above 70°C. A physical barrier with warning signs attached to hot surface is preferred to thermal insulation if it is not required for process reasons,
- To avoid external water condensation or ice,
- Steam or electrical heat tracing.

In all cases, insulation shall be minimised in order to limit CUI (Corrosion Under Insulation).

10.3 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) Norm.	ΔP (bar/km) Max.	Max. Velocity (m/s) (2) 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 uponCOMPANY 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 to 10000 Pa
- $\rho_m V_m^3$: 100 000 to 150 000 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/h ρ_V = vapour density in kg/m3

  W_V = vapour flow rate in kg/h

And the apparent fluid 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 vapour 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

ρm 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.

Two phase (liquid / gas) Lines

Each mixed phase flow line shall be handled as special cases, taking the following considerations into account:

a) Erosional velocity

Two phase flow should be sized primarily on the basis of flow velocity. Flow velocity should be kept at least below fluid erosional velocity. The velocity above which erosion may occur can be determined by the following empirical equation:

$$V_e = \frac{C}{\sqrt{\rho_m}}$$

V = fluid erosional velocity, ft/s
C = empirical constant
= 125 for non-continuous services
= 100 for continuous services
ρ_m = gas / liquid mixture density at operating pressure and temperature, lb/ft3

$$\rho_m = \frac{12409 S_l P + 2.7 R S_g P}{198.7 P + RTZ}$$

P = Operating pressure, psia
S_l = Liquid specific gravity (water=1, use average gravity for hydrocarbon water mixture) at standard condition
R = Gas/liquid ratio, ft3/barrel at standard condition
T = Operating temperature, R
S = gas specific gravity (air=1) at standard conditions
Z = gas compressibility factor

The minimum cross sectional area required to avoid fluid erosion may be determined from the following equation

$$A = \frac{9.35 + \frac{ZRT}{21.25P}}{V_e}$$

b) Minimum Velocity

Stable flow Pattern shall be established for two phase flow lines. This method is to be used to determine the maximum line size permissible, before unstable flow occurs. If possible, the minimum velocity at minimum flow (turn-down) should be about 10 ft/s to minimize slugging of separation equipment.

Pipeline Hydraulics

Pipeline hydraulics is to be calculated based on the relevant NCE work instructions with the following general guidelines:

- The Mukherjee & Brill pressure drop correlation is to be used, unless the client asks for another correlation.

- The Mukherjee & Brill Hold-up correlation is to be used, unless the client asks for another correlation.

- Minimum temperature of 60^oF(15.6^oC) and maximum temperature of 90^oF(32.2^oC) should be considered for soil temperature at one meter depth in the Iranian southern area.

- Soil conductivity is to be calculated from detail soil reports. If such data is not available, Soil conductivity of 0.5 Btu/hr.ft^2 in maximum soil temperature case and soil conductivity of 0.4 Btu/hr.ft^2 in minimum soil temperature case should be taken for Iranian south oil fields area.

- A 10^oC (18^oF) margin shall generally been considered between operating temperature and hydrate formation temperature.

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 finalised / 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

Absolute Roughness

Values for absolute roughness for commonly used materials, which are used in liquid and vapour 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)
Galvanised Carbon Steel	0.15 (0.0059)
GRP	0.02 (0.0008)
Epoxy Lined Pipe	0.15 (0.0059)

FLARE AND COLD VENT SYSTEMS

11.1 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.

The analysis of the causes of relief is required and an occurrence flaring loads balance including each individual relieving rate for each possible cause shall be performed.

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.

11.5 Flare and cold vent lines sizing criteria

11.5.1 Lines upstream relieving devices

PSV's:

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

- $\rho V2 \le 25\ 000$ kg/m/s2 for ø of line ≤ 2"
- $\rho V2 \le 30\ 000$ kg/m/s2 for P ≤ 50 bar g
- $\rho V2 \le 50\ 000$ kg/m/s2 for P > 50 bar g

DEPRESSURISATION DEVICE

- Minimum line size 2"
- ρV2 criteria are the same as for PSV's

11.5.2 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
- Velocity and ρV2 :

SINGLE PHASE (GAS AT THE RELIEF DEVICE INLET) :

- Intermittent flow:
- Lines downstream relieving devices and sub-headers : 0.7 Mach maximum and

$\rho V2 < 150000$ kg/m/s2 considering the maximum capacity of the relieving devices even if this figure exceeds the actual maximum flow rate due to process limitation and the relevant occurrence.

• Headers : 0.7 Mach maximum and ρV2 < 150 000 kg/m/s2 considering the maximum flow rate due to process limitations and for the relevant occurrence, however a velocity of 0.8 Mach could be accepted for a long straight line without elbows and connections (e.g stack, lines on bridge)

• For a ρV2 > 100 000 kg/m/s2 vibration and line support studies are required.

• Continuous flow:

• Velocity < 0.35 Mach and ρV2 ≤ 50 000 kg/m/s2

• MULTIPHASES (2 phase flow at the inlet of relieving device) :

• Velocity ≤ 0.25 Mach and ρmvm

2 ≤ 50 000 kg/m/s2

The sizing shall be done for the line downstream each device with the built-up back pressure for the corresponding occurrence and not with the maximum built-up pressure for the maximum flow rate to the flare or cold vent. The same shall be applied for the header and sub-headers.

11.6 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

11.7 Purge Gas

The purge gas is provided to avoid:

• An explosive mixture in the stack or header due to air intake into the flare or cold vent stack.

• The risk of burn back which induces the quickest deterioration of the flare tip.

The purge gas flowrate shall not be lower than the value given by the following equation:

Without gas seal : Purge gas flow = 24 000 x D3 x MW-0.565

• With gas seal : Purge gas flow = 12 000 x D3 x MW-0.565

Where : Purge gas flow in Sm3/h

D is the tip internal diameter (1) in m

MW is the purge gas molecular weight in kg/kmol

(1) For sonic flare, the tip internal diameter is taken as the equivalent diameter corresponding to exit gas area

The above formulae shall be applied only to the flare tip, assuming COMPANY/Project procedures do not allow the application of flare tip vendor's guaranteed purge rates.

For purging of sub headers and headers, the purge velocity shall be a minimum of 0.03m/sec as per API RP521 (Section 4.4.3.4.2).

For flare, if fuel gas is used for purge gas, the source of purge gas shall be common to the fuel source to the pilots in order to avoid a loss of purging while pilots remain in service.

The heaviest available gas should preferably be used as the normal source of purge gas in order to minimise the vacuum pressure in the flare header for an elevated flare or cold vent.

In some cases, nitrogen could be used as purge gas. In these situations, pilots able to run in a predominantly inert gas environment shall be installed after detailed case by case evaluations with the flare tip vendor.

Since the allowable radiation level is a function of the length of exposure, factors involving reaction time and human mobility should be considered. In emergency releases, a reaction time of 3 - 5 seconds may be assumed. Perhaps 5 seconds more would elapse before the average individual could seek cover or depart from the area, which would result in a total exposure period ranging from 8 to 10 seconds. The above table is maximum allowable radiation intensities inclusive of solar radiation. The solar radiation in southern parts of Iran shall be taken as 300 Btu/hr.ft2 . Flare stack diameter is generally sized on a velocity basis, although pressure drop should be checked. One may want to permit a velocity of up to 0.5 Mach for a peak, short-term, infrequent flow, with 0.2Mach maintained for the more normal and possibly more frequent conditions for low-pressure flares. However, sonic velocity operation may be appropriate for high-pressure flares. The tip pressure drop is taken from vendor's information. For sonic type tip the backpressure will be assumed 2 to 5 Barg depending on load, when there is not any information.

3-10-2) 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.

The sonic velocity of the relief gas is calculated as below.

$$V_{sonic} = 91.9 \sqrt{\frac{KT}{MW}} \ (\frac{m}{s})$$

$$K = \frac{Cp}{Cv}$$

T: Temperature (K)

MW: Molecular Weight

Maximum velocity in a line is 0.7 Mach for short duration relieves only.Maximum flowing velocity in the lines between of the PSV's to the first subheader shall in general be less than 0.7 Mach. For the PSV's where the outlet velocity is higher, a reducer shall be installed as close as possible to the PSV to increase line size and hence limit the velocity to max 0.7 Mach downstream at the reducer.

Instrumentation

Selection of Instrument Housing

Field mounted instrument shall be suitable for operation in industrial, humid, sulfurous and corrosive surrounding atmosphere and be adequately designed to prevent generation of an explosion.

Instrument enclosure's "degree of protection"shall be in accordance with IEC 529.

The minimum degree of protection for junction boxes (containing terminals only) shall be IP 54. For enclosures containing electronic components or coils (solenoid valves) the minimum degree of protection shall be IP 65.

Instruments/JB's located in areas subject to deluge shall be IP 66.

For instruments below grand level/underground, it shall be IP 68.

The minimum degree of protection for indoor instrument shall be IP 42.

Instruments, boxes and panels located in a hazardous area shall be certified to meet the electrical area classification; any certified equipment shall be stamped according to the protection and the relating code and shall be delivered with a conformity certificate issued by a recognized laboratory.

Gas Group classification is done according to CENELEC/IEC standards. The correspondence chart hereafter is used for CENELEC/IEC classification (only to use for conversion from API to CENELEC/IEC):

CENELEC/IEC	API	REMARKS
Group IIC	Class I, Group A	Acetylene
Group IIC	Class I, Group B	Hydrogen
Group IIB	Class I, Group C	Ethylene, ethyl-ether,
Group IIA	Class I, Group D	Methane, butane, propane, naphtha, …
Zone 0	Division 1	Explosive mixture is continuously present
Zone 1	Division 1	Explosive mixture is likely to occur in normal operation
Zone 2	Division 2	Explosive mixture is not likely to occur in normal Operation

The temperature class is indicted by the following symbols:

- T1 Maximum external temperature 450 $_{o}$C (842 $_{o}$F)
- T2 Maximum external temperature 300 $_{o}$C (572 $_{o}$F)
- T3 Maximum external temperature 200 $_{o}$C (392 $_{o}$F)
- T4 Maximum external temperature 135 $_{o}$C (275 $_{o}$F)

- T5 Maximum external temperature 100 ^{o}C (212 ^{o}F)

- T6 Maximum external temperature 85 ^{o}C (185 ^{o}F)

The method of protection is defined by the CENELEC/IEC rules and identified by a small letter as follow:

- d	Flameproof enclosure (explosion-proof)	CENELEC EN 50-018/IEC 79-1, 79-1A
- e	Increased safety	CENELEC EN 50-019/IEC 79-7
- ia	Intrinsic safety for Zone 0	CENELEC EN 50-020/IEC 79-3, 79-11
- ib	Intrinsic safety for Zone 1 or 2	CENELEC EN 50-020/IEC 79-3, 79-11
- p	Pressurized enclosures	CENELEC EN 50-016/IEC 79-2
- n	Electrical apparatus for potentially explosive atmospheres	CEI EN 50-021

For standardization purpose, installation of certified type instrument in non-hazardous area is acceptable.

As far as possible, explosion proof protection type shall be used instead of intrinsically safe.

The minimum requirement of protection method shall be done according to the following chart:

Equipment	**Zone 1**	**Zone 2**
Instrument	EEx-d/EEx-ia/ib	EEx-d/n
Solenoid valve	EEx-d	EEx-d
Junction box	EEx-e	EEx-e

Local enclosure (with relays, electronic, …)	EEx-d/EExp	EEx-n
Lamp indicator (LED)	EEx-ia/ib	EEx-d/n
Thermocouple	EEx-ia/ib	EEx-d/n
Push button	EEx-ia/ib	EEx-d/n
Lighting	EEx-e	EEx-e
Level gauge illuminator	EEx-d	EEx-d
Horn	EEx-d/e	EEx-d/e

Electrical Power Supply

All control and safety systems located in CCR's and ITR's shall be powered from 110V AC UPS system located in electrical substation. Necessary autonomy requires battery back up for 30 min. This UPS is limited to feed the FCS, F&G, ESD systems, PLC's, equipment, analyzers, and other instruments. This power supply shall not be used for lighting or tracing.

No voltage other than 24V DC, 110V DC or 110V AC will be used except if clearly specified by LORC. Other voltages may be used internal to the systems so long as these voltages do not exceed 110V AC or 110V DC and they are generated by system Supplier/ Vendor.

Equipment such as FCS, ESD, F&G system cabinets shall be powered by a set of redundant UPS feeders (i.e. 2 feeders) for each equipment. Equipment such as printers, stations, solenoid valves, etc. shall be powered by a single UPS feeder from related systems. FCS, ESD and F&G systems shall be equipped with reliable DC generation systems provided by Supplier. These internal power supplies and distribution systems shall be redundant.

Package control cabinets will receive 110V AC 50 Hz supplied by a single or dual feeder system (to be defined for each package).

Installation and Process Connections

13.1 Primary Instrument Process Connections

The connections shall have the following sizes:

- ¾" NPT (M) for pressure and differential pressure
- 1" NPT (F) for threaded thermowells
- ½" NPT (M) for sample points with sample probes for process analysis and for orifice tappings
- 1½" flanged with rating and facing as per vessel specifications for displacement level transmitters, level switches and level gauges.

13.2 Instrument Installation

The installation shall comply with the principles outlined in ANSI/API RP 551.

13.3 Flow and Pressure Instruments

The instruments shall be coupled as closely as possible to the process connections, in order to minimise lead errors and heat tracing problems. The instruments shall be accessible from ladders or platforms if not accessible from grade.

13.4 Instruments in Vapour or Gas Service

These instruments shall be located above the sensing point. Instruments in liquid, wet gas and steam service shall be mounted below the sensing point. If accessibility, visibility or clearance requirements preclude either of these situations, provision shall be made in the impulse piping to ensure proper instrument operation. Special precautions are to be taken where cross-ambient conditions exist. Closely coupled pressure gauges for mounting above the sensing points are excluded from the aforementioned. However, they shall be used only on non-vibration piping.

13.5 Flow and Level Transmitters

Flow and level transmitters (except capillary-type) shall be installed using separate manifolds with integral block-and-bypass valves. For ratings up to and including ASME 900#, instrument lead lines shall be min. 12 mm OD with tubes and fittings of the double ferrule-type in AISI 316. ½" pipes and socket-welded fittings shall be used above ASME 900#.

13.6 Pressure Transmitters

These transmitters shall be installed with block-and-bleed valves. For ratings up to and including ASME 900#, instrument lead lines shall be min. 12 mm OD with SS tubes and fittings of the double ferrule-type in AISI 316. ½" pipes and socket-welded fittings shall be used above ASME 900#.

Instrument Type	Process Side Size/Type/Rating	Instrument Side Size/Type/Rating
Pressure gauge	On pipe: 3/4"/SW, Thread/800# On vessel: 1"/Flange/300#	1/2"/NPT
Differential pressure or pressure instruments (general purpose)	On pipe: 3/4"/SW, Thread/800# On vessel: 1"/Flange/300#	1/2"/NPT
Differential pressure or pressure instruments (diaphragm seal type)	3"/Flange/300#	3"/Flange/300#
Level gauge	2"/Flange/300#	2"/Flange/300#
Displacer type level instruments (external chamber)	2"/Flange/300#	2"/Flange/300#
Float type level switches (external)	2"/Flange/300#	2"/Flange/300#
Differential pressure type level transmitters	1"/Flange/300#	1/2"/NPT
Temperature instrument	On pipe: 1 1/2"/Flange/300# On vessel: 2"/Flange/300#	On pipe: 1 1/2"/Flange/300# On vessel: 2"/Flange/300#
Pneumatic type instrument	Instrument air header	1/2" or 1/4"/NPT

Pneumatic Supply

The operating range for pneumatic signal transmission shall be 0.2 to 1 barg.

All pneumatic components of instrument system shall be designed for the following

supply conditions:

• Pressure:

- 5 Barg Minimum operation

- 7 Barg Maximum operation

• Temperature:

- Ambient Temperature (normal)

- 49 oC Temperature (maximum)

- -10 oC at 7 barg Dew point

• Oil content: Oil free

An air set with filter, output gauge and regulator shall be provided with each instrument

14.1 Instrument Air Supply

The supply will be available at 7.0 bar g, air quality according to ANSI/ISA-7.0.01 and design pressure at 10.5 bar g.

14.2 Signal Tubing and Fittings

Tubing and fittings shall be stainless steel with a minimum tube size of 6 mm OD.

14.3 Signal Inputs and Outputs

Inputs and outputs shall be 0.2 – 1.0 bar g.

consuming instrument air.

Field Sensors General Requirements

Field Sensor

The same type of instruments shall be used for control of utilities and for process control. Safety components shall be completely independent from process control component. Trip contact shall not be derived from the same instrument. Single component failure shall have a minimum effect on overall availability.

The following requirements with respect to the field instrumentation shall be implemented:

- Materials exposed to the process fluid shall be in accordance with the fluid conditions (pressure, temperature, corrosion) and with the relevant piping class.

- Carbon steel body construction (except transmitters, see here after) shall be a minimum specification for parts exposed to process fluid when not specified otherwise.

- For pressure and differential pressure transmitter, both body and element material shall be AISI 316 as a minimum standard, or the manufacturer's standard material, whichever provides the best corrosion resistance. Where the nature of fluid requires a higher alloy or other material, the material shall be consistent with the piping or equipment specification.

- Movements for instruments shall be stainless steel or better when specified.

- All inserted instruments (e.g. thermo-wells, sampling probes, etc.) shall be specified as per the process data sheet including all service conditions (pressure, velocity, temperature, density, fluid composition) which shall be provided by Contractor.

- NACE requirement shall be applied in case of sour service.

- The design of pressure parts shall be based on the allowable stresses of the ANSI.

- All components, particularly if containing electric contacts, shall be vibration resistant.
- On line instrument shall have flanged connections.
- All instruments shall have an over-range protection up to the maximum design static pressure indicated on the instrument data sheet.
- Instrument exposed to vacuum shall have under-range protection to full vacuum.
- All electronic field instruments shall have cable gland entries of ISO M20x1.5.

4.2.2.2 Local Switch

Process variables used for initiating the shutdown systems shall be derived, as a general rule, from the electronic switches.

When switches are used as sensing devices they shall have normally closed contact to open on trip condition.

When they are provided for safety purpose in non fail-safe configuration they shall include a resistor for line monitoring.

Switch devices shall have a minimum rating of 120V AC, 2A, inductive, unless specified otherwise on the relevant data sheets.

4.2.2.3 Transmitters

Electronic transmitters, strain gauge or capacity type shall be used as general rule.

Transmitters generally will be digital from FF certified bus-powered.

Those connected to the ESD system will be preferably of smart transmitter type and compatible with HART. If smart type transmitters are selected for ESD application they shall be configured as “read only”.

Smart transmitters (2 wires) with digital calibration superimposed on 4-20 mA signals shall be the rule to allow remote calibration from a “pocket” interface at marshalling level.

Electronic transmitters will be provided with an integral digital indictor for maintenance purpose. A digital display indicator can be provided, using digital mode communication when associated to “smart” transmitter.

4.2.2.4 Diaphragm Seal and Capillary

For measurement of viscous fluids, solids containing fluids, highly corrosive fluids or where temperature changes may influence the fluid conditions, the use of diaphragm seal and capillary may be considered as an alternative to instrumentation with flushing on the measuring impulse line. Diaphragm seal shall normally be integral with the instrument. Special coating materials may be considered where these will improve the corrosion resistance of the diaphragm.

For remote seal applications, capillaries shall be kept as possible (at least 1meter) and shall not exceed 6m. For differential pressure application the capillary shall be of the same length. The capillary tubing material shall be of AISI type 316 type stainless steel and be shielded by flexible stainless steel tubing with PVC cover, according manufacturer’s standard.

4.2.3 Signal Requirements

4.2.3.1 Inputs

- IS digital from FF certified bus-powered transmitters,
- Non-IS digital from FF certified bus-powered transmitters,
- IS analogue 4-20 mA, 24 VDC from smart type two-wire transmitters with HART protocol,
- Non-IS analogue 4-20 mA, 24 VDC from smart type two-wire transmitters with HART protocol,
- IS analogue 4-20 mA DC from smart type four-wire transmitters with HART protocol,
- Non-IS analogue 4-20 mA DC from smart type four-wire transmitters with HART protocol,
- On-Off hardwired signals for non-safety related interlock performance from volt-free contacts,
- IS inductive high frequency pulses from proximity sensors, pulse or BCD,
- Communication with ESD and other systems,
- On-Off signals from ESD, substation, other systems, via volt-free contacts.

4.2.3.2 Outputs

- IS digital to FF certified positioners via bus segment,
- Non-IS digital to FF certified positioners, via bus segment,
- IS analogue 4-20 mA, 24 VDC to smart type positioners with HART protocol,
- Non-IS analogue 4-20 mA, 24 VDC to smart type positioners with HART

protocol,

- On-off signals to external hardwired annunciator, substation, etc. volt-free

SPDT contact rated minimum 2 Amps at 24 VDC,

- Communication signals (Modbus, TCP/IP, etc).

Flow Instruments

As a general rule flow shall be measured from orifice plate differential pressure, unless special considerations make necessary to use other types of instruments such as:

- Variable-area flow meters for local indication,
- Electromagnetic flow meters,
- Ultrasonic flow meters,
- Vortex flow meters,
- Coriolis flow meter,
- Turbine flow meters or positive displacement meter,
- Thermal flow meter.

Flow Instruments

Flow measurements shall preferably be done by means of orifice plates and differential pressure instruments. The sizing flow shall be approx. 15% higher than normal flow. Minimum rate of flow that can be measured is approx. 15% of sizing flow.

d/p Flow Transmitters

The transmitters shall be for fieldbus communication or 'intelligent' with HART protocol. Bodies shall be in stainless steel with AISI 316 pressure elements.

The transmitter shall be furnished with an LCD output meter with range 0-100% of squared d/p. The overall total performance accuracy shall be better than ± 0.2% of calibrated span. The output signal shall be linear with the differential pressure.

Orifice meter installation with operational flow below 15% of sizing flow shall have an additional flow transmitter for the low range.

Armoured Rotameter Types

These may be used in pipes of 2" and smaller. The meter shall be selected for normal flow at 85% of the span. Tubes must be stainless steel.

Special Flow Applications

These applications may require measurement devices, such as turbine meters, magnetic flow meters, Vortex meters, mass flow meters, averaging Pitot tubes, weirs, floats, etc. Such situations shall be considered individually, and the most suitable type of meter shall be selected.

Flow Switches

Flow switches for direct process fluid operation may be rotameter or paddle-type for low accuracy requirements. Orifice plate and differential pressure-type transmitters shall be used for high accuracy requirements.

Primary Flow Differential Producers

Calculations

Calculations shall be in accordance with ISO 5167-1.

Orifice plates of the square-edged (concentric type) shall be specified, except where unsuitable for the application. Materials shall be AISI 316, unless special materials are required for the service.

To limit the differential thermal expansion of flange and plate, AISI 410 shall be used for temperatures above 300°C for plates installed in carbon steel and low alloy steel piping systems.

Flanges with Flange Taps

This type of flange shall be used, unless otherwise specified and shall comply with ASME B16.36. Orifice flanges shall have a minimum ASME rating class 300. Higher ratings will be according to piping specifications. Tap size shall be ½" NPT for all flange ratings.

The general Piping Specification shall govern for sizes not covered by ASME B16.36.

Small Precision Bore Orifices

These shall be manufactured and calculated in accordance with ASME MFC-14M. However, pressure tapping shall be ½" NPT (F) and located 90° apart. Each meter run should be calibrated.

The meter pipe shall be machined from AISI 304 thick wall pipe (or solid rod) with the same nominal size as the process pipe and with flanged ends. The assembly shall be honed after completion of all welding.
The meter lengths shall be according to the table below:

Size	Upstream Length (mm)	Overall Length (mm)
½"	450	600
¾"	500	800
1"	750	1000
1½"	1200	1600
2"	1500	2000

Classic Venturi Tubes

Tubes in accordance with ISO 5167-1 may be used to measure the flow of low-pressure gases or fluids where loss of pressure is an important consideration.

Flow Nozzles (ISA 1932 Profile)

These nozzles shall be used where erosion prohibits the use of square-edged orifices and in high-pressure steam service above 80 bar g. Flow nozzles are calculated and manufactured in AISI 316 and in accordance with ISO 5167-1.

Pitot Elements

Pitot elements of the averaging type may be used where high accuracy is not required, or where the pipe diameter is too large for acceptable orifice plate design, but shall be limited to combustion air and cooling water services, unless specially approved.

Pipe Circularity

Circularity of pipe and straight pipe lengths, upstream and downstream a primary device, shall be verified to comply with ISO 5167-1.

Level Instruments

As a general rule level for remote transmission or local control shall be from differential pressure transmitter or from displacement type level instrument.

Displacement-type transmitter shall be selected for interface measurements.

For special applications, other principles of measurement may be considered, such as ultrasonic instrument or instruments based on capacity, conductivity, radar/laser or bubble type.

Level Transmitters

Differential pressure-type transmitters shall be specified, unless unsuitable for the application. Instruments of this type shall be in accordance with §3.1, 'd/p Flow Transmitters' but with 0-100% linear LCD output meter.

Differential pressure instruments with equal length armoured stainless steel capillaries and 3" remote seal diaphragms shall be used when the liquid tends to crystallise or solidify.

Remote seal diaphragms shall also be used if cross-ambient temperature conditions of the impulse lines exist.

The diaphragms shall be wafer-type with rating and facing as per vessel specification. A flushing connection shall be included if the process fluid may block the diaphragm. Fill fluid shall be selected for the most extreme process temperatures and with smallest coefficient of thermal expansion. Capillary length shall be as short as possible.

External Cage Displacement

This type of instrument shall not be used above a range of 1219 mm. Chamber material shall be equivalent to or better than the vessel material. The displacer shall be in AISI 316 and the torque tube in Inconel.

The following standard ranges and c/c side-to-side distances shall be used for displacers: 356 mm, 813 mm and 1219 mm.

The chamber shall be equipped with vent plug and drain valve of OS & Y (outside screw and yoke) type. Heads shall be rotatable.

Direct-operated Type Level Controls

This type of level control, e.g. ball floats, mechanically-linked valves, etc. may be used for utility service.

Special Level Measuring Problems

This may dictate the use of internal displacers, ball floats with direct action, bubble tubes, capacitance, radioactive, radar, ultrasonic type, etc. Solutions shall be considered individually and the most suitable type specified.

Level Switches

These shall only be used in utility service. Level transmitters shall be used for the main process control and in emergency shutdown service.

Level switches shall be the external, float cage-type. Chamber material shall be equivalent to or better than the vessel material. Level switches shall be of the vertical chamber-type with side-bottom connections. Standard centreline distance is 440 mm with the switch point 220 mm from either connection. The switch operation shall be with magnetic transfer. The chamber shall be equipped with a top plug and a drain valve of the OS & Y type.

Level Gauges

Magnetic-type Level Gauges

Stainless steel, magnetic-type level gauges shall be used wherever suitable for gas/liquid level and interface level. The chamber shall be equipped with a full-size bottom flange with OS & Y type drain valve and with a top plug.

Connections shall be side-to-side and c/c distances and visible lengths shall be standardised to the following: 300, 500, 800, 1100, 1400, 1800, 2100, 2500, 3000, 4000 and 5000 mm. However, the visible length shall be extended below the bottom connection to indicate a punctured float.

Red and white flap indicator shall be enclosure protection class IP 67.

In cases where the operating temperature is below ambient and where the liquid is close to boiling point, gauges shall have a narrow float allowing vapours to pass around the float. Such floats shall be guided either by distance sleeves on the floats, or by built-in guide rods. The gauges shall be well insulated.

Frost extension shall be provided if the operating temperature is below 0°C.

Level Gauge Glasses

These may in some cases be dictated by code or special process requirements. Gauge glasses shall normally be reflex-type, except for boiler drums and in corrosive services where transparent gauges with glass protection and illumination of minimum 40W shall be used.

Chamber material shall be equivalent to or better than the vessel material, and the armoured gauge glasses shall be No. 7 glass (10¼" visibility).

The maximum unit length shall be four sections.

The following standard gauges shall be used:

	Centre-to-centre (mm)	Visibility (mm)
1 section	500	260
2 sections	800	560
3 sections	1100	860
4 sections	1400	1160

Gauge glasses shall be supplied with gauge valves, safety ball check valves (except in vacuum service) plus drain valves and vent plugs. All valves shall be OS & Y type.

Frost extension shall be provided if the operating temperature is below 0°C.

Tubular-type Gauge Glasses

This type shall not be used.

4.5 Pressure Instruments

Generally the range upper limit will be 1.5 times the normal operating pressure.

Over-range pressure protection shall be provided, up to design pressure indicted on data sheets. For differential pressure transmitters over-range pressure protection shall be able to protect the sensing element from the maximum design pressure applied to each side with the opposite side vented to atmosphere.

Pressure gauges shall normally be bourdon tube-type with external part filled with glycerin or silicone oil. Process connection shall be 1/2" NPT male, bottom position suitable for direct mounting.

Pressure transmitters and differential pressure transmitters shall be for fieldbus communication or ‘intelligent’ with HART protocol. Bodies shall be in stainless steel with AISI 316 pressure elements. To be provided with 0-100% linear LCD output meter.

The reference accuracy shall be better than ± 0.2% of calibrated span.

Pressure Controllers

Local indicating controllers may only be used inside package units for applications where transmission is not required. The pressure element shall be in AISI 316. The enclosure protection class shall be IP 65. Convenient set point setting and auto/manual switching shall be provided.

Pressure Switches

These shall be diaphragm- or bourdon tube-type and of materials suitable for the specified service. Set pressure and preferably also differential shall be adjustable. Connections shall be ½” NPT male. Pressure switches shall only be used in utility service. Pressure transmitters shall be used in the main process control and in emergency shutdown service.

Pressure Gauges

Gauges for process and utility service shall be the industrial gauge type with stainless steel cases. The gauge shall be a safety type with blow-out protection and with solid front where pointer and glass are separated from the elastic element by a solid disc. Pressure gauges on vibrating equipment shall be standard gauges with flexible connections (impulse line) and mounted on rigid supports. If not possible, oil-filled gauges may be used. Pulsation dampeners shall be installed with the gauges where pulsating pressure occurs. Minimum protection shall be IP 54.

Pressure gauges for steam and hot vapour service shall be equipped with siphons.

Gauge size shall be 100 or 150 mm for process and utility services with white face with black marking.

Pressure elements shall be austenitic stainless steel. Special elements such as diaphragms and bellows can be selected in other materials. Martensitic stainless steel must not be used for gases containing hydrogen.

Chemical seals with body and diaphragm in stainless steel shall be used if the medium tends to crystallise, is highly viscous, or where suspended matter exists.

Sockets and tips shall be of the same material as the elements.

Connections shall be ½" NPT male.

Dials shall be white, non-corroding metal or plastic with black figures.

The range shall be specified so that the gauge normally operates in the middle-third of the scale. Over-range protection shall be selected in accordance with manufacturer's recommendations.

However, over-range protection shall be specified as a general rule for capsule gauges when the design pressure exceeds the range, and for bourdon gauges when the design pressure exceeds the range times 1.3. Diaphragm requires no over-range protection. Accuracy of all direct-connected bourdon gauges shall be guaranteed for 0.5% of full-scale and for diaphragm and capsule 1.6% of full-scale.

When pressure gauge and transmitter are located on the same pipe, the pressure gauge shall be installed so that it is visible from the transmitter location.

The standard ranges indicated below shall be specified:

Capsule (not for liquid)					-4 - +6	mbar g
		-10 - +15	-15 - +25	-20 - +40	-40 - +60	
		0 – 2.5	0 – 4	0 – 6	0 – 10	
	0 – 16	0 – 25	0 – 40	0 - 60		
Diaphragm		0 – 25	0 – 40	0 – 60	0 - 100	mbar g
	0 – 160	0 – 250	0 – 400			
Bourdon	-1 - +0.6	-1 - +1.5	-1 - +3	-1 - +5	-1 - +9	bar g
				0 – 0.6	0 – 1	
	0 – 1.6	0 – 2.5	0 – 4	0 – 6	0 – 10	
	0 – 16	0 – 25	0 – 40	0 – 60	0 – 100	
	0 – 160	0 – 250	0 – 400	0 – 600	0 - 1000	

If required, special ranges may be specified.

4.6 Temperature Instruments

For process temperature up to 500 $_{o}$C, as a general rule, temperature transmission shall be achieved by resistance element associated with a transmitter.

Use of RTD separate amplifier and use of thermocouples shall be restricted to machines and heaters.

RTDs and thermocouples shall be ground insulated type.

Head mounted ohm/I (RTD) or mV/I (T/C) converters shall generally be applied.

The temperature detectors shall be installed in thermowells. Standard length thermowells shall be used. Process connection for thermowells shall be 1 1/2" on pipe work up to 2500# and 2" on lines over 2500# and on vessels.

For the measurement of fluid temperature below 0 ^{o}C, the length of the head extension shall suit the insulating thickness but the head shall extend at least 200 mm outside the insulation.

Thermowells shall be solid machined and drilled in a tapered configuration. They shall be stainless steel as a minimum, flanged type. Where the nature of fluid requires a higher alloy or other material, the thermowell material shall be consistent with the piping or equipment specification.

Thermowells for test points shall be provided with plug.

Where high velocity gases are present, it will be necessary to check thermowells for the “vortex shedding effect”.

Where the application of thermowells would be impractical, thermocouples and resistance thermometers may be located on the surface of pipes or vessel, etc.

Spring-loaded sensor shall be used.

The minimum length for 4" pipe and larger shall be approximately midway between the center of the pipe and the opposite wall, unless otherwise specified by calculated fluid velocity.

Wake frequency calculation to ASME PTC 19.3 shall be produced in high velocity lines; the wake frequency shall not exceed 80% of the natural frequency of the thermowell. Calculations shall be provided for all non-standard lengths

Thermocouples

These shall be single-type, high-purity magnesium oxide, insulated and sheathed. The measuring hot junction shall be isolated from ground. Sheath shall be 6 mm OD depending on the service. The wire diameter shall be minimum 0.90 mm. Thermocouple type K shall normally be used above 400°C.

Thermocouples must comply with IEC 60584-1 and 2, Class 1 and IEC 61515. Insulation shall be able to withstand a test voltage of 500V rms.

6.2 Thermowells

The thermowells shall be of AISI 316 stainless steel. AISI 347H shall be used for temperatures above 538°C. Thermowells shall be machined from bar stock material. Other materials shall be furnished as required in the Piping Specification. Thermowells shall be tapered in high velocity streams in order to avoid resonance.

According to ANSI/API RP 551, the immersion length of thermowells in pipes (the length from well tip to pipe/vessel wall) shall be maximum 5" or 125 mm.

The immersion length in vessels containing liquid shall be 300 mm. In vessels containing gas, the immersion length shall be according to the table below:

Vessel Diameter (D)	Thermowell Immersion Length
D up to 800 mm:	200 mm
800 mm <D< = 1200 mm:	300 mm
1200 mm <D< = 1600 mm:	400 mm
1600 mm <D< = 2000 mm:	500 mm
D above 2000 mm:	600 mm

The insertion length depends on the length of the nozzle or pipefitting, taking any possible refractory lining into account.

Process Connections

The connections on all thermowells shall be 1" NPT male.

Thermo-electric Properties

Thermo-electric properties and limits of errors shall conform to IEC 60584-2.

Resistance Temperature Detectors

These shall be used for applications below 400°C where very narrow spans and high accuracy are required. Detectors shall be 6 mm OD, AISI 316 stainless steel sheathed with Pt 100 ohms (0°C) elements according to IEC 60751, Class A.

Detectors shall be the vibration-proof element type, suitable for three-wire connection. Test voltage shall be 500V rms.

Temperature Sensor Heads

The sensor heads shall have enclosure protection class IP 65. A spring-loaded design is required.

Temperature Transmitters

Temperature transmitters are to be used. The transmitters shall be for fieldbus communication or be 'intelligent' with HART protocol. The transmitters shall be separated from the thermowell heads and be installed on a stand or in a junction box or panel easily accessible for maintenance. The accuracy shall be ± 1°C.

Local Thermometers

The thermometers shall be the bimetallic, heavy-duty, back-connected type with minimum 120-130 mm dial with adjustable and rotatable head and stem. Case and stem shall be in stainless steel. Enclosure protection class shall be minimum IP 55.

The following standard ranges shall be used:

-70 - +50	-30 - +70	-30 - +170	-30 - +270			°C
0 - 60	0 – 120	0 – 160	0 – 250	0 – 400	0 - 600	

If required, special ranges may be specified.

9 Analysers and Accessories

The analysers shall comprise the following types:

- Infrared analysers for CH_4, NH_3, CO, CO_2 (extractive)
- Thermal conductivity for H_2 (extractive)
- Zirconium oxide for O_2 in flue gases (in-situ)
- Chemi-luminescence for NOx in flue gases (in-situ or extractive)
- IR for NOx in flue gases (in-situ or extractive)
- UV pulse-fluorescent for SO_2 in flue gases (extractive)
- NDIR for SO_2 in flue gases (in-situ)
- Conductivity and pH (extractive)
- Gas Chromatographs or Mass Spectrometers will be considered if nitrogen shall be measured in the synthesis loop, or if total compositions are required for feed streams
- UV or lead acetate for Sulphur
- Other principles for specific gravity, LEL, etc.

Analyser selection and installation shall normally comply with ANSI/API 555.

9.1 Extractive Analyser Systems

These systems shall be supplied as engineered, pre-mounted package units complete with analyser, sample conditioning and calibration systems all wired and tubed.

Extractive process analyser systems shall normally comprise a local sampling system located close to the tapping and the final sampling/calibration system with the analyser located in an analyser house or shelter. Conductivity and pH analysers shall be installed close to the tapping, but in a bypass, so that the electrodes can be serviced without interrupting the process. Pressure reduction and drainage to sewer shall be applied for higher process pressures.

As most process sample gases are combustible, the analyser section, or the whole analyser shall be provided with nitrogen purge (Exp). Vent lines shall have moisture separation. In case of low nitrogen purge, the analyser shall immediately be de-energised and an alarm shall be generated.

The analysers can optionally be in Exd enclosures.

Extractive emission analysers need not be installed in analyser houses or shelters, but in any non-hazardous area. The analysers can be the general-purpose type located in weatherproof

9.2 In-situ Analyser Systems

These systems shall be installed so that calibration and servicing is possible without affecting the process. The analysers and their accessories shall be suitable for the area where they are installed.

9.3 Cabinets

Cabinets for the analysers shall be electrically heated if required, in order to prevent internal condensation when not in operation.

9.4 Transmissions

The required transmissions use foundation Fieldbus for the measured component, and a direct serial port for interface with the FCS. This serial port shall be used for hardware status information and data validation.

9.5 Gas and Vapour Sampling System

Volumes shall be kept to a minimum. The tubing shall be stainless steel, 6 mm in diameter or less if required.

For gas samples, pressure shall be reduced at the sampling point to increase the velocity through the sample system and to reduce the time lag between the sample point and the analyser.

Special low-volume, insert-type sample probes, as included in the general Piping Specification shall be used for analysers, particularly for high-pressure applications.

Sample coolers are not required for most flue gas applications. Normally, process gas streams above 100°C require cooling, and a calculation based upon the sample rate and the latent heat will clarify whether an air cooler is sufficient, or if a water cooler is required.

Sample bypasses shall be provided around the analysers. This will ensure that the sample lines are purged and the time lag of the sampling is reduced. The sample bypass shall be vented to the atmosphere at a safe location.

The sample must be clean and free of particles. Either a suitably sized strainer shall be installed immediately ahead of the primary pressure reducer, or the reducer shall have a built-in filter.

Additional filters, strainers and drains shall be specified as part of the system. All components shall be as small as practically possible to minimise the volume of the sampling system. It may be necessary to water-wash the stream when dirty samples, e.g. from stack gas shall be analysed. The water shall be recycled with only a small make-up and drain stream to minimise composition changes.

Normally, desiccants should be avoided when drying a sample stream. Chilling and trapping of moisture is preferred, because desiccants can be spent, fail to function or may absorb other constituents besides water.

Steam or electrical tracing and/or insulation of the sample line are required if the sample may condense under ambient conditions. The manufacturer shall provide a heated cabinet for the sample-conditioning system if there is any risk of condensation.

Sample calibration span and zero gases shall be provided with double block-and-bleed valves to ensure positive isolation.

9.6 Liquid Sampling Systems

The systems are similar to gas or vapour systems. Filtering, pressure reduction, cooling or heating may be required. The medium in the process line shall determine the required extent of sample conditioning.

Liquid bypasses shall normally be provided around the analyser, in order to reduce the sampling time lag. They shall normally be drained to a sewer.

15 Electrical Supply, Classification and Instrument Wiring

15.1 Electrical Supply

The supply for the instrumentation shall be as follows:

- Distributed Control System:	110V AC
- Emergency Shutdown System:	110V AC
- Instruments:	110V AC
- Solenoid Valves:	24V DC
- Local Panels:	110V AC
- Local Illumination, Air-conditioning Equipment, Space Heaters, Ventilation of local panels and similar purposes:	230V AC
- Field-mounted Transmitters and Switches:	24V DC
- Safety Circuits with Lamps and Relays:	24V DC

The 110V AC shall be supplied from an Uninterrupted Power Supply (UPS) of 110V ± 10%, 50 Hz ± 1% with directly earthed neutral.

Local rectifier units shall form an integral part of the control package where 24V DC power is required. The power supply to these units shall be taken from the UPS. Where 24V DC is used for Safety Circuits, the rectifier units shall be duplicated and have a high reliability. A failure in any unit must activate an alarm.

A separate instrument earthing system interconnected to the power supply protective earthing system at one particular earthing pit shall be applied.

15.2 Electrical Classification

All electrical instruments, equipment and installations shall meet the requirements specified in HTAS documents "General Specification for Classification of Hazardous Areas" with relevant "Data Sheets, Ex-Equipment".

Certification for installation in hazardous areas in accordance with IEC 60079 series is shown below: For Fieldbus devices a FISCO certification is preferred, entity certification can be accepted if FISCO is not available.

Thermocouples, RTD's:	No certification, 500V DC insulation level
Transmitters, positioners, I/P converters, etc.:	Ex ib IIC T3 or Ex d IIC T3
Switches:	Ex d IIC T3
Analysers and Panels:	Ex p II T3
Solenoid Valves:	Ex i IIC T3
Junction Boxes and Cable Glands:	Ex e II T3

15.3 Cables, Wiring and Cable-laying

- **Galvanised Steel Wire Armouring** with PVC outer sheathing shall be used for all cables.

- **Electronic Instrument Signal Cables** shall be twisted cable pairs, 15 twists or more per metre. Conductors shall be $1.5mm^2$ for one- and two-pair cables and $0.5mm^2$ for multi-pair cables and shall be stranded, tinned copper. Insulation shall have a minimum radial thickness of 0.25 mm. Insulation between conductors shall withstand a test voltage of min. 2000V rms.

  Multi-pair cables shall be shielded with a common aluminium Mylar tape with tinned copper drain wire. The temperature rating shall be min. 90°C. Conductor pairs shall be numbered from 1 to 12.

- **Power and Control Cables for Solenoids, Flame Detectors, etc.** shall be three-core with a conductor size of $1.5mm^2$. However, conductor sizes for power cables shall be coordinated with the design for the electrical installations in order to avoid many different cable types.

- **Resistance Temperature Element Wiring** shall be done with cables equivalent to electronic instrument signal cables, but with 3 wires.

- **Thermocouple Compensating Cables** shall be with twisted cable pairs, 15 twists or more per metre. Conductors shall be $1.5mm^2$ for one- and two-pair cables and $0.5mm^2$ for multi-pair cables. Conductors shall be numbered and colour-coded according to the specified standard. Individual cable pairs and the individual pairs in multi-pair cables shall be shielded with aluminium Mylar tape with tinned copper drain wire. Multi-pair cables shall also have a similar common shield. Compensating cables shall comply with IEC 60584-3.

PVC is standard insulation with a minimum temperature rating of 90°C.

Separate conduits and separate multi-conductor cables shall be supplied for thermocouple wiring, 4-20mA wiring, for shutdown system wiring and for power circuits. Intrinsically safe cables, shutdown cables and power cables shall be routed separately.

Closed conduit wiring design shall not be used.

- **For Hot Area Service**, e.g. steam drums where the cable temperature is likely to exceed 90°C, high temperature silicone cables are required. These cables shall only be laid within the hot area and be terminated in a junction box mounted outside the hot area.

- **Intrinsically Safe** circuits shall be clearly marked to distinguish them from other circuits. Cables and terminals shall be colour-coded; the outer sheaths and terminals in light blue. The enclosures shall be labelled.

- **Outer Sheaths** of cables shall be flame-retardant and self-extinguishing in accordance with IEC 60332-3-24.

16 Electromagnetic Compatibility (EMC)

All electronic equipment like FCS, ESD, transmitters, positioners, etc. shall comply with IEC 61000-6-2 for immunity to emissions. Emissions from the instruments shall comply with IEC 61000-6-4.