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KLM Technology Group #03-12 Block Aronia, Jalan Sri Perkasa 2 Taman Tampoi Utama 81200 Johor Bahru Malaysia	PLANT PIPING SYSTEMS DESIGN CRITERIA (PROJECT STANDARDS AND SPECIFICATIONS)	

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SCOPE

This Project Standard and Specification covers minimum requirement(s) for general aspects to be considered in design of piping for petroleum and petrochemical plants to be designed in accordance with ANSI B31.3 which includes but not limited to the following:

- Loading and unloading terminals.
- Crude oil & gas gathering central facilities.
- Production units.
- Package equipment, in accordance with ANSI-B 31.3.
- Pump house and compressor stations (booster stations).
- Tank farms and oil/gas depots.

This Standard is not intended to be applicable to the following systems:

- Heating, ventilation and domestic water system within building (HVAC).
- Steam piping system: within the steam generation unit and power station plant designed in accordance with ANSI B31.1.
- Non-metallic piping systems
- Hydraulic systems
- Offshore facilities

REFERENCES

Throughout this Standard the following dated and undated standards/codes are referred to. These referenced documents shall, to the extent specified herein, form a part of this standard. For dated references, the edition cited applies. The applicability of changes in dated references that occur after the cited date shall be mutually agreed upon by the Company and the Vendor. For undated references, the latest edition of the referenced documents (including any supplements and amendments) applies.

1. ANSI/ASME (American National Standard Institute / American Society of Mechanical Engineers)
 - B-31.3 "Chemical Plant and Petroleum Refinery Piping"
 - B-36.10 "Welded and Seamless Wrought Steel Pipe"
 - B-16.5 "Pipe Flanges and Flanged Fittings"
2. API (American Petroleum Institute)
 - 650 "Welded Steel Tanks for Oil Storage"
 - RP-521 "Guide for Pressure-Relieving and Depressuring Systems"

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3. BP (British Petroleum)

C P-3	"Plant Layout"
C P-14	"Over Pressure Protection Systems"
C P-16	"Passive Fire Protection of Structures & Equipment"
Std.-107	"Forced Drought Burners for Fired Process Heaters"

4. BSI (British Standard Institution)

BS 3293	"Specification for Carbon Steel Pipe Flanges (over 24" nominal size) for the Petroleum Industry"
BS 4485	"Water Cooling Towers"

5. EJMA (Expansion Joint Manufacturers Associations)

6. NACE (National Association of Corrosion Engineers)

MR-01-75	"Standard Material Requirement Sulfide Stress Cracking Resistant Metallic Material for Oil Field Equipment"
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7. NFPA (National Fire Protection Association)

30-12	"Flammable and Combustible Liquids Code"
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8. UK Health and Safety Executive Guidance

DEFINITIONS AND TERMINOLOGY

Battery Limit - The boundary of a process unit, enclosing all equipment and unit limit block valves.

Cold Spring - Cold spring is the intentional deformation of piping during assembly to produce a desired initial displacement and stress.

Complex - A group of units, the operation of which are interlinked. (On small plants, the term "complex" may refer to all the process units on the plant).

Depot - A storage area with capacity less than 5000 tones with import and export facilities.

Designer - The person or party which is responsible to the Company for engineering/design of the plants.

Note:

Any specific application of the terms and responsibilities for the parties defined above, are a matter for the conditions of contract on a project.

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Executor - The party which carries out all, or part of the construction, installation and commissioning aspect for the projects.

High pressure service steam - above 24 barg (normally 40 barg)

Low pressure service steam - up to 7 barg

Medium pressure service steam above - 7 barg up to 24 barg

Piping System - It covers the overall systems of pipes and piping components, e.g. fittings, valves, nozzles and supports, that are employed to transfer liquid, gas, steam, etc. between the equipment such as tanks, pumps, vessels and so forth.

Stress Relieving - Uniform heating of a structure or portion thereof to a sufficient temperature and maintaining for a specified period to relieve the major portion of the residual stresses followed by uniform and controlled cooling.

Unit (Area) - A main production component of a refinery plant or chemical complex, e.g. distillation unit, utility unit, etc.

Utilities - Air supply, water supply and treatment, steam generation, power generation and similar services.

UNITS

This Standard is based on International System of Units (SI) except where otherwise specified.

GENERAL DESIGN REQUIREMENTS

Design Procedure

The Design of Piping is characterized by two successive phases as follows:

1. Basic Design

The following documents are minimum requirements for piping design in this stage.

- Plot Plan and/or Equipment Layout
- Piping and Instruments Diagrams
- Piping Specifications Relating to Individual Project.
- Line Identification List

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2. Detail Engineering Design

Layout for erection and Detailed Piping Drawings for construction shall be produced during this stage.

Detail design of piping shall include but not limited to the following:

- Final (detailed) P&ID (Piping & Instrument Diagram).
- General plot plan.
- Unit plot plan or equipment layout.
- Above ground piping layout.
- Under ground piping and foundation layout.
- Piping plans (erection drawings).
- Isometric drawings.
- Line identification list.
- M.T.O. (Material Take Off list).
- Piping material specification.
- Pipe support schedule.
- Stress analysis calculation.
- Design model (optional).
- Pressure testing P&ID.
- Tie-in diagram.

a. Piping and instrumentation diagram (P&ID)

The following items shall be considered and shown in the P&ID.

- Data and information of equipment.
- Line identification.
- Nozzle's position and size, for vessels and towers.
- Type of valves.
- Vents, drains and relief systems for lines and equipment.
- Insulation and tracing on lines.
- Pipe class (wall thickness and material).
- Control systems and loops (Instrumentation).

The Utility Flow Diagrams (UFD) is a type of P&ID that represents the utility systems within a plant and shows all equipment and piping in respect of utilities (water, air, steam,...).

b. General plot plan

- The general plot plan shall give the layout of the whole plant(s). It should be prepared to one of the following scales: 1:500, 1:1000, 1:2000.
- The following items shall be shown in plot plan:
 - o Battery limits of complex (Area boundary).
 - o Geographic and conventional or plant north.
 - o Elevation, with regard to the nominal plant 0 elevation.

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- Coordinates of main roads, process units, utility units, buildings, storage tanks and main pipe rack.
- Location of flares and burn pit.
- Direction of prevailing wind.

Note:

Plant coordinates may be started from point N = O and E = O.

- The arrangement of units areas, storage areas, buildings, and devices for shipment to be provided within the plant, shall be decided on the base of the following factors:
 - Soil characteristics.
 - Main road or rail access ways.
 - Location of pipelines to and from plant.
 - Direction of prevailing wind.
 - Local law and regulation which may affect the location of units and storage facilities.
 - Natural elevation for location of units and equipment (such as storage tanks, waste water unit, oil/water separator, etc.).
- The units shall be separated by roads. Major roads shall have minimum width of 6 m., with maximum length of 400 m. The minor roads shall have minimum width of 4 m. (Minor roads shall not be in an area classified as zone 0 or 1).
- A plant may contain one or several process units. Where any unit processes flammable fluids and may be operated independently (i.e. one unit may be shut down with others in operation). The minimum spacing between equipment on the two adjacent units shall be at least 20 m.
- For units processing flammable fluids, the central control building shall be adjacent to a road. It shall not be located in any area classified as zone 0 to 1.
- Security fence
 - All sites (plants or complex) shall be within a security fence.
 - Any public building, such as administration office, restaurant, clinic, etc., shall be located outside of the process area boundary.
 - Except for case (d) the minimum space between security fence and units' boundary shall be 20 m, and between security fence and equipment shall be 30 m.
 - In case of special units such as flammable material storage with vapor release and toxic materials, minimum space shall be at least 60 m from site boundaries adjacent to centers of population (domestic, work or leisure).

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- Except where they are an integral part of a process unit, site utility units should be grouped together in an area classified as non-hazardous.
- Fire water pumps and equipment shall be sufficiently remote from processing, storage and loading area, where a major fire could occur.
- The waste water treatment facilities shall be located at the lowest points of plant.
- Loading/unloading areas for road transport shall have adequate space to provide access for filling, parking and maneuvering. A drive through rack arrangement is preferred. The loading and unloading facilities should be downwind or crosswind from process units and sources of ignition, based on the direction of prevailing wind.
- Flares

The location, spacing, orientation and general design consideration shall be in accordance with the Standard BP-CP-14.

- Access requirements
 - o Access ways within the plant shall be provided for maintenance, emergency case, and for fire fighting from the road around the plant. Piping system shall be laid in such a way to make possible passage of mobile equipment.
 - o Minimum widths of access way shall be as follows:

Vehicular access ways within units:	4.0 m	
Pedestrian access ways and elevated walk way:		1.2 m
Stairways and platforms:	0.8 m	
Footpaths in tankage areas:	0.6 m	
Maintenance access around equipment:	1m	
 - o Minimum headroom clearance for access ways shall be as follows:

Over railways or main road:	6.8 m
Over access roads for heavy trucks:	6 m
For passage of truck:	4 m
For passage of personnel:	2.1 m
Over fork-lift truck access:	2.7 m

c. Unit plot plan

The unit plot plans shall be designed based on general plot plan.

The drawing shall be prepared in one of the following scales: 1:200, 1:500.

The drawing shall show the following items:

- Conventional north.
- Coordinates of battery limits and roads.
- Symbols for equipment and coordinates of their center lines.
- Finished floor elevation.

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- Equipment index list.

The area of any unit shall not exceed 20,000 m², and the length of each side should not exceed 200 m.

d. Layout

The piping layout should minimize piping runs on very high pressure and corrosive/toxic services such as acidic gases, and shall consider economy, accessibility for operation, maintenance, construction and safety.

Layout of equipment

- Compressors
 - o Generally, compressors shall be installed outdoors. In case a shelter is required, the ventilation of room shall be taken into consideration.
 - o In so far as it is practical, all compressors shall be positioned under one shelter. This arrangement makes work easier for operators and maintenance crew; in addition one crane may serve all compressors if its deployment becomes necessary.
 - o Minimum spacing between gas compressor and open flames shall be 30 m.
- Pumps
 - o Pumps should generally be located in the open area, at or near grade level. Adequately ventilated shelters shall be provided for large machines requiring in situ maintenance. The pumps should also be located under the piperack.
 - o All pumps shall be accessible for operation and maintenance. Adequate space for lifting and handling facilities for maintenance shall be provided.
 - o Pumps should be located and specified so that an acceptable NPSH can be obtained without undue elevation of suction vessels or columns. Pumps on flammable or toxic duties shall not be located in pits to meet this requirement.
 - o In flammable fluid service, the horizontal distance between the related pump and adjacent heat source of 650°C or more shall be 30 meters min.
- Fired heaters
 - o A heater, or group of heaters shall be located on the periphery of a plot and immediately adjacent to an unrestricted road. There shall be adequate access for fire fighting from all sides of a heater.

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- The layout and design of heaters shall normally be such that the tube removal can be effected by mobile lifting equipment, for which there shall be proper access.
- Air cooled heat exchangers (fin fan)
 - The location of air cooled heat exchangers shall be specifically considered with respect to any areas of special fire risk. Such consideration shall include:
 - The effect of the exchanger on air movement and increased fire spread.
 - The possibility of failure of exchanger tubes releasing more combustible fluid to the fire.
 - Air cooled heat exchangers may be located above piperacks, where practicable and economical.
 - Air cooler shall not be located within 7.5 m horizontally from pumps on hydrocarbon service, and where practicable be at least 20 m horizontally from fired heaters, to minimize the possibility of circulation of hot air.
- Shell and tube heat exchangers
 - Heat exchanger shall be located so that, when their tube bundles are withdrawn, they do not project into an emergency escape route or any road with unrestricted vehicle access. They shall be so arranged that can be readily dismantled for cleaning and maintenance.
 - Heat exchangers shall be located collectively, at one point as far as possible, and their tube bundle pulling area shall be provided (tube bundle length + min. 2 m).
- Cooling towers

The direction of the prevailing wind shall be considered in selecting the location of cooling towers. The towers shall be located to minimize any nuisance, both within and outside the site, from the water blow-out, evaporation, drift and ice formation. The requirements of BS-4485 shall be met.
- Air intakes and discharges

Air intakes, including intakes to heating and ventilating system, air compressors for process, instrument, plant and breathing air, and to gas turbines shall be located as far as is practicable away from areas where air contamination by dust or by flammable or toxic material can occur. They shall not be located in any area classified as zone 0, 1 or 2 (except for gas turbine air intakes which shall be in accordance with

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manufacturer's requirement), nor located above or below an area classified as zone 0, or 1.

Note:

Intakes and discharges shall be separated to prevent cross contamination by recirculation, taking into account natural wind effects. The distance between intakes and discharges shall be not less than 6 m.

- Storage tanks (Liquids)
 - o Storage tanks in tank farm should be laid out in a separate area (unit) and shall be completely surrounded by a bund or dyke as specified in NFPA 30-12 (for minimum tank spacing).
 - o For tanks with diameter less than 48 m individual bounded compounds are not required, but for each crude oil tank with a diameter of 48 m or greater, a separate bounded compound shall be provided. In no case shall the number of tanks in any bounded compound exceeds 6; nor the total capacity shall exceed 60,000 m³. Intermediate walls of lesser height than the main bunds may be provided to divide tankage into groups of a convenient size, to contain small spillage and act as firebreaks.
 - o Tanks shall be laid out to provide access for fire fighting. There should be no more than two rows of tanks between adjacent access roads.
 - o Pumps associated with tankage operation shall not be located inside a bounded tank compound.
- Pressurized LPG storage
 - o LPG storage shall be laid out in accordance with UK Health and Safety Executive Guidance (Par. 15 to 29).
 - o Any site boundary to third party property shall have such a distance that the radiation at ground level, in the event of ignition of the leakage from a single relief valve and/or from a fire in a spill contaminated area, shall not exceed 4.7 kW/m².
The ground level radiation shall be calculated using the method in API Recommended Practice 521, Appendix A.
- Sour NGL storage

In sour NGL storage tanks in addition to heat radiation mentioned above, safe distance with regard to H₂S contaminated area shall be considered.

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e. Isometric drawings

All lines DN 50 (NPS 2) and larger in the process and utility areas shall have isometric (spool) drawings; utility and instrument piping DN 50 (NPS 2) are exempted.

Isometric drawings shall be prepared for construction of each pipe (prefabrication or site fabrication), as per piping plan drawings.

Drawings shall be designed without using scale and shall include graphic part, dimensional tables, list of materials, and plant north, design data, insulation, test, etc.

f. Line identification list

Line identification list (line list) shall include, but not limited to the following information:

- Start point & end of line (connected to equipment or other lines).
- Medium service.
- Phase of flow (liquid, vapor, etc.).
- Pressure and temperature (design, operating).
- P & ID and reference drawing.
- Line number.
- Piping specification code (line class).
- Type of insulation.
- Pipe size.
- Heat treatment.
- Branch reinforcement.
- Special information, if required.

g. Pipe supports

Pipe supports schedule shall be prepared with the following data:

- Type of support
- Reference drawing for fabrication and installation.
- Line number
- Location of installation (unit, area, coordinates)
- Piping plan and civil drawing number

The location and identification of all pipe supports shall be shown on the piping plan and isometric drawings.

h. Stress analysis

i. Model

Model or three dimensional software (if required) shall be made during detail engineering. The model of software shall be reviewed by Company with designer for any necessary modification.

The scale for construction of model components shall be 1:321/3 (or 1:30 if approved by Company).

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j. Pressure testing P&ID

This drawing shall be prepared based on final P&ID (s) with the following considerations:

- Position of valves (closed or open).
- Isolation of equipment nozzles and limit of test section with the spectacle blind or similar facilities.
- Installation of vent and drain connections for test.
- Isolation or removing of all instruments.
- Test pressure and test medium.
- Test procedure.

k. Tie-in diagram

- In case of modification or expansion of existing plants, the tie-in diagram(s) shall be prepared to clarify piping connection points and their tie-ins between the existing plant and its expansion parts.
- This diagram shall be as detailed as P&ID.
- The tie-in diagram shall show the location points and procedure of tie-in.

ABOVE-GROUND PIPING SYSTEMS

Piping Design

1. Design Condition

a. Design pressure

i) Design pressure for piping system shall be determined in accordance with ANSI/ASME B 31.3 with the following additions:

- Where the pressure is limited by a relieving device, the design pressure shall not be less than the pressure which will exist in the piping systems when the pressure relieving device starts to relieve or the set pressure of the pressure relieving device, whichever is the greater.

The maximum differences in pressure between the inside and outside of any piping component or between chambers of a combination unit, e.g. a jacketed pipe, shall be considered, including the loss of external or internal pressure.

Piping subject to vacuum shall be designed for a negative pressure of 1 bar unless a vacuum break or similar device is provided, in which case a higher design pressure may be approved.

- The value of the design pressure to be used, shall include the static head, where applicable, unless this is taken into account separately.

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ii) Design pressure of a piping system subject to internal pressure shall be defined as one of the following:

- Design pressure of the equipment to which the piping is connected.
- Set pressure of relief valve of the piping equipment system.
- A pressure not lower than the shut off pressure or that resulting from the sum of the maximum suction pressure plus 1.2 times the design differential pressure, for discharge lines of pumps and/or compressors not protected by a relief valve.
- The maximum differences in pressure between inside and outside of any piping component or between chambers of a combination unit, e.g. a jacketed pipe, shall be considered including the loss of external or internal pressure.

iii) Vacuum piping

The piping subject to vacuum shall be designed for a negative pressure of 100 KPa (1 bar) unless a vacuum breaker or similar device is provided.

b. Design temperature

Design temperature shall be determined in accordance with ANSI/ASME Code B 31.3 with following additions:

- Design temperature shall include an adequate margin to cover uncertainty in temperature prediction.
- Design maximum temperature shall not be less than the actual metal temperature expected in service and shall be used to determine the appropriate design stress "S" for the selected material.

In case exterior of components are thermally insulated, the lowest metal temperature shall be taken to be the minimum temperature of the contents of the pipe.

c. Operating temperature

The operating temperature of a piping shall be determined as the temperature corresponding to that of the fluid in normal operating conditions.

In case of steam-traced piping, the operating temperature shall be assumed as equal to one of the following:

- Temperature equal to 70 percent of steam operating temperature if conventional tracing is employed without the use of heat-conductor cement, and when steam temperature is higher than the operating temperature of process fluid.

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- Steam operating temperature, in case of tracing with the use of heat-conductor cement.
- Steam operating temperature, in case of jacketed piping.

2. Pipe

a. Pipe material

Pipe material as cited in ANSI/ASME B31.3. For sour services, requirements of NACE. MR-01-75 shall be considered.

b. Pipe size requirement

Pipe smaller than DN 15(NPS $\frac{1}{2}$ ") should not normally be used, except for instrumentation.

The use of steel pipe in sizes: DN 32 (NPS 1 $\frac{1}{4}$), DN 65 (NPS 2 $\frac{1}{2}$), DN 90 (NPS 3 $\frac{1}{2}$), DN 125 (NPS 5), DN 175 (NPS 7), DN 225 (NPS 9) and DN 550 (NPS 22) should be avoided.

c. Pipe wall thickness

The required thickness of pipes shall be determined in accordance with ANSI/ASME B 31.3.

The selection of standard wall thicknesses of pipes shall be in accordance with ANSI/ASME B 36.10.

d. Branch connections

Branch connections shall be calculated in accordance with ANSI B 31.3.

3. Piping Components

For sour services, requirements of NACE-MR-01-75 shall be considered.

a. Type of piping joints

Piping joints shall be designed in accordance with ANSI/ASME B 31.3.

i) Threaded joints (addition to B 31.3-314):

- Threaded joints may be used for normal fluid service and when:
 - o The fluid handled is non-flammable and non-toxic, non-hazardous, non-erosive and the duty is non-cyclic.
 - o The design pressure does not exceed 10 bar (ga) (150 psig).
 - o The design temperature is between -29°C (-20°F) and 186°C (366°F), except that steam is not included in this category.
 - o The connection is provided for pressure test.
- Where seal welding of threaded joints is used, the material shall be weldable.
- Threaded joints and fittings shall not be used for:
 - o General chemical service.
 - o Corrosive fluid.

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- o Steam service
- To reduce the incidence of leakage, the use of threaded joints and unions where permitted should be minimized consistent with needs of pipe work fabrication. Sufficient threaded joints or unions, where permitted, shall be provided to facilitate dismantling of pipe work for all operational, maintenance and inspection purposes, including requirements for shutdown and gas freeing.
- With the exception of connections to instruments and instrument valve manifolds, threaded joints shall not be used in stainless steel, alloy steel or aluminum piping systems.
- No threaded joints or fittings shall be used between a pressure vessel or main pipes DN 50 (NPS 2) or above, and the first block valve isolating a piping system. This valve shall be flanged or may be socket-welded with a flanged joint immediately downstream.
- Layout of piping employing threaded joints should in so far as possible, minimize stress on joints.
- ii) Socket weld joints (additional to B 31.3):
 - Socket welding connections should be used wherever possible up to the limiting size of DN 40 (NPS 1½) except for water service which could be used up to DN 80 (NPS 3).
 - Where permitted, socket welding joints are preferred to threaded joints, except for non-hazardous service.
 - Socket welding rather than threaded fittings shall be used for searching fluid service (e.g. for glycol service).
- iii) Flanged joints (additional to ANSI/ASME B 31.3).
 - The use of flanged joints should be kept to a minimum particularly on hazardous service. However, sufficient break flanges shall be provided to allow removal and replacement of piping where:
 - o Process duties may be fouling
 - o Deterioration of piping or valves is anticipated in service due to corrosion, erosion, etc.
 - Flanges types

Flange type shall be with following considerations:

 - o Flanges should normally be welding neck type.
 - o Slip-on flanges shall not be welded directly on to elbows or other fittings and shall be double welded for all services.
 - o Class 400 flanges shall not be used.
 - o Where BS 3293 flanges are required, because of adjacent equipment, a check calculation on the suitability of the flange design for hydrostatic test conditions shall be made.