Design of Process Skids

by 3D-LABS

Table of Contents

Prepared by: Shiek Abdulla Company: 3D-LABS

Approved by: Abdul Khader Date: 21-08-17

1.0 INTRODUCTION:

A Skid is a transportable package of a process system which contains equipments like filters and heat exchangers, piping, valves and supporting structures for the same. Individual skids can contain complete process systems and multiple process skids can be combined to create larger process systems or entire portable plants. The main advantage of a process skid is quality control. Because only one party will be responsible for the construction and build of the skid process unit, there is a higher level of responsibility and quality control.

A designer must have a good knowledge in basic piping, structural and equipments before going to design a process skid. At the same time, designers must acquire the knowledge of the any one modeling software such as CAD Worx and PDMS. This reference manual provides basic knowledge of piping, structural and equipments in the following chapters to ease design of process skids.

2.0 PIPING:

Piping is used for Industrial (process), Marine, transportation, Civil engineering, and for commercial purposes. This chapter primarily concerned with industrial piping for processing and service systems. Process piping is used to transport fluids between storage tank and processing units.

2.1 Introduction:

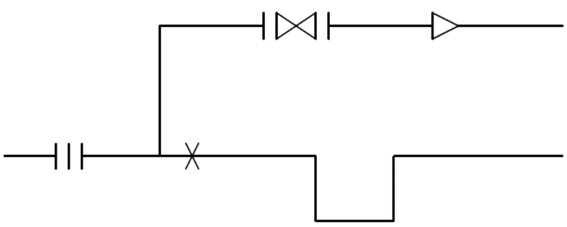
Piping is an assembly of piping components used to convey, distribute, mix, separate, discharge, meter, control or snub fluid flows. Piping also includes pipe-supporting elements but does not include support structures, such as building frames, bents, foundations, or any equipment excluded from Code definitions.

Piping components are mechanical elements suitable for joining or assembly into pressure-tight fluid containing piping systems. Components include pipe, tubing, fittings, flanges, gaskets, bolting, valves and devices such as expansion joints, flexible joints, pressure hoses, traps, strainers, in-line portions of instruments and separators.

2.2 Piping and Instrumentation Nomenclature, Components:

Graphic of sample piping system illustrating

- header
- branch connection
- valve
- flange
- pipe support
- reducer & elbow



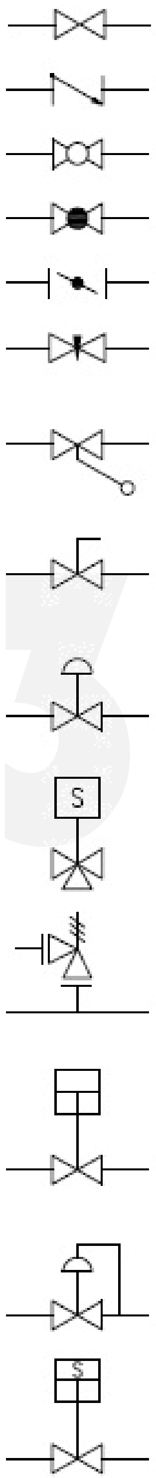
Few other piping, equipment and instrument symbols listed below to ease your understanding of Piping and instrumentation diagram. The flow diagrams presented in this chapter are representative of the types used by many engineering and design companies. While actual symbols may vary slightly from company to company, the general appearance of flow diagrams is the same throughout the piping industry.

PIPING SYMBOLS IDENTIFICATION

SYMBOLS	NAMES
	NEW PROCESS LINE
	EXISTING PROCESS LINE
	FENCE LINE
	OFF PAGE CONNECTOR
	END OFF LINE FLAME ARRESTOR
	STRAINER BUCKET TYPE
	'Y' TYPE STRAINER
	SPECTACLE BLIND (OPEN)
	SPECTACLE BLIND (CLOSE)
	SPACER & BLANK
	PIPE CAP
	HOSE COUPLING
TP XX	TIE–IN POINT
	CONCENTRIC REDUCER
	ECCENTRIC REDUCER (TOPSIDE FLAT)
	TWO WAY HYDRANT

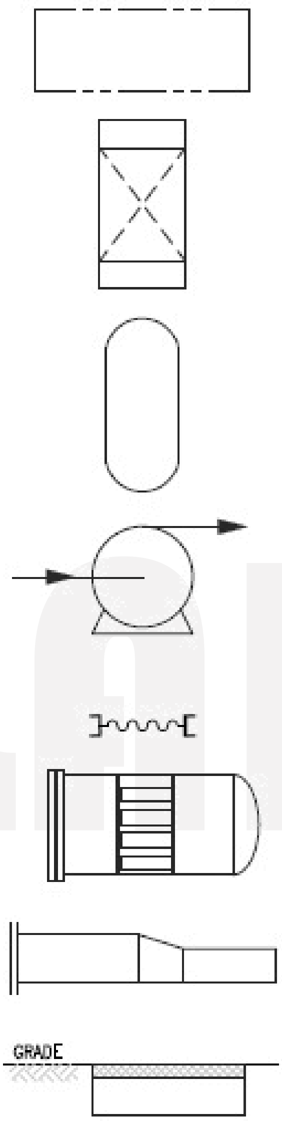
SYMBOLS	NAMES
	TUNDISH / FUNNEL
	INSULATION
	DRAIN
	BARRED TEE
	SPLIT TEE
A/G U/G	ABOVE GROUND UNDER GROUND
SC XXX	SAMPLING POINT
RO XXX	RESTRICTION ORIFICE
	ISOLATION JOINT
	FLOW CONDITIONER
	FIELD WELD
	VENT CAP
	ANCHOR FLANGE
XXX SP XXX	SPECIALTY ITEM TAG
VENDOR EPC CONTRACTOR	SCOPE BREAK

VALVE SYMBOLS



SYMBOLS	NAMES
	GATE VALVE (MANUAL OPERATED)
	CHECK VALVE (NON–RETURN)
	BALL VALVE
	GLOBE VALVE
	BUTTERFLY VALVE
	NEEDLE VALVE
	FLOAT VALVE
	PLUG VALVE
	CONTROL VALVE
	3 WAY SOLENOID VALVE
	PRESSURE RELIEF VALVE OR SAFETY VALVE
	REMOTE OPERATED VALVE PNEUMATIC SPRING RETURN ACTUATOR (GAS POWERED ACTUATOR)
	PRESSURE CONTROL VALVE(SELF ACTUATED)
	SLAM SHUT VALVE (SELF ACTUATED)

EQUIPMENT SYMBOLS



SYMBOLS	NAMES
	PACKAGE UNIT SCOPE
	PACKED BED SCRUBBER
	VERTICAL VESSEL/DRUM
	CENTRIFUGAL PUMP
	FLEXIBLE HOSE
	FILTER
	PIG LAUNCHER / RECEIVER
	UNDER GROUND OPEN PIT

INSTRUMENT TAG. IDENTIFICATION

MEASURED VARIABLE / INSTR. FUNCTION	ANALYSIS	FLOW RATE	MANUAL	LEVEL	PRESSURE	PRESSURE DIFFERENTIAL	TEMPERATUR	SPEED/FREQ.	OPERATION	TIME SCHEDULE DIFFERENTIAL	EVENT OR STATE	POSITION	VIBRATION	PIG SIGNALLER	CURRENT (ELECTRICAL)	INTRUDER SWITCH- GATE	POWER/ POTENTIAL
ELEMENT	AE	FE		LE	PE	PDE	TE	SEB					VE	ZE			
INDICATOR	AI	FI		LI	PI	PDI	TI	SI	R		YI	ZL	VI	ZI	II		EI
INDICATOR TOTALIZER		FQI															
TRANSMITTER	AT/AIT	FT/FIT		LT/LIT	PT/PIT	PDT	TT	ST				ZT	VT				ET
RECORDER	AR	FR		LR	PR	PDR	TR	SR				ZR	VR				
CONTROLLER	AC	FC		LC	PC	PDC	TC	SC				ZC					
INDICATING CONTROLLER	AIC	FIC	HIC	LIC	PIC	PDIC	TIC	SIC				ZIC					
CONTROL VALVE	AV	FCV	HV	LV	PV	PDV	TV	SV									
CONTROL VALVE SELF-ACTING				LCV	PCV	PDCV	TCV	SCV									
SWITCH LOW/OPEN	ASL	FSL	HSO	LSL	PSL	PDSL	TSL	SSL				ZSO					
SWITCH HIGH/CLOSED	ASH	FSH	HSC	LSH	PSH	PDSH	TSH	SSH				ZSC					
GAUGE				LG	PG	DPG	TG/TW										
ALARM	AAH					PDA			OA						IA		
ALARM LOW		FAL		LAL	PAL		TAL										EAL
ALARM HIGH				LAH	PAH		TAH										EAH
ALARM LOW-LOW				LALL	PALL		TALL										
ALARM HIGH-HIGH				LAHH	PAHH		TAHH										
RELAY/CONVERTER	AY	FY	HY	LY	PY	PDY	TY	SY				ZY					
SWITCH LOW-LOW	ASLL	FSLL	HSLL	LSLL	PSLL	PDSL	TSLL	SSLL				ZSLL					
SWITCH HIGH-HIGH	ASHH	FSLL	HSHH	LSHH	PSHH	PDSHH	TSHH	SSHH				ZSHH	VAH				
SWITCH		FS	HS	LS	PS	PDS		SS		KS		ZS				XS	

2.3 Codes and Standards:

The following codes are used for the design, construction and inspection of piping systems.

2.3.1 The ASME B31 Piping Codes:

Piping codes developed by the American Society of Mechanical Engineers:

B31.1 Power Piping:

Piping typically found in electric power generating stations, in industrial and institutional plants, geothermal heating systems and central and district heating and cooling plants.

B31.3 Process Piping:

Piping typically found in petroleum refineries, chemical, pharmaceutical, textile, per, semiconductor and cryogenic plants and related processing plants and terminals.

B31.4 Pipeline Transportation Systems for Liquid Hydrocarbons and Other Liquids:

Piping transporting products which are predominately quid between plants and terminals and within terminals, pumping, regulating, and metering stations.

B31.5 Refrigeration Piping:

Piping for refrigerants and secondary coolants.

B31.8 Gas Transportation and Distribution Piping Systems:

Piping transporting products which are predominately gas between sources and terminals including compressor, regulating and metering stations, gas gathering pipelines.

B31.9 Building Services Piping:

Piping typically found in industrial, institutional, commercial and public buildings and in multi-unit residences which does not require the range of sizes, pressures and temperatures covered in B31.11.

B31.11 Slurry Transportation Piping Systems:

Piping transporting aqueous slurries between plants and terminals within terminals, pumping and regulating stations.

2.3.2 The Dimensional standards:

The following codes are used to specify the geometric, material and strength of piping and components:

B16.1	-	Cast Iron Pipe Flanges and Flanged Fittings
B16.3	-	Malleable Iron Threaded Fittings, Class 150 and 300
B16.4	-	Cast Iron Threaded Fittings, Classes 125 and 250
B16.5	-	Pipe Flanges and Flanged Fittings
B16.9	-	Factory Made Wrought Steel Buttwelding Fittings
B16.10	-	Face to Face and End to End Dimensions of Valves
B16.11	-	Forged Fittings, Socket Welding and Threaded
B16.14	-	Ferrous Pipe Plugs, Bushings and Locknuts with Pipe Threads
B16.15	-	Cast Bronze Threaded Fittings Class 125 and 250
B16.18	-	Cast Copper Alloy Solder Joint Pressure Fittings
B16.20	-	Ring Joint Gaskets and Grooves for Steel Pipe Flanges
B16.21	-	Nonmetallic Flat Gaskets for Pipe Flanges
B16.22	-	Wrought Cu. and Copper Alloy Solder Joint Pressure Fittings
B16.24	-	Cast Cu. Alloy Pipe Flanges and Flanged Fittings Class 150, 300, 400,600, 900, 1500 and 2500
B16.25	-	Buttwelding Ends
B16.26	-	Cast Copper Alloy Fittings for Flared Copper Tubes
B16.28	-	Wrought Steel Buttwelding Short Radius Elbows and Returns
B16.29	-	Wrought Cu. and Wrought Cu. Alloy Solder Jt. Drainage Fittings
B16.33	-	Manually Operated Metallic Gas Valves for Use in Gas Piping systems Up to 125 psig (sizes ½ through 2)
B16.34	-	Valves – Flanged, Threaded and Welding End
B16.36	-	Orifice Flanges
B16.37	-	Hydrostatic Testing of Control Valves
B16.38	-	Large Metallic Valves for Gas Distribution (Manually Operated, NPS 2 ½ to 12, 125 psig maximum)

B16.39 - Malleable Iron Thrd. Pipe Unions, Classes 1150, 250 and 300

B16.40 - Manually Operated Thermoplastic Gs Shutoffs and Valves in Gas Distribution Systems

B16.42 - Ductile Iron Pipe Flanges and Flanged Fittings, Class 150 & 300

B16.47 - Large Diameter Steel Flanges (NPS 26 through NPS 60)

B36.10 - Welded and Seamless Wrought Steel Pipe

B36.19 - Stainless Steel Pipe

2.3.3 MS standards:

These are piping and related component standards developed by the Manufacturer's Standardization Society. The MSS standards are directed at general industrial applications. The pipeline industry makes extensive use of these piping component and quality acceptance standards.

SP-6 - Standard Finishes for Contact Faces Pipe Flanges and Connecting End Flanges of Valves and Fittings

SP-25 - Standard Marking System for Valves, Fittings, Flanges and Union

SP-44 - Steel Pipeline Flanges

SP-53 - Quality Standards for Steel Castings and Forgings for Valves, Flanges and Fittings and Other Piping Components - Magnetic Particle

SP-54 - Quality Standards for Steel Castings and for Valves, Flanges and Fittings and Other Piping Components - Radiographic

SP-55 - Quality Standards for Steel Castings and for Valves, Flanges and Fittings and Other Piping Components - Visual

SP-58 - Pipe Hangers and Supports - Material, Design and Manufacture

SP-61 - Pressure Testing of Steel Valves

SP-69 - Pipe Hangers and Supports - Selection and Application

SP-75 - High Test Wrought Butt Welding Fittings

SP-82 - Valve Pressure Testing Methods

SP-89 - Pipe Hangers and Supports - Fabrication and Installation Practices

2.3.4 API:

The API standards are focused on oil production, refinery and product distribution services. Equipment specified to these standards are typically more robust than general industrial applications.

Spec. 5L	Line Pipe
Spec. 6D	Pipeline Valves
Spec. 6FA	Fire Test for Valves
Std. 594	Wafer and Wafer-Lug Check Valves
Std. 598	Valve Inspection and Testing
Std. 599	Metal Plug Valves - Flanged and Butt-Welding Ends
Std. 600	Steel Gate Valves-Flanged and Butt-Welding Ends
Std. 602	Compact Steel Gate Valves-Flanged Threaded, Welding, and Extended-Body Ends
Std. 603	Class 150, Cast, Corrosion-Resistant, Flanged-End Gate Valves
Std. 607	Fire Test for Soft-Seated Quarter-Turn Valves
Std. 608	Metal Ball Valves-Flanged and Butt-Welding Ends
Std. 609	Lug-and Wafer-Type Butterfly Valves
Std. 613	Special Purpose Gear Units for Refinery Services
Std. 614	Lubrication, Shaft-Sealing and Control Oil Systems for Special Purpose Application
Std. 670	Vibrations, Axial Position, and Bearing-Temp. Monitoring Systems
Std. 671	Special Purpose Couplings for Refinery Service
Std. 674	Positive Displacement Pumps-Reciprocating
Std. 675	Positive Displacement Pumps-Controlled Volume
Std. 676	Positive Displacement Pumps-Rotary
Std. 677	General Purpose Gear Units for Refineries Services

2.4 Material Selection:

Material Selection – Common Specifications for Carbon Steel Systems.

Commodity	B31.1	B31.3	B31.4	B31.8
Pipe	ASTM A 106	ASTM A 53 API 5L	ASTM A 53 API 5L API 5LU	ASTM A 53 API 5L
Pipe – Low Temp	ASTM A 333 Gr.6	ASTM A 333 Gr.6	ASTM A 333 Gr.6	ASTM A 333 Gr.6
Pipe – High Temp	ASTM A 106	ASTM A 106	ASTM A 106	ASTM A 106
Bolting	ASTM A 193 B7	ASTM A 193 B7 ASTM A 320	ASTM A 193 B7 ASTM A 320	ASTM A 193 B7 ASTM A 354/ A 449
Nut	ASTM A 194 2H	ASTM A 194 2H	ASTM A 194 2H	ASTM A 194 2H
Fittings	ASTM A 234 WPB	ASTM A 234 WPB		MSS SP-75
Fittings – Low Temp	ASTM A 420 WPL6	ASTM A 420 WPL6	ASTM A 420 WPL6	
Fittings – High Temp	ASTM A 234 WPB ASTM A 216 WCB	ASTM A 234 WPB ASTM A 216 WCB	ASTM A 234 WPB	
Flanges	ASTM A 105 ASTM A 181 ASME B16.5	ASTM A 105 ASTM A 181 ASME B16.5	ASTM A 105 ASTM A 181 ASME B16.5	ASTM A 105 ASTM A 372 MSS SP-44
Flanges – Low Temp	ASTM A 350 LF2 ASTM A 352 LCB	ASTM A 350 LF2 ASTM A 352 LCB	ASTM A 350 LF2	
Flanges – High Temp	ASTM A 105 ASTM A 181 ASTM A 216 WCB	ASTM A 105 ASTM A 181 ASTM A 216 WCB	ASTM A 105 ASTM A 216 WCB	
Valves	ASTM A 105 ASME B16.34	ASTM A 105 API 600	API 6D API 600	ASTM A 105 / API 6D ASME B16.34 / B16.38
Valves – Low Temp	ASTM A 350 LF2 ASTM A 352 LCB	ASTM A 350 LF2 ASTM A 352 LCB		
Valves – High Temp	ASTM A 216 WCB	ASTM A 216 WCB		

2.5 Code Considerations for Design:

Design of piping systems is governed by Codes. All codes have a common theme, they are intended to set forth engineering requirements deemed necessary for safe design and construction of piping installations.

The Codes are not intended to apply to the operation, examination, inspection, testing, maintenance or repair of piping that has been placed in service. The Codes do not prevent the User from applying the provisions of the Codes for those purposes.

Engineering requirements of the Codes, while considered necessary and adequate for safe design, generally use a simplified approach. A designer capable of applying a more rigorous analysis shall have the latitude to do so, but must be able to demonstrate the validity of such analysis.

Design Conditions:

Design conditions refer to the operating and design temperature and pressure that the piping system will operate at over the course of its design life.

Code	Design Temperature	Design Pressure
B31.1	The piping shall be designed for a metal temperature representing the maximum sustained condition expected. The design temperature shall be assumed to be the same as the fluid temperature unless calculations or tests support the use of other data, in which case the design temperature shall not be less than the average of the fluid temperature and the outside wall temperature.	The internal design pressure shall be not less than the maximum sustained operating pressure (MSOP) within the piping system including the effects of static head.
B31.3	The design temperature of each component in a piping system is the temperature at which, under the coincident pressure, the greatest thickness or highest component rating is required in accordance with par. 301.2	The design pressure of each component in a piping system shall be not less than the pressure at the most severe condition of coincident internal or external pressure and temperature expected during service, except as provided in par. 302.2.4.

B31.4	The design temperature is the metal temperature expected in normal operation. It is not necessary to vary the design stress for metal temperatures between −20 °F and 250 °F.	The piping component at any point in the piping system shall be designed for an internal design pressure which shall not be less than the maximum steady state operating pressure at that point, or less than the static head pressure at that point with the line in a static condition. The maximum steady state operating pressure shall be the sum of the static head pressure, pressure required to overcome friction losses and any required back pressure.
B31.8	No design temperature. The Code mentions only ambient temperature and ground temperature. (1975)	Design pressure is the maximum operating pressure permitted by the Code, as determined by the design procedures applicable to the materials and locations involved.

2.6 Thickness calculations under Pressure:

Design of Piping – B31.1

B31.1 essentially limits the pressure design consideration to three items:

Minimum thickness for pressure:

$$t_{min} = \frac{(P*DO)}{2(SE+PY)} + A \qquad (or) \qquad t = \frac{P*d+2SE+2yPA}{2(SE+Py-P)}$$

The limit is based on the limit stress being less than the basic allowable stress at temperature. This limit is based on the static yield strength of the material.

Maximum longitudinal stress due to sustained loadings (SL):

SL # Sh; stress due to sustained loadings shall be less than the basic allowable stress at temperature. Sustained loadings are those due to pressure, self-weight of contents & piping and another sustained loadings particular to the situation. The limit is based on the static yield strength of the material.

$$S_{lp} = \frac{P * Do}{4 * tn}$$

The computed displacement stress range SE:

SE ≤ SA = f (1.25 Sc + 0.25 Sh). SE stresses arise from the constraint of the thermal strain displacements associated with the expansion of pipe due to temperature. The limit is based on fatigue considerations. Where the sum of the longitudinal stresses is less than Sh, the difference may be used as an additional thermal expansion allowance.

$$S_E = \sqrt{S_b^2 + 4 * S_t^2} \qquad S_b = \frac{\sqrt{i_i M_i^2 + i_o M_o^2}}{Z}$$

The computed displacement stress range SE:

The factor "f" is a stress range reduction factor:

Cycles, N	Factor, f
7,000 and less	1.0
> 7,000 to 14,000	0.9
>14,000 to 22,000	0.8
> 22,000 to 45,000	0.7
> 45,000 to 100,000	0.6
> 100,000 to 200,000	0.5
> 200,000 to 700,000	0.4
7,000 and less	1.0

Design of Piping – B31.3

B31.3 essentially limits the pressure design consideration to three items:

Minimum thickness for pressure:

$$t = \frac{P*D}{2(SE+PY)} \quad \text{(or)} \quad t = \frac{P*D}{2SE} \quad \text{(or)} \quad t = \frac{D}{2} * \left((1 - \sqrt{\frac{SE-P}{SE+P}} \right)$$

The limit is based on the limit stress being less than the basic allowable stress at temperature. This limit is based on the static yield strength of the material.

Maximum longitudinal stress due to sustained loadings (SL):

SL ≤ Sh; stress due to sustained loadings shall be less than the basic allowable stress at temperature. Sustained loadings are those due to pressure, self-weight of contents & piping and other sustained loadings particular to the situation. The limit is based on the static yield strength of the material.

The computed displacement stress range SE:

SE ≤ SA = f(1.25 Sc + 0.25 Sh). SE stresses arise from the constraint of the thermal strain displacements associated with the expansion of pipe due to temperature. The limit is based on fatigue considerations. Where the sum of the longitudinal stresses is less than Sh, the difference may be used as an additional thermal expansion allowance.

Design of Piping – B31.4

B31.4 essentially limits the pressure design consideration to three items:

Minimum thickness for pressure:

$$t = \frac{Pi * D}{2S}$$

The limit is based on the limit stress being less than the basic allowable stress at temperature. This limit is based on the static yield strength of the material.

S = 0.72 ∗ E ∗ SMYS,

where SMYS is the specified minimum yield strength of the material

Maximum longitudinal stress due to sustained loadings (SL):

SL ≤ 0.75 • SA

where SA = 0.72 ∗ SMYS

SL, the stress due to sustained loadings shall be less than 0.75 x the allowable stress range, SA at temperature. Sustained loadings are those due to pressure, self-weight of contents & piping and other sustained loadings particular to the situation.

The computed displacement stress range SE:

For restrained lines:

SL = E ∗ a ∗ ΔT − v ·∗Sh ≤ 0.9SMYS

For unrestrained lines:

SE ≤ SA

Design of Piping – B31.8

B31.8 essentially limits the pressure design consideration to three items:

Design pressure:

$$P = \frac{2 * S * t}{D} F.E.T$$

F = design factor for construction type (includes a location factor)

E = longitudinal joint factor

T = temperature derating factor

S = SMYS,

where SMYS is the specified minimum yield strength of the material

Total combined stress:

The total of the following shall not exceed S:

a) Combined stress due to expansion

b) Longitudinal pressure stress

c) Longitudinal bending stress due to internal + external loads

Further,

The sum of (b) + (c) $\leq 0.75 \bullet S \bullet F \bullet T$

The computed displacement stress range SE:

B31.8 applies itself to the above ground piping in discussing expansion and flexibility to a temperature of 450 °F.

For these “unrestrained” lines:

$SE \leq 0.72 \bullet S$

2.7 Flange Ratings:

Rating, as applied to flanges, may best be defined as the maximum pressure allowed by the pressure piping code for the specific temperature at which the flange will be operating. Flanges and nozzles are sized according to pressure ratings established by the ASME. These pressure ratings are divided into seven categories for forged steel flanges. They are 150#, 300#, 400#, 600#, 900#, 1500# and 2500#. Cast Iron flanges have ratings of 25#, 125#, 250#, 800#.

Pound ratings, when combined with the temperature of the commodity within the pipe, are used to select the appropriate size, rating, and type of flange. This pressure/temperature relationship will allow any given flange to be used in many different applications. For example, a 150# forged steel flange is rated to perform at 150# PSIG at 500 °F. If the temperature were decreased to 100 °F, this same flange could be used for 275# PSIG. However, if the temperature were increased to 750 °F, the flange could only be used for 100# PSIG. As you can see, the pressure/temperature relationship is important. When temperature decreases, the allowable pressure increases, and vice versa.

3.0 EQUIPMENTS:

Although piping components such as fittings, flanges, and valves are important and impossible to do without in a process facility, they play a minor role in the actual manufacturing of a salable product. Other components of a piping facility actually perform the tasks for which the facility is being built. Collectively, they are known as mechanical equipment. Mechanical equipment can be used to start, stop, heat, cool, liquefy, purify, distill, refine, vaporize, transfer, store, mix, or separate the commodity flowing through the piping system. The discussion in this chapter will concentrate on the pieces of equipment that are used in a majority of all chemical and refining facilities.

3.1 Type of Equipments:

Horizontal Vessels/Accumulators

The horizontal vessel, similar to the one shown in Figure, is a cylindrical-shaped storage tank that is installed in a facility with its long axis parallel to the horizon. Also known as an accumulator, it is used primarily as a receiving and collecting container for liquids and/or gaseous vapors and, therefore, has no internal moving parts. Accumulators can be located at grade level or placed high in an equipment structure. Support saddles, which are U-shaped supports, are welded on the underside to secure and stabilize the vessel as it rests on two concrete foundations, which are located near each end of the vessel. A nozzle on the top of the vessel allows liquids to enter and fill the vessel. Another nozzle, coming off the bottom, allows the liquids to be drawn out. Smaller nozzles are positioned that are used for venting, draining, and instrumentation attachment.

Vertical Vessels/Fractionation Columns/Reactors

The vertical vessel, similar to the one shown in Figure, is a cylindrical vessel whose long axis is perpendicular to the horizon. It is one of the most visible pieces of equipment, and some vertical vessels can exceed 200 ft in height. Configured as a Fractionation column, these vertical vessels have internal plates called trays that aid in the refining and collection of the various molecular compounds of a feedstock. The process of refining, or breaking a feed-stock down into its various molecular compounds, is called fractional distillation. Distillation elicits only a physical change in a commodity, not a chemical one. After further refinement and processing, these com-pounds will become salable commodities such as fuels, plastics, and many other essential products.

Exchangers

Another common piece of mechanical equipment is the exchanger. The exchanger's primary function in a piping facility is to transfer heat from one commodity to another. Whether the objective is to heat a liquid to a desired temperature or cool a product for final storage, the exchanger can accomplish both. The most important feature of the exchanger is that commodities are mot mixed with another agent to heat it up or cool it down. A substantial amount of time and money has been invested to purify the commodity, so mixing any-thing with it, just to heat it up or cool it down, would be counterproductive. Exchangers simply transfer heat through contact with a metal surface of a different temperature. An exchanger most people are familiar with is the common household water heater whereby cold-water flows around a heated element to warm the water. Several exchanger types are available; they include the shell and tube, double pipe, reboiler, and air fan.

Pumps

Pumps, like the one shown in Figure, are mechanical devices used to move fluids under pressure from one location to another. Pumps accelerate the speed at which a commodity travels within a pipe, thereby increasing its rate of flow. Pumps used in piping facilities typically will be one of the following classifications: centrifugal, reciprocating, or rotary.

Centrifugal Pumps

The centrifugal force created by the high-speed impellers of a centrifugal pump creates a smooth non-pulsating rate of flow. With a fast spinning impeller creating a low-pressure center point, any commodity entering the pump will naturally seek the center of the impeller only to be spun out at a high rate of speed. The efficient operation of the centrifugal pump makes it the standard of most piping facilities.

Reciprocating pumps

The reciprocating pump creates Pr. with a piston or plunger that alternately move back and forth. With each stroke of the piston, pressure is increased forcing the commodity out of the pump. The reciprocating pump is installed in piping system where extremely high pressures are required.

Compressors:

The compressor is similar to pump, but it is designed to move air gases or vapors rather than liquids. The compressor is used to increase the rate at which a gaseous commodity flows from one location to another. Gases, unlike liquids, are elastic and must be compressed to increase flow rate. Liquids obviously cannot be compressed, unless you are building a hydraulic application. Like pumps, compressors are manufactured in centrifugal, reciprocating, and rotary configurations.

Reboiler:

The reboiler, as the name implies, is a device used to replenish the heat lost by a process commodity. It is natural that during the refining process commodities will lose heat. In many cases lower temperature means less efficiency and productivity. Therefore, it becomes necessary to reheat certain commodities after a period of time. Two types of reboilers are available for use: the kettle-type and the thermosyphon. A kettle-type reboiler is similar in design and appearance to the shell and tube exchanger. The commodity to be heated is routed, via pipe, to and from the heater and fractionation column. The thermosyphon reboiler, however, is attached directly to a fractionating column via its nozzles. The inlet and outlet nozzles of a reboiler are bolted directly to the two nozzles on the fractionating column.

Storage tanks:

From the name, it is easy to determine what this piece of equipment used for. Storage tanks are used in several phases of the refining process. They can be used to store crude oil before its use in the facility, as holding tanks for a partially refined product awaiting further processing, or to collect a finished product before its delivery or pickup by a customer.

Usually placed within a common area of a facility known as a tank farm, Storage tanks come in various shapes and sizes. Some are shaped similar to horizontal vessels and some are spherical like ball. Most of storage tanks, as much as 200 ft. in diameter and up to 60ft tall.

3.2 Codes and Standards:

The following codes and standards are used for the design, construction and inspection of Equipments.

ASME I Rules for Construction of Power Boilers

ASME III Rules for Construction of Nuclear Facility Components

- Subsection NCA — General Requirements for Div. 1 and Division 2
- Appendices
- Division 1*
  - Subsection NB — Class 1 Components
  - Subsection NC — Class 2 Components
  - Subsection ND — Class 3 Components
  - Subsection NE — Class MC Components
  - Subsection NF — Supports
  - Subsection NG — Core Support Structures
- Division 2 — Code for Concrete Containments
- Division 3 — Containment Systems for Transportation and Storage of Spent Nuclear Fuel and High-Level Radioactive Material
- Division 5 — High Temperature Reactors

ASME IV Rules for Construction of Heating Boilers

ASME V Nondestructive Examination

ASME VI Recommended Rules for the Care and Operation of Heating Boilers

ASME VII Recommended Guidelines for the Care of Power Boilers

ASME VIII Rules for Construction of Pressure Vessels

- Division 1
- Division 2 — Alternative Rules
- Division 3 — Alternative Rules for Construction of High Pr. Vessels

ASME IX Welding, Brazing, and Fusing Qualifications

ASME X Fiber-Reinforced Plastic Pressure Vessels

ASME XI Rules for in service Inspection of Nuclear Power Plant Components

ASME XII Rules for Construction and Continued Service of Transport Tanks

ASME B73.1 Horizontal, End Suction Centrifugal Pumps

ASME B73.2 Vertical In-line Centrifugal Pumps

ASME B133.2 Basic Gas Turbine

API Std. 611 General Purpose Steam Turbines for Refinery Services

API Std. 616 Gas Turbines for Refinery Services

API Std. 617 Centrifugal Compressors for General Refinery Services

API Std. 618 Reciprocating Compressors for General Refinery Services

API Std. 619 Rotary-Type Positive Disp. Compressors for Gen. Refinery Services

API Std. 620 Design and Construction of Large, Welded, Low Pr. Storage Tanks

API Std. 630 Tube and Header Dimensions for Fired Heaters for Refinery Service

API Std. 650 Welded Steel Tanks for Oil Storage

API Std. 660 Heat Exchangers for General Refinery Service

API Std. 661 Air-Cooled Heat Exchangers for General Refinery Service

3.3 Piping to vessels & columns:

Vessel connections are often made with couplings (for smaller lines), flanged or welding nozzles, and pads fitted with studs, designed to mate with flanged piping. Nozzle outlets area also made by extrusion, to give a shape like that of the branch of a welding tee-this gives a good flow pattern, but is an expensive method usually reserved for such items as manifolds and dished heads. Weldless, sockolets and thredolets are suitable for vessel connections and are available flat-based for dished heads, tanks, and large vessels.

Nozzles needed on vessels:

- Nozzles needed on non-pressure vessels include: inlet, outlet, vent (gas or air), manhole, drain, overflow, agitator, temperature element, level instrument, and a 'steamout' connection, sometimes arranged tangentially for cleaning the vessel.
- Nozzles needed on pressure vessels include: inlet, outlet, manhole, drain, pressure relief, agitator, level gauge, pressure gage, temperature element, vent and for steamout, as above.
- Check whether nozzles are required for an electric heater, coils for heating or cooling: or vessel jacket. A jacket requires a drain and vent.
- Check special nozzle needs, such as for flush-bottom tank valves.

Pipe flexibly to nozzles:

- Provide additional flexibility in lines to a vessel from pumps and other equipment mounted on a separate foundation (if liable to settle).
- Be cautious in making rigid straight connections between nozzles. Such connections may be acceptable if both items of equipment are on the same foundation, and are not subject to more than normal atmospheric temperature changes.

Nozzle loading

- Ensure that a nozzle can take the load imposed on it by connected piping, under "supporting pipe at nozzles'. Manufacturers often can provide nozzle-loading data for their standard equipment.
- Check all connections to ensure that stresses due to thermal movement, and shock pressure ('kicks') from opening pressure relief valves, etc., are safely handled.

4.0 PIPE SUPPORTS:

The weight of piping is usually carried on supports made from steel. So, the Pipe supports should be as simple as conditions allow. To support piping from below, supports are usually made to suit from platestock, pipe and pieces of structural steel. In the open, Single pipes are usually routed so that they may be supported by fixtures to buildings or structures. A group of parallel pipes in the open is normally supported on the pipe rack.

There are various types of supports used in the piping, as outlined below.

- Anchor support
- Guide support
- Tie support
- Shoe
- Hanger
- Saddle
- Slide plate
- Dummy leg

4.1 Requirements of pipe supports:

The pipe supports should be arranged bearing in mind below points:

1. To carry the weight of piping with fluid, with an ample safety margin-use a factor of safety 3 or the safety factor specified for the project.
2. The system of supports should minimize the introduction of twisting forces in the piping due to offset loads on the supports.
3. To ensure that the material from which the pipe is made is not stressed beyond a safe limit.
4. To allow for draining. Hold up of liquid can occur due to pipe sagging between supports. Complete draining is ensured by making adjacent supports adequately tilt the pipe.
5. To permit thermal expansion and contraction of the piping under stresses on piping.
6. To withstand and dampen vibrational forces applied to the piping by compressors, pumps, etc.

4.2 Types of pipe supports:

This chapter discusses the types of pipe supports.

Anchors:

Anchors are required to state in the following two points. However, advice from the stress and/or piping support groups should be obtained:

- Provide anchors as necessary to prevent thermal or mechanical movement overloading nozzles on vessels or machinery, branch connections, cast-iron valves, etc.
- Provide anchors to control direction of expansion; for example, at battery limits and on piping leaving units, so that movement is not transmitted to piping on a pipe rack.

Pipe guides:

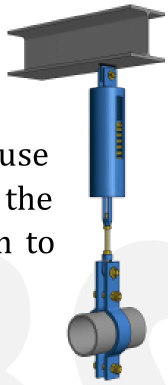
When total restriction of pipe movement is not required, pipe guides are used. Pipe guides confine movement along the pipe's lineal axis. Used primarily to maintain proper line spacing in a pipe rack, pipe guides prevent lateral or sideways movement. Unlike the pipe anchor, which is welded to the pipe and structural support, the guide allows pipe to slide lengthwise between two angle. When a pipe is supported on shoes, the angle shapes are positioned on either side of the shoe.

Hanger rods

Hanger rods are the standard supporting devices used when a pipe, or pipes, must be supported from above. Hanger rods are suspended from overhead lines or structural supports. Two major styles of hanger rods are used. One is designed to support a single pipe and the other is intended to support multiple lines. Used on lines up to 24" in diameter, and having a load capacity of 4,800 pounds, the single pipe hanger uses a rod and clevis to provide support. When several lines require support, the multiline hanger is used.

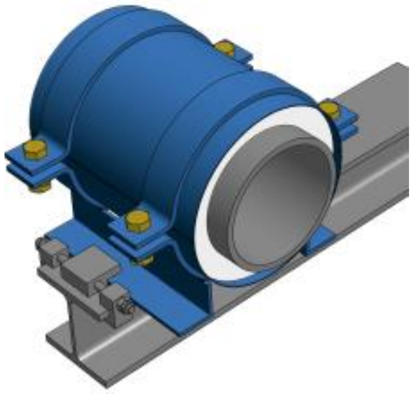
Spring hangers

Lines having significant growth, due to expansion, prevent the use of a stiff support such as a hanger rod or trapeze. These lines require the use of spring hangers. Spring hangers allow expanding pipes room to grow without placing stress on the supporting rod.

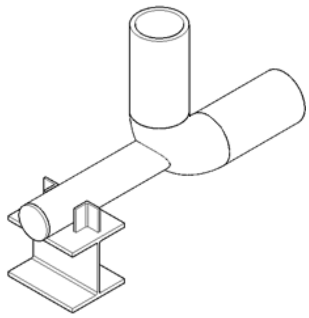


Pipe insulation shoes:

Pipe is insulated to prevent the heat loss or to ensure worker safety. Anchoring lines with insulation requires special preparations because resting insulated pipe directly on structural support damages the insulation. To protect insulation on pipes 3" and larger, pipe shoes are attached to the pipe at the location where it rests on a support. Depending on the governing pipe specification, shoes can either be welded or bolted. Welded shoes are approximately 6" long and are made from 3" tall structural tees or 6" wide flanges that have been cut into halves and then welded to the bottom of a run of pipe. Bolted shoes resemble a cradle that the pipe rests in a U-shaped strap is placed over the pipe and is bolted to the cradle to secure the pipe to the shoe. Because of the expense to x-ray and post-heat treat all welds, bolted shoes are a common occurrence. Pipe smaller than 3" typically has insulation thin enough to be cut away from the pipe at the point where the insulation would rest on a support. Therefore, no shoes are required.



Dummy legs:

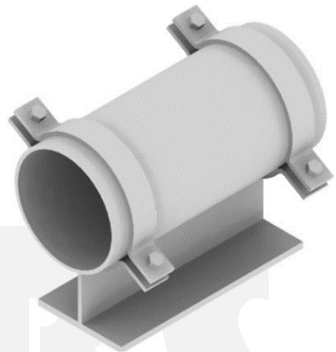


Below table suggests sizes for dummy legs. The allowable stress on the wall of the elbow or line pipe to which the dummy leg is attached sets a maximum length for the lug. The Advice of the stress group should be sought.

Approximate sizes for dummy legs

NPS of piping (inches)	2	3	4	6	8	10	12	14
NPS of pipe forming leg (in.)	1.5	2	3	4	6	8	8	10
Size of W. Flange (in.)					6	8	8	10

Shoes:



Do not use shoes on uninsulated pipes, unless required for sloping purposes. Slide plated are an alternative. Use of wye type shoes enables pipes to be placed on the shoe before welding and makes construction easier. Welding the pipe directly to shoes is not always acceptable; for example, with rubber lined pipe. Bolted or strapped shoes are more suitable.

4.3 Spacing of pipe supports:

When a horizontal pipe is supported at intermediate points, sagging of the pipe occurs between these supports, the amount of sag being depend upon the weight of the pipe, fluid, insulation and valves or fittings which may be included in the line. If the pipeline is installed with no downward pitch, pockets will be formed in each span in which case condensation may collect if the line is transporting steam. In order to eliminate these pockets, the line may be pitched downward so that the outlet of each span is lower than the maximum sag.

Suggested maximum spacing between pipe supports for horizontal straight runs of standard pipes.

Nominal pipe size (Inches)	Suggested Max. Span ft.	
	Water service	Steam/Gas/ Air Service
1	7	9
2	10	13
3	12	15
4	14	17
6	17	21

Nominal pipe size (Inches)	Suggested Max. Span ft.	
	Water service	Steam/Gas/ Air Service
8	19	24
12	23	30
16	27	35
20	30	39
24	32	42

5.0 STRUCTURAL DESIGN:

This chapter specifies minimum requirements and gives recommendations for structural design of steel for the on-shore plant.

5.1 Codes and standards:

AISC	- Specification for Structural Steel Buildings
AISC	- Manual for steel construction, 9th edition
ACI 318 M	- Building Code Requirements for Reinforced Concrete Commentary on Building Code Requirements for Reinforced Concrete
AISC 360-10	- Specification for structural steel buildings
ASCE 7 -10	- Minimum design loads for buildings and other structures
IBC.2009	- International building code
UBC-1997	- structural design requirements
BS 5950	- Structural use of steel works in buildings
BS 6399	- Loading for Buildings Part 1: Code of Practice for Dead and Imposed Loads Part 2: Code of Practice for Wind Loads Part 3: Code of Practice for Imposed Roof Loads
EN 1990	- Eurocode: Basis of Structural Design

5.2 Structural Design considerations:

Design requirements:

- The Preliminary beam selection based on previous and satisfactory experience is acceptable. The same shall be verified after receiving the stress analysis report.
- Structural steel shall be mild steel and comply with the requirements of BS EN 10025 (BS 4360) Grade S275 JR (43B) or subject to the prior approval of Client.
- The minimum thickness of any structural steel plate shall be 6mm.
- Gusset plates shall not be thinner than the members to be connected, and shall have a thickness of at least 10 mm.
- Moment resisting connections shall be designed for field bolted and shop welded.

- Shop connections may be welded or bolted. Field connections shall be bolted. No field welding shall be permitted for structural steel work, unless approved by Company.
- Bolts:
  - The minimum spacing of bolts shall be 150 mm or 8 times the bolts diameter whichever is greater.
  - Anchor bolts of 20 mm diameter and above shall be used for major equipment and structures. 16 mm bolt may be used for small pumps and guardrails.
  - Minimum edge distance, measured to outside of bolt shall be 120 mm or 6 times the bolt diameter whichever is greater.
  - Bolted connections shall be designed based on bearing-type connections using minimum, 2-M20 bolts at each joint.
- The design shall consider special erection loads and forces and indicate temporary measures such as for instance the application of temporary bracings and/or guy wires to cater for these loads and forces.
- Single side welding should not be for I-shaped built up sections formed by welding web to flange plates.

Deflection limits:

Design vertical deflections on structural steel members under the effect of dead loads, equipment loads, live loads, crane loads and wind / seismic loads shall not exceed the following values:

Category	Member Type	Vertical Deflection
Steel Members	Purlins and Girts	L/400
	Steel Pipe Supports	L/300
	Cantilever Beams	L/400

Design horizontal deflection of structural steel frames under the effect of equipment loads, live loads, crane loads and wind loads shall not exceed the following values:

Category	Member Type	Vertical Deflection
Steel Members	Without Equipment	H/200
	With Equipment	H/300

6.0 DESIGN PROCEDURE OF PROCESS SKIDS:

The following are only guidelines based on the good engineering practice. This is not an attempt to cover every possibility nor is it to become a substitute for using the code.

Step: 1 Analyze P&ID

Flow diagrams describe, in a schematic drawing format, the sequential flow of fluids as they enter, flow through, and exit the process facility. By using simplified drawing symbols, to represent various pieces of mechanical equipment, valving, and instrumentation, and specific notes, callouts, and abbreviations, the flow diagram provides the piping designer with an overall view of the operation of a facility. It guides the designer in the same manner a road map guides a traveler. This drawing provides the following specific design criteria

- The operating and design conditions (pressures and temperatures)
- Pipe line numbers with direction of commodity flow
- Pipe specifications and line sizes
- All mechanical equipment
- All operating and isolating valves
- All controlling instrumentation with transmitting devices

Refer section 2.2 for more details.

Step: 2 Collect basic input design data's

Collect the following input data's from "step: 1" to find out the preliminary design considerations.

- Design Pressure
- Design temperature
- Process Fluid and their properties
- Fluid service
- Design code
- Preliminary pipe sizes
- Plot area
- Skid boundary

Refer section 2.5 for more details.

Step: 3 Determine the required design considerations:

Find out the following factors by using the basic input data's.

- Confirm the line sizes
- Material selection and certifications (Refer section 2.4 for more details.)
- Calculate the thickness of the pipes (Refer section 2.6 for more details.)
- Requirement of heat treatment and testing
- Find out the flange ratings (Refer section 2.7 for more details.)
- Connection type (Butt welded/ socket welded / threaded connection)
- Assume the base frame and support beam size (Refer sec 2.7 for details.)
- Collect Equipment preliminary details (Overall dimensions / occupied area / working) (Refer section 3.1 for more details.)
- Conclude the valve types based on client requirements / availability of valves (Lever type / handwheel type / motor operated)
- Control systems requirement (like Junction box, power unit, etc.,)
- Painting and other lining requirements.

Step: 4 Preparation of the preliminary 3D model:

A designer should have kept in mind the following points before going to model a skid. The mentioned information as minimum and not limited to this.

- Use standard available items wherever possible.
- Do not use miters unless directed to do so.
- Do not run piping under foundations. (Pipes may be run under beams).
- Piping may have to go thru concrete floors or walls. Established these points of penetration as early as possible and inform the group concerned (architectural or civil) to avoid cutting existing reinforcing bars.
- Preferably lay piping such as lines to outside storage, loading and receiving facilities, at grade on pipe sleepers. If there is no possibility of future roads of site development.
- Avoid burying steam lines that pocket, due to the difficulty of collecting condensate. Steam lines may be run below grade in trenches provided with covers or (for short runs) in sleeves.
- Lines that are usually buried include drains and lines bringing in water or gas. Where long cold winters freeze the soil, burying lines below the frost line may avoid the freezing of water and solutions, saving the expense of tracing long horizontal parts of the lines.

- Include removable flanged spools to aid maintenance, especially at pumps, turbines, and other equipment that will have to be removed for overhaul.
- Take gas and vapor branch lines from tops of headers where it is necessary to reduce the change of drawing off condensate (if present) or sediment which may damage rotating equipment.
- Avoid pocketing lines-arrange piping so that lines drain back into equipment or into lines that can be drained.
- Vent all high points and drain all low points on lines.
- Simple arrangements and short lines minimize pressure drops and lower pumping costs.
- Designing piping so that the arrangement is “flexible” reduces stresses due to thermal movement.
- Inside buildings piping is usually arranged parallel to building steelwork to simplify supporting and improve appearance.
- Outside buildings, piping can be arranged (1) on pipe racks. (2) Near grade on sleepers. (3) In trenches. (4) Vertically against steelwork of large items of equipment.
- Design hangers for 21/2 inch and larger pipe to permit adjustment after installation.
- If piping is to be connected to equipment, a valve, etc., or piping assembly that will require removal for maintenance, support the piping so that temporary supports are not needed.
- Base load calculations for variable-spring and constant-load supports on the operating conditions of the piping (do not include the weight of hydrostatic test fluid).
- If necessary, suspend pipes smaller than 2-inch nominal size from 4-inch and large pipes.
- Arrange for supporting:
    - Group lines in pipe ways, where practicable.
    - Support piping from overhead, in preference to underneath.
    - Run piping beneath platforms, rather than over them.
- Provide union and flanged joints as necessary, and in addition use crosses instead of elbows, to permit removing materials that may solidify.
- Clearances & access
    - Route piping to obtain adequate clearance for maintaining and removing equipment.
    - Locate within reach, or make accessible, all equipment subject to periodic operation or inspection – with special reference to check valves, pressure relief valves, traps, strainers and instruments.
    - Take care to not obstruct access ways – doorways, escape panels, truck-ways, walkways, lifting wells, etc.

- Position equipment with adequate clearance for operation and maintenance. Clearances often adopted. in some circumstances, these clearances may be inadequate- for example. With shell and tube heat exchangers, space must be provided to permit withdrawal of the tubes from the shell.
- Established sufficient headroom for ductwork, essential electrical runs, and at least two elevations for pipe run north-south and east-west (based on clearance of largest lines, steelwork, ductwork, etc.)
- Elevations of lines are usually changed when changing horizontal direction where lines are grouped together or are in a congested area, so as not to block space where future lines may have to be routed.
- Stagger flanges, with 12” minimum clearance from supporting steel.
- Keep field welds and other joints at least 3” from supporting steel, building siding or other obstruction. Allow room for joint to be made.
- Allow room for loops and other pipe arrangement to cope with expansion by early consultation with staff concerned with pipe stressing. Notify the structural groups of any additional steel required to support such loops.

CLEARANCES & DIMENSIONS		Imperial	Metric.
MINIMUM CLEARANCES			
HORIZ. CLEARANCE	Operating space around equipment.	2ft 6in.	762 mm
	C.L of railroad to nearest obstruction: Straight track	8ft 6in.	2591mm
	C.L of railroad to nearest obstruction: Curved track	9ft 6in.	2896mm
	Manhole to railing or obstruction.	3ft 0in.	914 mm
VERTICAL CLEARANCE	Over walkway, platform, or operating area.	6ft 6in.	1981mm
	Over stairway.	7ft 0in.	2134mm
	Over high point of plant roadway: Minor roadway	17ft 0in.	5182mm
	Over high point of plant roadway: Major roadway	20ft 0in.	6096mm
	Over railroad from top of rail.	22ft 6in.	6858mm
MIN. HORIZ. DIMENSION	Width of walkway at floor level	3ft 6in.	1067mm
	Width of elevated walkway or stairway	2ft 6in.	762mm
	Width of rung of fixed ladder	16in.	406mm
	Width of way for forklift truck	8ft 0in.	2438mm
VERT. DMNSN.	Railing, top of floor, platform, or stair, to: lower rail	1ft 9in.	610mm
	Railing, top of floor, platform, or stair, to Upper rail	3ft 8in.	1158mm

- Refer Cad Worx plant ref. manual(3DL-CWP-01) to get more details about making of 3D model.

Step: 5 Stress analysis of Piping and Structural:

Check the following points as minimum with equipment, piping and structural stress analysis engineers.

- For Piping:
  - Pipe thickness and flange rating verification
  - Thermal expansion and stress range
  - Flexibility analysis
  - Support design and location
  - Flange leakage
  - Consideration of external Tie in loads
  - Deflection
  - Environmental load effects
  - Allowable Pressure drop check
  - Allowable velocity limit
- For equipment:
  - Equipment allowable nozzle loads and moments
  - Necessity of Finite Element Analysis
- For Structural:
  - Base and support Beam strength verification
  - Code stress check
  - Deflection
  - Environmental load effects

Step: 6 Revision of 3D model:

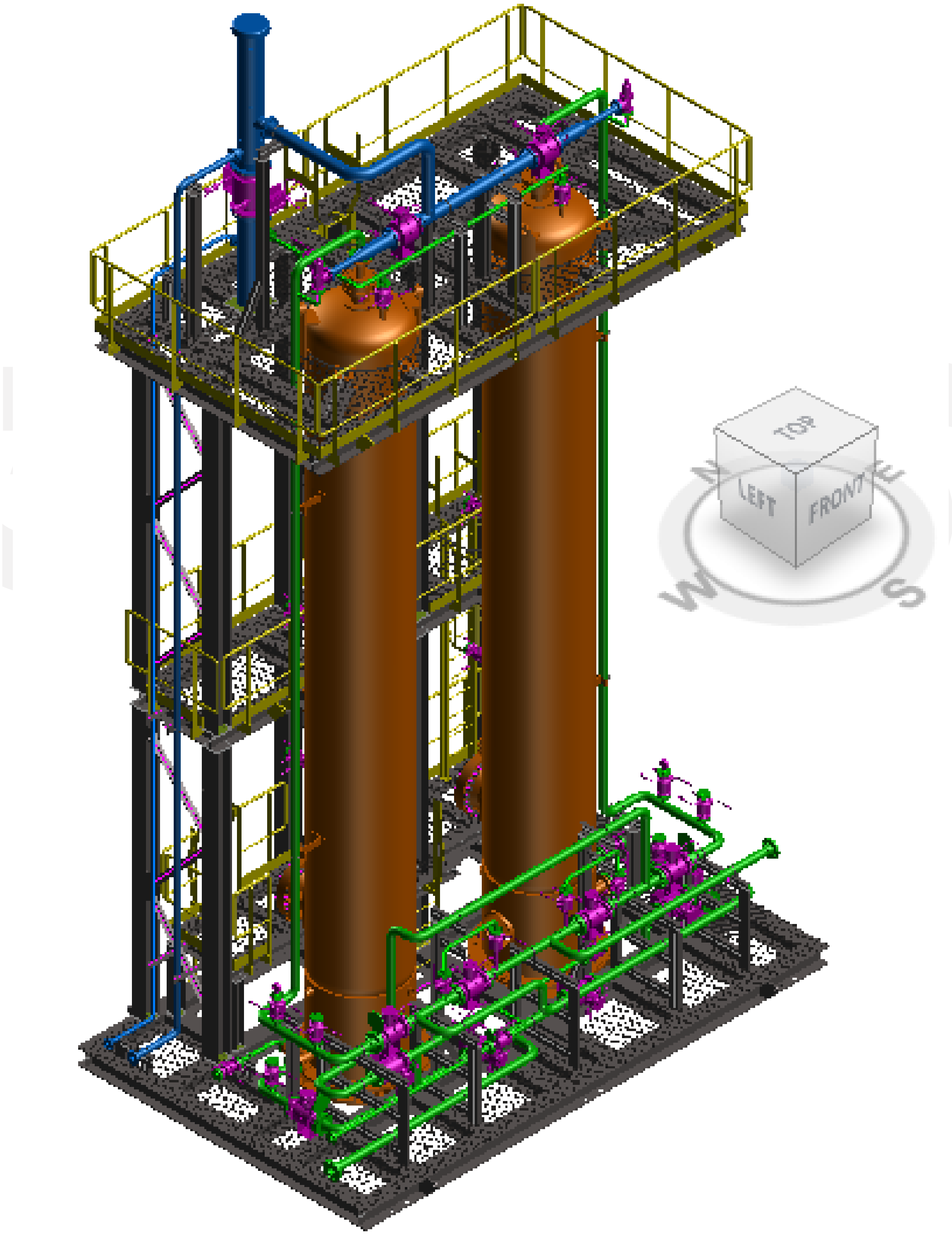
Based on the stress analysis study (Step: 5), Revise the 3D model if necessary.

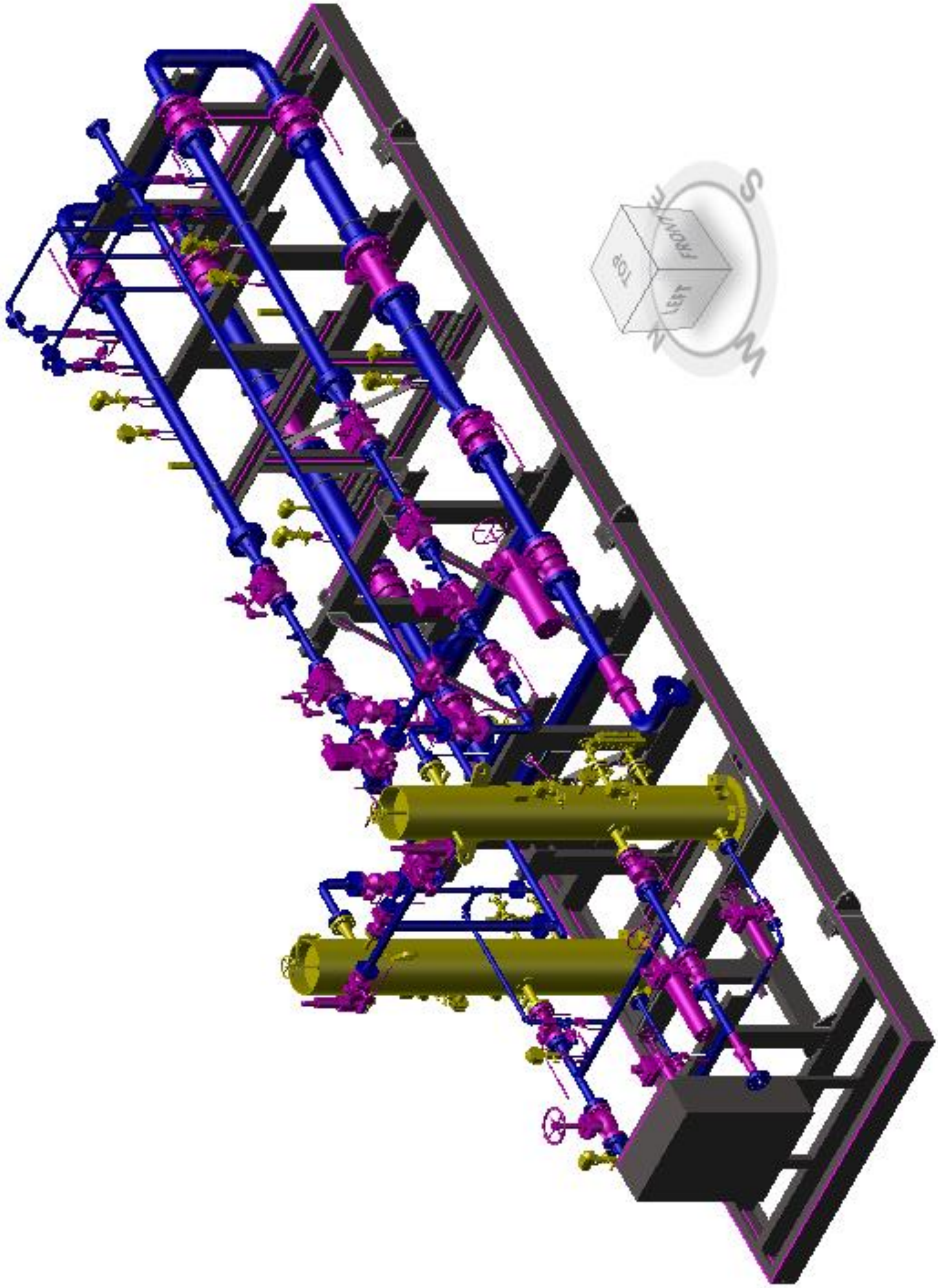
Step: 7 Preparation of General Assembly drawing:

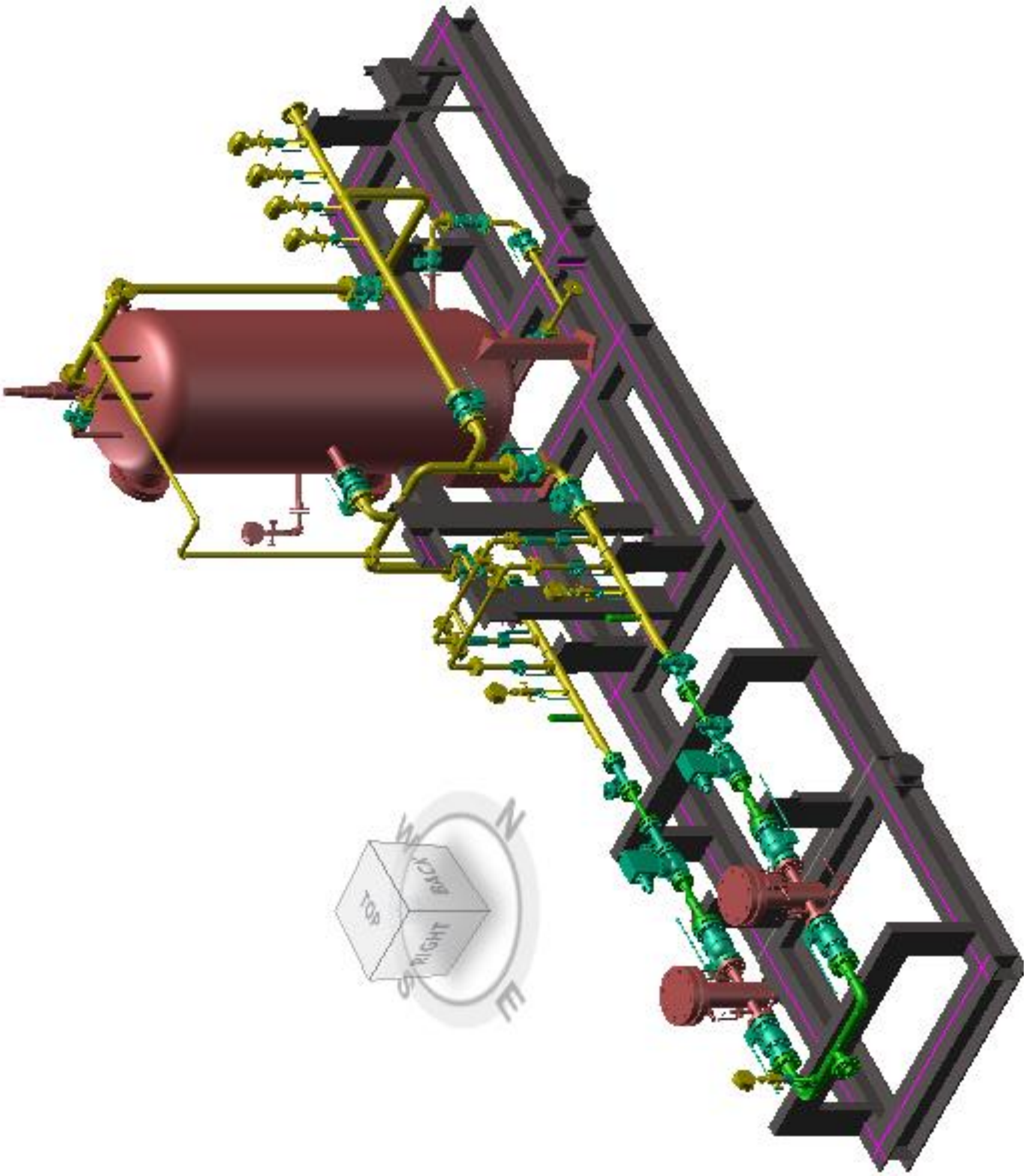
Once a 3D model has been built the routing of each pipe is clearly defined. Although the procedure is different in each program, Designers can use the 3D modelling software to automatically generate dimensioned 2D views from any desired orientation. Use the following checklist as an aid when developing General arrangement drawings.

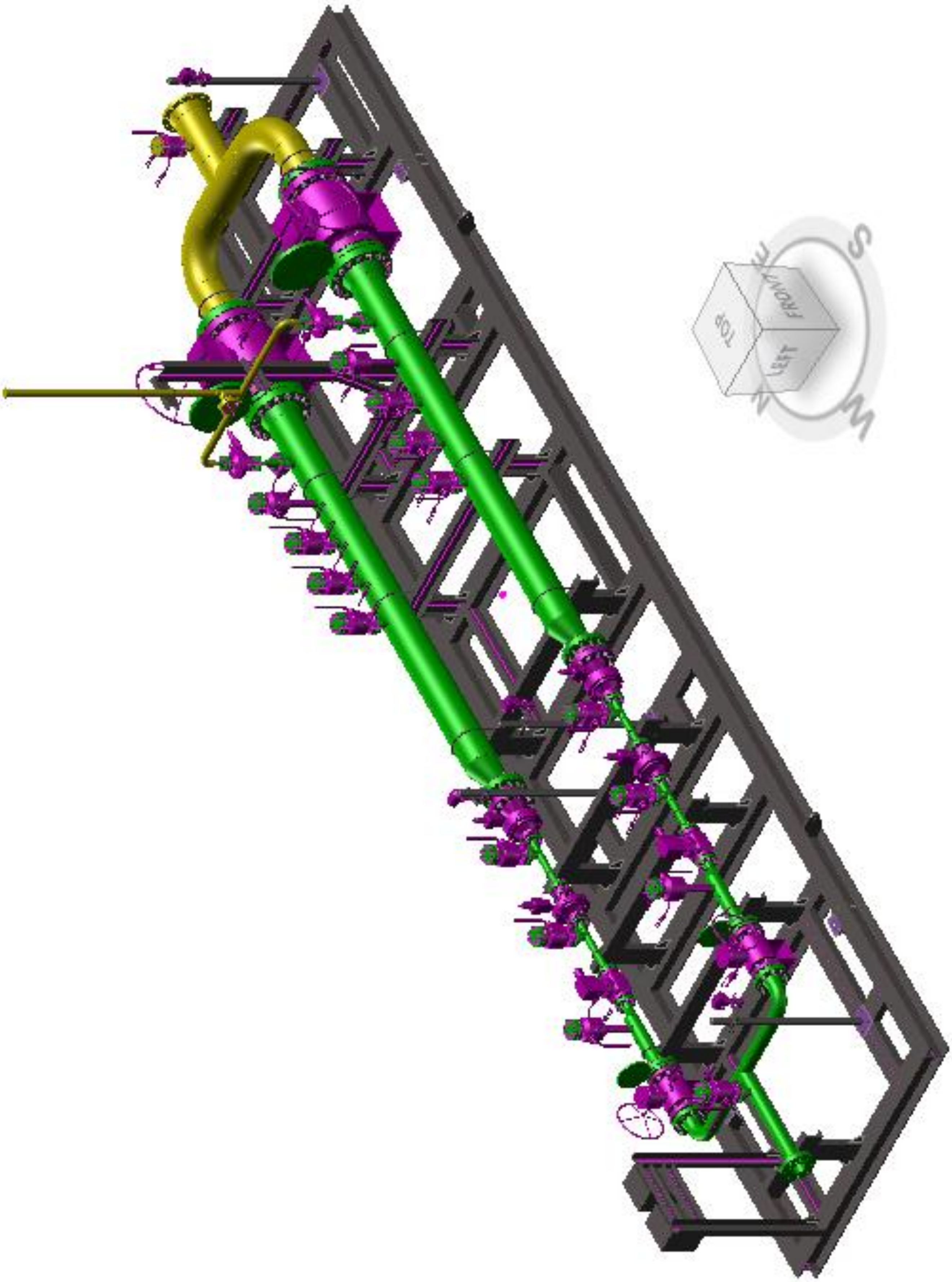
- Define plot area outline.
- Place a north arrow in upper right-hand corner of the drawing.
- Locate foundations for buildings, pipe rack columns and mechanical equipment from the coordinates used to locate the foundation drawing.
- Show only enough details on mechanical equipment outlines to provide a generalized description.
- Represent mechanical equipment centerlines, outlines and foundations within the dark lines.
- Show all piping and instrument connections on mechanical equipment.
- Add line numbers, codes, specs, specialty item numbers and call outs.
- Space mechanical equipment to avoid overcrowding. Add notes to symbols where necessary for clarity. Use arrows to show commodity flow direction.
- Show equipment numbers when it is necessary to identify mechanical equipment.
- Show control systems on the sketch. The control scheme is frequently the most important part of a flow plan sketch.
- Show important valves, orifice flanges, and control valves.
- Show commodity flow directions through exchangers with arrows.
- Do not run lines diagonally across the drawing. Label feed lines entering the unit from the field where the line enters the unit. Label product lines leaving the unit by name.
- Do not draw lines any closer together than necessary.
- Add instrument balloons and call outs.
- Include tie-in connection tags and notes as required.
- Label coordinates for mechanical equipments, pipe supports, etc., if required for job.

7.0 Samples:

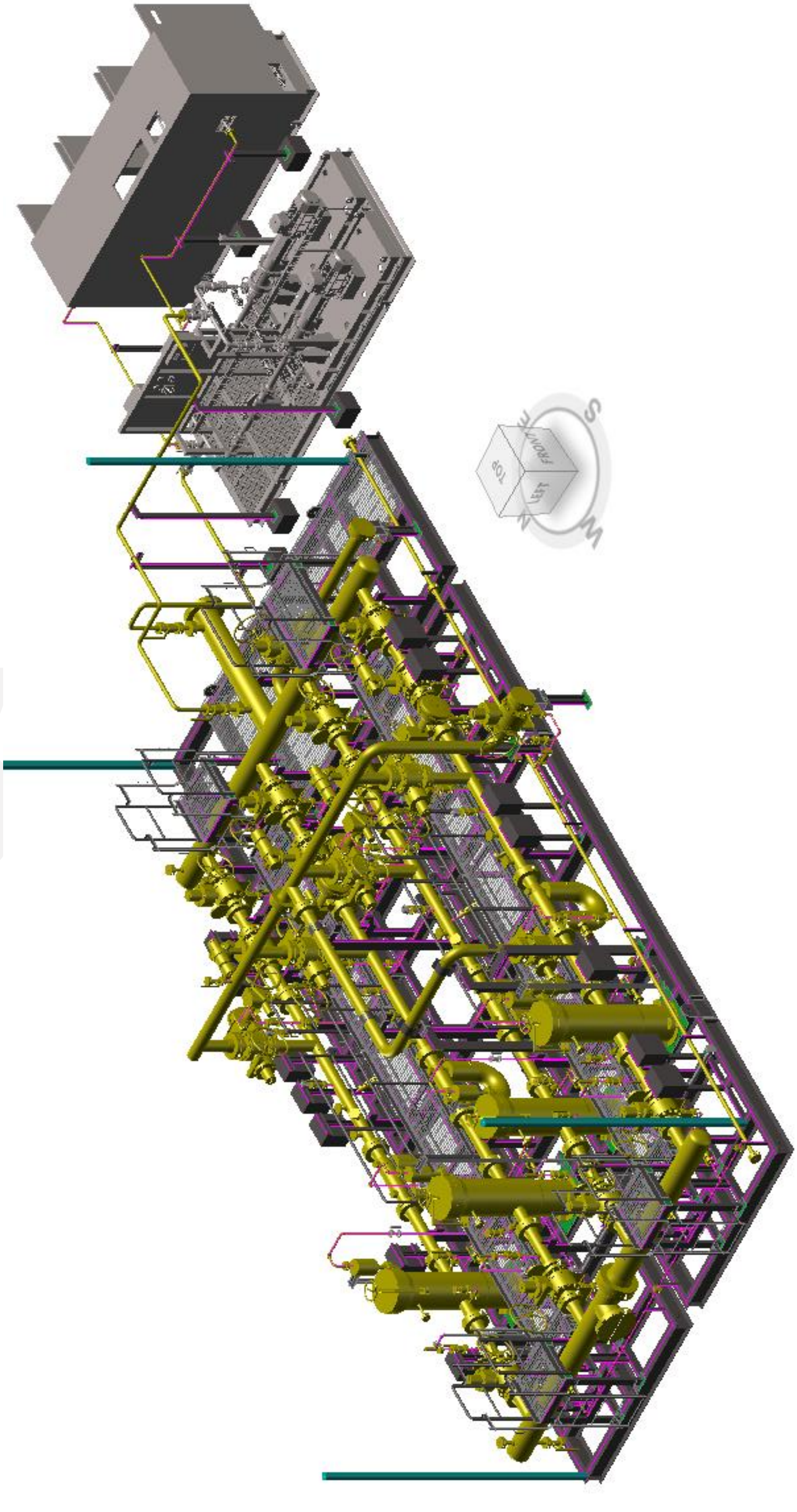


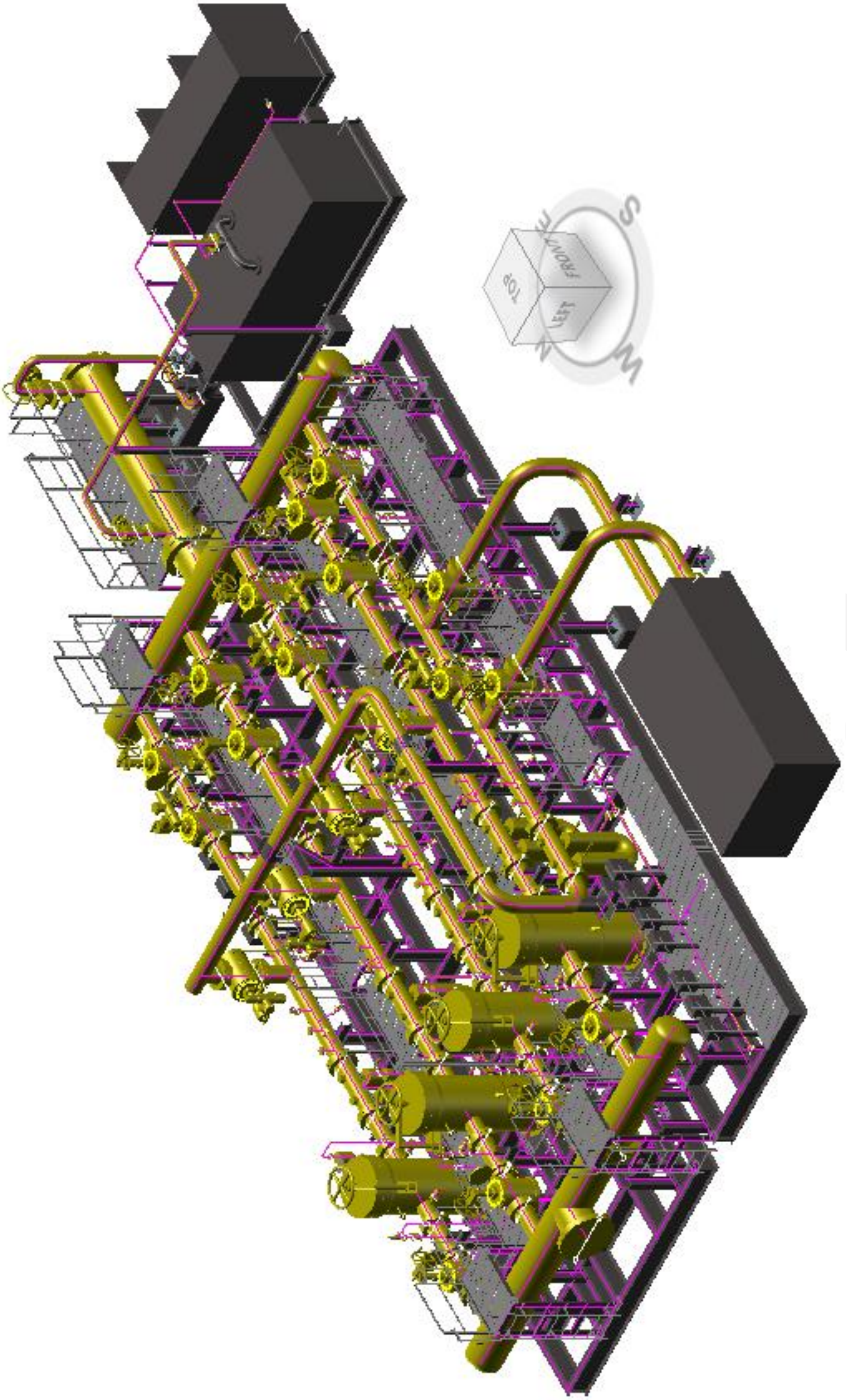

TOP
FRONT
LEFT
S
W
N

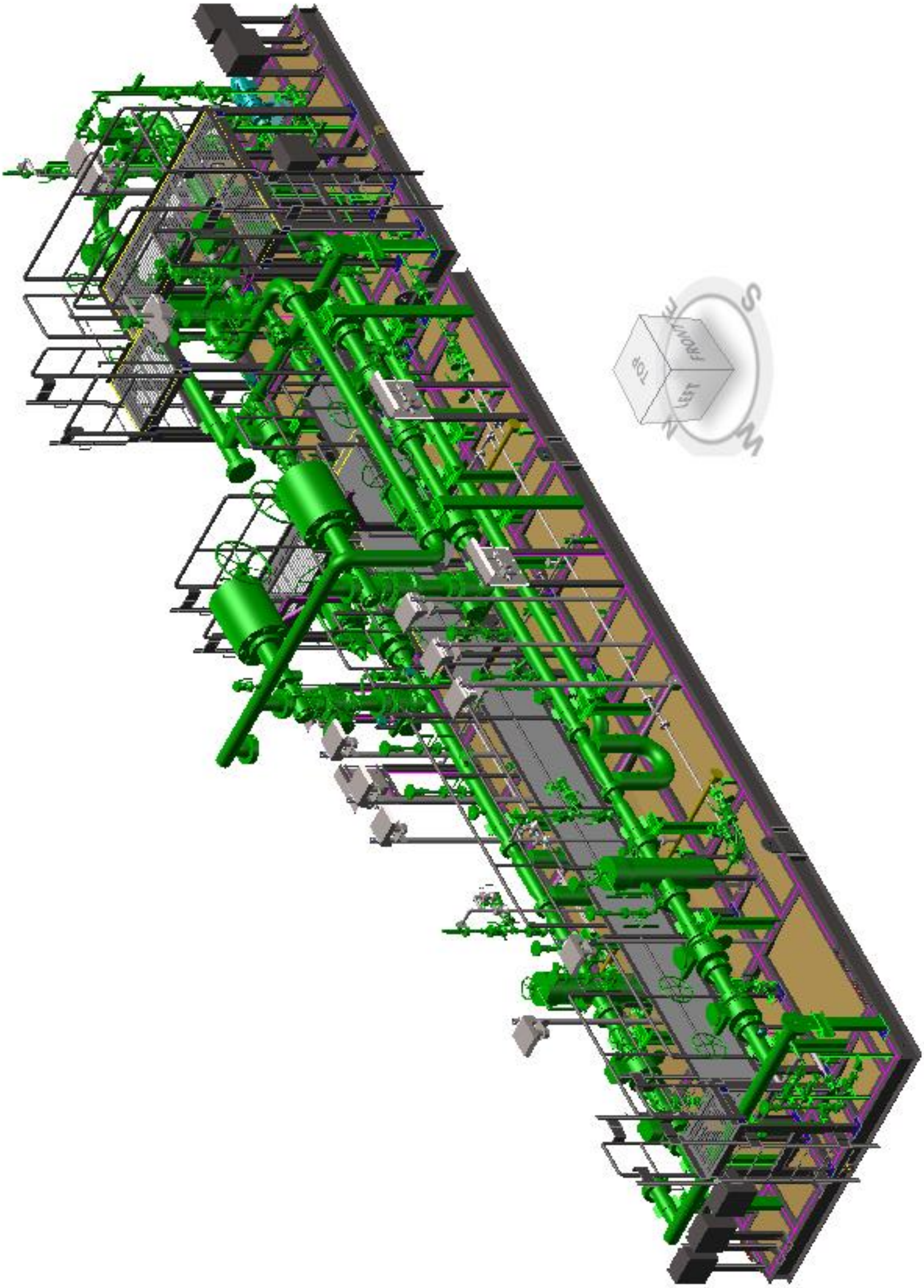

N
TOP
BACK
RIGHT
E

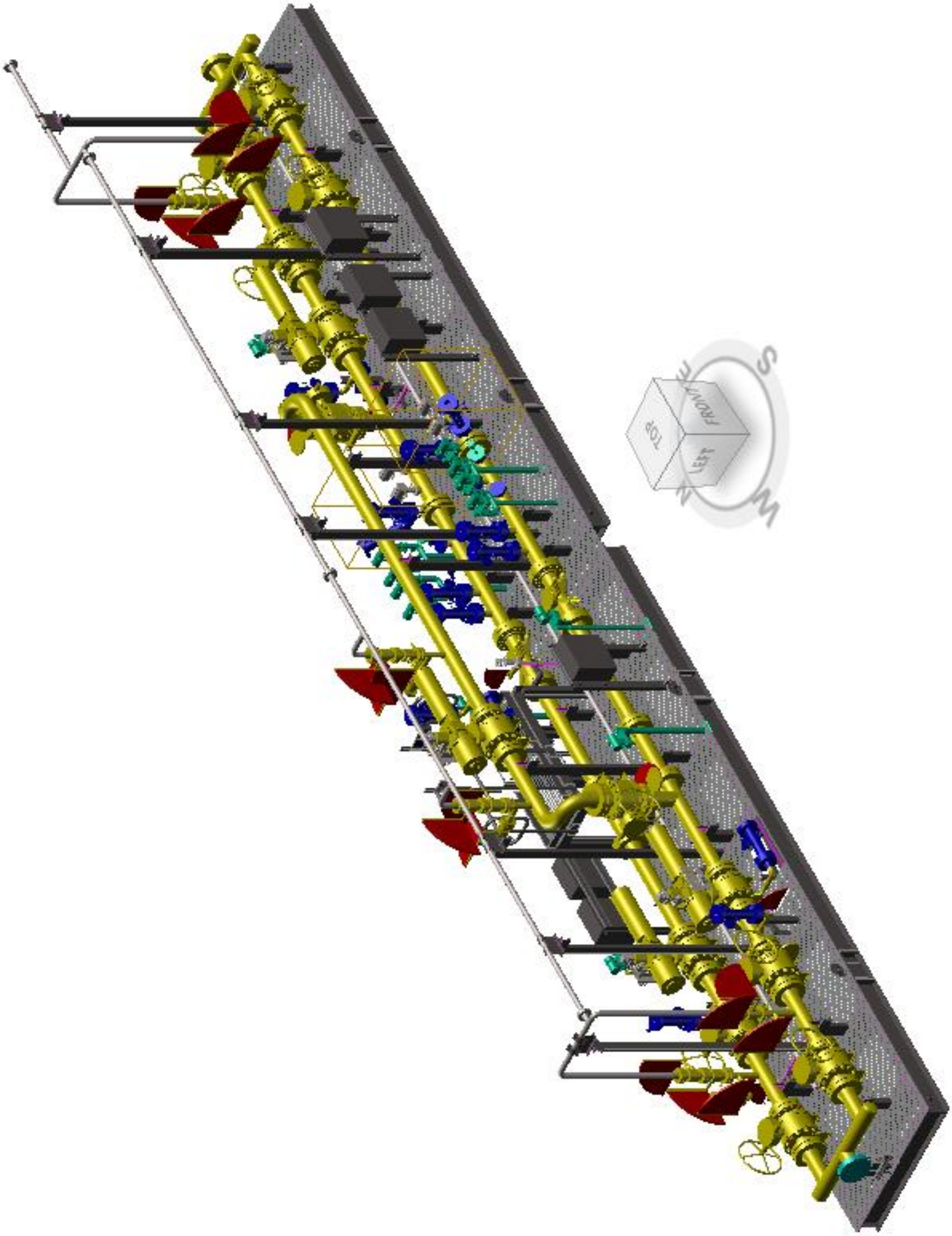

TOP
FRONT
LEFT
S
W

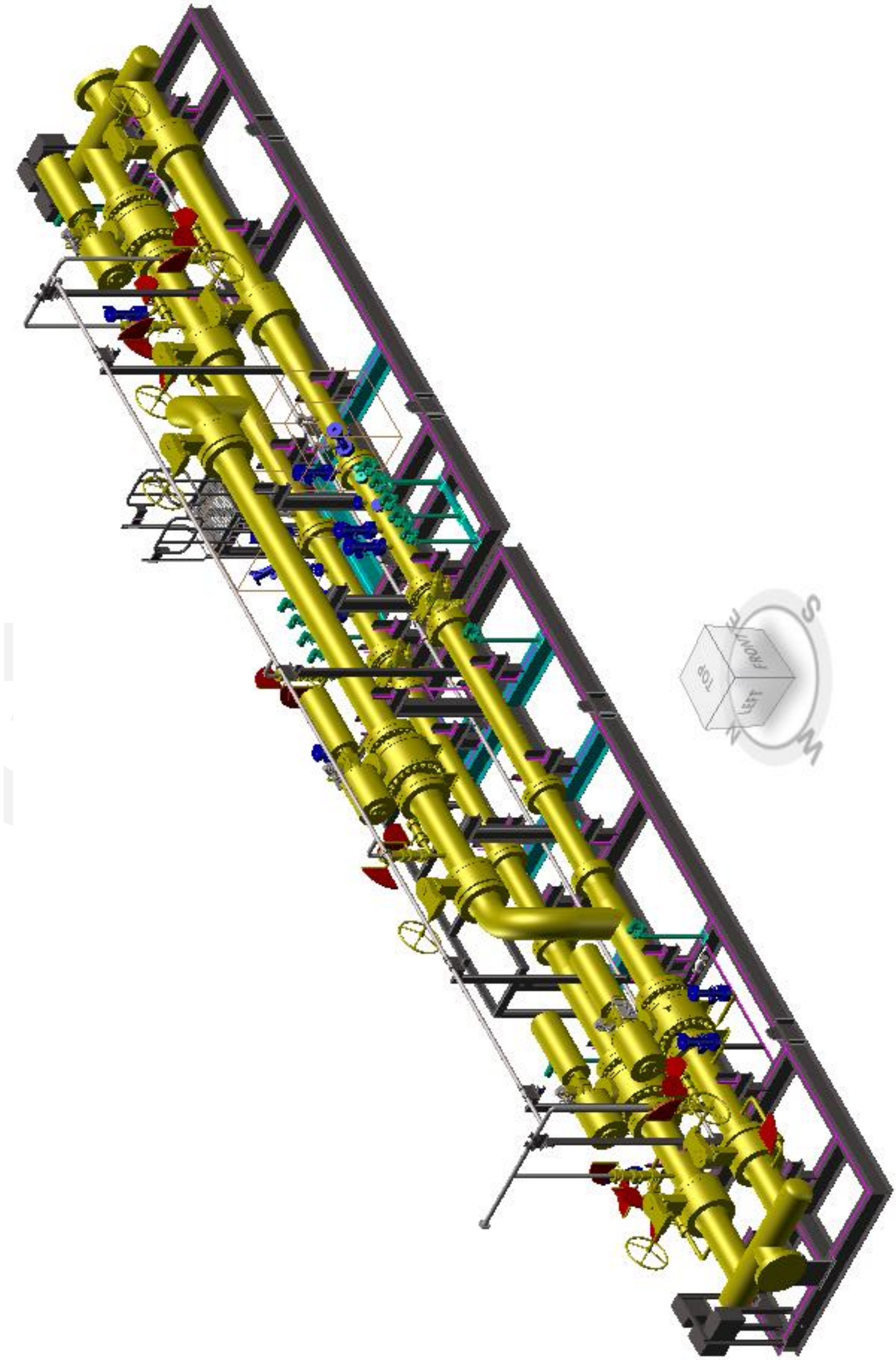

TOP
LEFT
FRONT
N
E
W
S




TOP
FRONT
LEFT
S
W
N


TOP
FRONT
LEFT
S
W
N




TOP
FRONT
LEFT