Best Practice

SAABP-007 31 August, 2002

Steel Piperack Design

Document Responsibility: Onshore Structures Standards Committee

Steel Piperack Design

Developed by: Hisham Abu-Adas
Developed: July, 2002
Civil Engineering Unit/M&CED
Consulting Services Department

Previous Issue: New Next Planned Update: 1 September, 2007

Primary contact: Abu-Adas, Hisham on phone 874-6908

STEEL PIPERACK DESIGN

Table of Contents

Table of Contents

1 Introduction

1.1 Purpose

The purpose of this practice is to provide guidelines for steel piperack design for use by engineers working on Saudi Aramco projects and Saudi Aramco engineers.

1.2 Scope

This design guide defines the minimum requirements for the design of piperacks in process industry facilities at Saudi Aramco sites. It covers general design philosophy and requirements to be used in the analysis and design of piperacks. Criteria presented herein pertain to loads, load combinations, allowable stresses, and superstructure and foundation design. Section 2 of this instruction includes reference codes, and Saudi Aramco Standards.

1.3 Disclaimer

The material in this Best Practices document provides the most correct and accurate design guidelines available to Saudi Aramco which comply with international industry practices. This material is being provided for the general guidance and benefit of the Designer. Use of the Best Practices in designing projects for Saudi Aramco, however, does not relieve the Designer from his responsibility to verify the accuracy of any information presented or from his contractual liability to provide safe and sound designs that conform to Mandatory Saudi Aramco Engineering Requirements. Use of the information or material contained herein is no guarantee that the resulting product will satisfy the applicable requirements of any project. Saudi Aramco assumes no responsibility or liability whatsoever for any reliance on the information presented herein or for designs prepared by Designers in accordance with the Best Practices. Use of the Best Practices by Designers is intended solely for, and shall be strictly limited to, Saudi Aramco projects. Saudi Aramco® is a registered trademark of the Saudi Arabian Oil Company. Copyright, Saudi Aramco, 2002.

1.4 Conflicts with Mandatory Standards

In the event of a conflict between this Best Practice and other Mandatory Saudi Aramco Engineering Requirement, the Mandatory Saudi Aramco Engineering Requirement shall govern.

2 References

This Best Practice is based on the latest edition of the references below, unless otherwise noted. Short titles will be used herein when appropriate. Short titles will be used herein when appropriate.

2.1 Saudi Aramco Standards

Saudi Aramco Engineering Standards

SAES-A-112	*Meteorological and Seismic Design Data*
SAES-Q-005	*Concrete Foundations*

Saudi Aramco Best Practices

SABP-002	*Spread Footings Design*
SABP-006	*Wind loads on Piperacks & Open Frame Structures*

2.2 Industry Codes and Standards

American Concrete Institute (ACI)

ACI 318	*Building Code Requirements for Reinforced Concrete and Commentary*

American Society of Civil Engineers (ASCE)

ASCE 7	*Minimum Design Loads for Buildings and Other Structures*

Wind Load and Anchor Bolt Design for Petrochemical Facilities

Guidelines for Seismic Evaluation and Design of Petrochemical Facilities

American Institute of Steel Construction (AISC)

AISC Manual of Steel Construction – Allowable Stress Design (ASD)

American Society for Testing and Materials (ASTM)

ASTM A36	*Specification for Carbon Structural Steel*
ASTM A325	*Specification for High strength Bolts for Structural Steel Joints, Including Suitable nuts and Plain Washers*
ASTM A992/A992M	*Specification for Steel for Structural Shapes for Use in Building Framing*

3 General

3.1 Piperacks are structures that support pipes and auxiliary equipment within and between process areas of industrial plants. Piping loads can vary greatly from project to project as can the loads from wind and earthquake. Clearly, it is difficult to define specific criteria for the design of such structures. This guideline, however, sets forth general requirements, which the Engineer should incorporate into piperack designs if possible.

3.2 This guideline applies to the following three basic types of steel piperacks:

- Strutted main piperacks
- Unstrutted secondary or miscellaneous piperacks
- "T" supports

3.3 Structural steel design shall be in accordance with the referenced AISC specifications and codes. The plastic design method in the AISC manual shall not be used in steel design. Steel for piperack design will normally be A-36 or ASTM A992/A992M.

3.4 Piperacks and their foundations shall be designed to support loads associated with full utilization of the available rack space, and any specified future expansion.

3.5 Foundation concrete shall be designed in accordance with ACI 318. The minimum 28 day compressive strength of concrete shall be 4000 psi, and shall be noted on the drawings.

3.6 Piperack superstructures and foundations shall be designed for the loads and load combinations specified in Sections 4.0 and 5.0 of this guideline.

3.7 The deflection requirements for piperack beams and transverse bents shall be as follows:

The maximum allowable beam ***deflection*** Dmax due to total load shall be as follows:

Dmax = L/240 L = the Span Length

The maximum allowable ***drift limits*** for piperack shall not exceed ***H/150*** (where H = piperack height).

The maximum allowable **seismic** ***drift limits*** for piperack shall be in accordance with ASCE 7 - 95 Table 9.2.2.7 (Category IV Structure in accordance with ASCE 7 Table 1-1 classification). Piperacks shall be considered as building.

The maximum allowable ***drift limits*** for piperack shall not exceed ***H/100*** (where H = piperack height).

3.8 Connections for steel piperacks shall conform to the following requirements:

a. Shop connections may be either bolted or welded. Field connections shall be bolted where possible. Connections may be field welded when conditions are such that a bolted connection is not suitable.

b. Bolted connections for primary members shall utilize high-strength bolts conforming to ASTM A-325-N, bearing-type connections with threads included in the shear plane. However, slip-critical-type connections shall be used in connection subject to vibration or repeated stress reversal.

c. Standard connections shall be designed by the fabricator in accordance with the project construction specifications and loads shown on the drawings. Moment connections and special connections, however, shall be designed by the engineer and shall be shown on the engineering drawings.

d. Moment connections shall preferably be of the bolted end plate type.

4 Primary Loads

The following loads shall be considered in the design of piperack superstructures and foundations:

D - Dead Load

P_L - Product Load

P_t - Test Load

TL - Thermal Load

W - Wind Load

E - Earthquake

O - Other Loads

The above loads are defined as follows:

4.1 Dead Load (D)

4.1.1 Dead load shall include the weight of all process equipment, pipes, valves and accessories, electrical and lighting conduits, trays, switchgear, instrumentation, fireproofing, insulation, structural steel plates and shapes, etc. Foundation concrete weight along with any soil overburden shall also be considered as dead load. All piping shall be considered empty of ***product load (P_L)*** when calculating dead load.

4.1.2 Piperacks shall be designed for present and future dead loads. Unless stipulated otherwise by Saudi Aramco, piping and electrical loads shall not be less than the following:

a. A minimum pipe deck load of ***23 psf*** (1.10 kPa) shall be used for the design of ***major piperacks***. This is equivalent to 8-inch (203 mm) diameter, Schedule 40 pipes spaced at 15-inch (381 mm) centers.

b. Along with the minimum pipe deck loads specified above, a concentrated load shall be added at pipes that are larger than 12 inches (300 mm) nominal diameter on the support. The concentrated load in pounds, P_{DL}, shall be calculated using the following equation:

$$P_{DL} = S\,(W_{DL} - p_{DL}\,D)$$

Where:

S = Pipe support spacing (ft)

W_{DL} = Large pipe weight per foot (plf)

p_{DL} = Average pipe deck loading (psf)

D = Large pipe diameter (ft)

c. Single level and double level electrical ***cable trays*** shall have a minimum uniformly distributed weight of ***20 psf*** (0.96 kPa) and ***40 psf*** (1.92 kPa), respectively. The cable tray load shall be considered as ***dead load***. Tray locations shall be as shown on electrical drawings.

4.2 Product Load (P_L)

4.2.1 Product load shall be defined as the gravity load imposed by liquid or viscous material in piping during operation.

4.2.2 Piperacks shall be designed for present and future product loads. Unless stipulated otherwise by Saudi Aramco, product loads shall not be less than the following:

a. A minimum product load of ***17 psf*** (0.81 kPa) shall be used at each level for the design of major piperacks. This is equivalent to 8-inch (203 mm) pipes full of water spaced at 15-inch (381 mm) centers.

b. Along with the minimum piping product loads specified above, a concentrated load shall be added at pipes that are at least larger than 12 inches (300 mm) nominal diameter on the support. The concentrated load in pounds, P_{PL}, shall be calculated using the following equation:

$$P_{PL} = S\,(W_{PL} - p_{PL}\,D)$$

Where:

S = Pipe support spacing (ft)

W_{PL} = Large pipe product load per foot (plf)

p_{PL} = Average product loading (psf)

D = Large pipe diameter (ft)

4.3 Test Load (P_t)

The test load shall be defined as the gravity load imposed by the liquid (normally water) used to pressure test the piping. Large vapor lines may require hydrotesting. If so, it may be possible to test them one at a time while the other lines on the support are empty and thus avoid the heavy pipe support loading. When such procedures are used, special notes should be placed on the structural and piping drawings to specify test procedures. Small vapor lines are normally considered filled with water.

4.4 Thermal Loads

Thermal loads shall be defined as forces caused by changes in the temperature of piping. For piperack design, both ***friction forces (FF) and anchor forces (AF)*** shall be considered. Pipe supports must be designed to resist longitudinal loads arising from pipe thermal expansion and contraction. On the average pipeway, the lines expand and contract varying amounts at random times. These loads are applied to the transverse beams either through friction or through pipe anchors. Thermal loads shall be considered as ***dead load*** and included in the appropriate load combinations.

4.4.1 Friction Forces (FF)

Friction forces caused by hot lines sliding across a pipe support during start-up and shut-down are assumed to be partially resisted by adjacent cold lines. The resultant longitudinal friction force, however, shall be taken as the larger of the following:

a. 10% of the total operating weight of all lines tributary to the support

b. 30% of the total operating weight of those lines tributary to the support, which will expand or contract simultaneously.

The 10% of the total piping weight shall be taken as an estimated longitudinal friction forces (FF) applied only to local supporting beams. However, an estimated friction force equal to 5% of the total piping weight shall be accumulated and carried into piperack struts, columns, braced anchor frames, and foundations.

Pipe friction loads shall not be combined with wind or seismic loads for the design of piperack struts, columns, braced anchor frames, and foundations, when there are multiple frames. During high wind or earthquake, the vibration and deflection of the supports under load will likely relieve the friction forces.

4.4.2 Anchor Forces (AF)

Anchor forces may dictate the use of horizontal channels or horizontal bracing as well vertical bracing at anchor bents. This should not occur too frequently since Piping Engineering like to anchor large lines on only a few bents in a pipeway. Anchor and guide forces and locations shall be obtained from the ***piping stress analysis*** and piping isometric drawings.

Pipe anchor and guide forces (AF) produced from thermal expansion, internal pressure, and surge shall be considered as ***dead loads***. Piperacks beams, struts, columns, braced anchor frames, and foundations shall be designed to resist actual pipe anchor and guide loads. For local beam design consider only the top flange as acting in horizontal bending unless the pipe anchor engages both flanges of the beam. Anchor and pipe forces shall be obtained from the checked ***pipe stress analysis*** computer run.

Anchor and guide loads (excluding their friction component) shall be combined with wind or seismic loads.

4.4.3 Temperature Force (TF)

Thermal forces caused by structure expansion and contraction should be considered in the design with the structural steel checked for temperature change. Range of temperature change shall be in accordance with SAES-A-112. Refer to Section 7.1.6 for requirements. Design temperature shall be defined as the difference between the highest and lowest one day mean temperature plus the metal temperature for the sunheating effects on structural steel which can be estimated at about 20°C.

4.5 Wind Load (W)

4.5.1 Wind loads on all pipe, equipment, structural members, cable trays, platforms, ladders, and other attachments to the piperack shall be considered in the design. Wind pressures, wind pressure distribution, and pressure coefficients shall be computed and applied in accordance with ASCE 7 - 95 and the Saudi Aramco Best Practice SABP-006 "Wind Loads on Piperacks and Open Frame Structures".

4.5.2 The total wind load per foot on pipes, F, can be determined using the following equation:

$$F = q_z\ G\ C_f\ A \qquad \text{(ASCE 7 - Table 6-1)}$$

where:

q_z = $0.00256\ K_z\ K_{zt}\ V^2\ I$ (lb/ft^2) (ASCE 7 - Eq. 6-1)

I = Importance Factor

V = Wind Velocity (MPH)

K_Z = Exposure Coefficient

K_{Zt} = Topographic Factor (per ASCE 7 provision 6.5.5).

K_{Zt} = 1.0 for Piperacks

G = Gust Response Factor

C_f = Force Coefficient

A = Projected Area normal to wind

4.5.3 For major piperacks, the design lateral wind load on pipes at each pipe deck shall not be less than the wind load computed for 12-inch (300 mm) pipes at 15-inch (381 mm) centers.

4.5.4 Longitudinal wind load on piperacks is negligible compared to other longitudinal forces and, therefore, can normally be disregarded.

4.5.5 For detailed wind load calculations on piperacks, refer to criteria specified in Saudi Aramco Best Practices SABP-006 "Wind Loads on Piperacks and Open Frame Structures".

4.6 Earthquake Load (E)

Earthquake loads shall be computed and applied in accordance with ASCE 7 - 95. The earthquake loads in ASCE 7 are limit state seismic loads and this should be taken into account when using allowable stress design methods and applying load factors from other codes, etc.

ASCE's Guideline for Seismic Evaluation of Design of Petrochemical Facilities shall also be used for seismic design. The Rw factors in ASCE's Seismic Guidelines Tables 4.4 may be converted to R factors for use with ASCE 7 by dividing by 1.4. For steel piperack, with an Ordinary Moment Resisting Frame, the Rw value is 6. Therefore, the response modification factor to be used in ASCE 7 is 6 divided by 1.4 equals to R = 4.29.

Seismic zones, effective peak acceleration, effective peak velocity and site soil coefficient shall be determined in accordance with SAES-A-112 "Meteorological And Seismic Design Data". All plant area structures shall be considered ***essential facilities***.

The Importance Factor ***I*** shall be ***Category IV***.

4.7 Other Loads (O)

Piperacks may be subjected to loads not covered by the six categories described above.

5 Load Combinations

5.1 Loading Combinations – Allowable Stress Design

The following load combinations of loads are for use in conjunction with the allowable stress method of design. The load combinations shown below are the most common load combinations but may not cover all possible conditions. Any credible load combinations that could produce the maximum stress or govern for stability should be considered in the calculations. Theses load combinations shall be considered in superstructure and foundation design of piperacks.

$D + P_L + FF + TF + AF$ (if any) — ***Load Comb. 1***
(Max. Operating Gravity Loads)

$0.75\ (0.9\ D + W)$ — ***Load Comb. 2***
(Min. Dead Load + Wind)

$0.75\ (D + P_L + AF + W$ or $E)$ — ***Load Comb. 3***
(Max. Oper. Gravity + W or E)

$0.80 [D + P_t + (1/4 W \text{ or } 1/4E)]$ ***Load Comb. 4***
(Test Load + W or E)

where:

D = Dead Load

P_L = Product Load

AF = Anchor Force

TF = Temperature Force

P_t = Test Load

W = Wind Load

E = Earthquake Load

5.1.1 Wind forces and earthquake forces shall not be considered to act simultaneously.

5.1.2 The engineer should use his judgment in selecting potential critical combinations. Load conditions that have primarily a localized effect generally do no need to be included in the main analysis as these loads may be considered during individual structural component design.

5.1.3 In combinations involving Test Load (P_t), and W or E load, only ¼ of the load need be considered. For wind load, this is justified because hydrotests are not conducted during high winds and, for earthquake load; the probability of shocks occurring during hydrotest is low.

5.2 Loading Combinations and Load Factors – Strength Design

The following load combinations of loads are for use in conjunction with the strength design method and may be used for foundation design. The load combinations shown below are the most common load combinations but may not cover all possible conditions. Any credible load combinations that could produce the maximum stress or govern for stability should be considered in the calculations.

$1.4 (D + P_L + FF + TF + AF)$ ***Load Comb. 1***
(Max. Operating Gravity Loads)

$0.9 D + 1.3W$ ***Load Comb. 2***
(Min. Dead Load + Wind Load)

$0.75[1.4D + 1.4P_L + 1.4AF + (1.7W \text{ or } 1.9E)]$ ***Load Comb. 3***
(Max. Oper. Gravity + W or E)

$1.4D + 1.4P_t + (0.57W \text{ or } 0.63E)$ ***Load Comb. 4***
(Test Load + W or E)

6 Allowable Stresses and Strength Requirements

6.1 Structural Steel

The allowable stresses and stress increases specified in the AISC manual shall be used for all piperack steel design with the following exception:

Exception:

Under test conditions, the allowable stress for all structural steel elements and their connections may be increased 20% when a partial wind or earthquake load is included.

6.2 Anchor Bolts

The design of anchor bolts shall conform to requirements of Paragraph 4.7 of SAES-Q-005 and SABP-001.

6.3 Cast-in-Place Concrete

Strength design methods of ACI shall be used in piperack footing design. For footing design requirements see SAES-Q-005 and Saudi Aramco Best Practice SABP-002 "Spread Footings Design".

7 Piperack Superstructure Design

7.1 General

7.1.1 The principal structural components of a piperack are the transverse bent beams, the bent columns, longitudinal struts, and vertical bracing. Design criteria applicable to each of these components are presented below.

7.1.2 In general, the pipe support framing system is designed as rigid frame bents with fixed or pinned bases in the transverse direction and as braced frames in the longitudinal direction.

7.1.3 A determined effort should be made early on the project to establish the correct number of transverse beam levels required for piping and electrical support, and the number of longitudinal beams required to support pipes entering or leaving the pipeway. Additional longitudinal and/or intermediate transverse beam may be required to support electrical conduit, instrumentation lines, or other small lines. Electrical conduit and cable trays usually must be supported every 10 feet.

7.1.4 Structural components of the piperack must be capable of resisting the axial loads, shears, moments, and torsion produced by the load combinations given in Section 5.0 of this guideline.

7.1.5 An elastic analysis shall be used to determine moments and forces in piperack members.

7.1.6 Structural Steel Expansion

For piperack design, provisions shall be made for thermal expansion of steel, with the structural steel checked for temperature change. Slotted connections (sliding connection) shall be provided in each segment of the piperack between vertical bracing to allow for structural steel thermal expansion. The maximum segment for the piperack shall be limited to ***140 feet*** (42.5 meters) in length unless calculations show otherwise. Details and requirements for the slotted connection shall be provided on the engineering drawings.

7.2 Transverse Bent Beams

7.2.1 In computing the allowable bending stress, F_b, the unbraced length shall be taken as the span of the beam and the AISC factor Cb shall be used to account for end fixity. A Cb value of 1.0 is a very conservative and safe assumption. In no case shall the assumption of lateral support from piping be used in computing F_b.

7.2.2 Generally, the depth of horizontal members should not be less than 1/24 of the span.

7.2.3 If top flange lateral loads are significant, the transverse beam shall be investigated for bending about the y-y axis and for torsion. This can be estimated by using $M_y \times 2 / S_y$.

7.2.4 In axial load design, the total span of the beam should be used, modified by the appropriate effective length factor for each direction. This factor should be equal to 1.0 for the weak direction of the beam.

7.2.5 Special consideration shall be given to the design of transverse beams which support large vapor lines to be hydrotested or which support large anchor or guide forces. Horizontal bracing may be required locally if the local bending stresses are too high.

7.3 Bent Columns

7.3.1 In strutted piperacks, columns shall normally be designed with pinned or fixed bases depending on the lateral drift requirements.

7.3.2 In unstrutted piperacks, column bases shall be considered pinned in the transverse direction and fixed in the longitudinal direction. The major axis of columns should normally be perpendicular to the longitudinal direction of the piperack (i.e., plane formed by column web is parallel to longitudinal direction).

7.3.3 "T" support column bases shall be considered fixed in both the transverse and longitudinal directions. The major axis of columns may be turned in either direction.

7.3.4 Column base plates for major and miscellaneous piperacks and "T" supports that are to be attached to concrete foundations shall be ***four-bolt*** base plates.

7.4 Longitudinal Struts

7.4.1 In areas where gravity loading of struts is anticipated, struts shall be designed for axial loads produced by longitudinal pipe loads plus gravity load moments and shears. Such struts should be designed for the actual load but not less than ***50%*** of the gravity loading of the loaded transverse pipe support beam. This loading requirement will account for the usual piping and electrical conduit that is "rolled-out" of the piperack. Concentrated loads for large pipes shall also be included in design.

7.4.2 Where gravity loading is not anticipated, struts shall be designed for axial load only. The primary source of axial loads is longitudinal pipe loads.

7.5 Vertical Bracing

7.5.1 Vertical bracing may be used to transmit transverse and longitudinal forces to the foundations. K-bracing or X-bracing is usually used for this purpose.

7.5.2 Braced bays in strutted piperack systems should be spaced at 140 feet (42.5 meters) maximum. Longitudinal bracing should be provided in about every fourth bay.

7.5.3 Compression bracing for steel piperack systems shall normally be designed with wide flange and structural tee shapes. For tension bracing, single angle, double angle or structural tees may be used.

8 Piperack Foundations

8.1 Foundations shall be designed in accordance with the project soil report recommendations and SAES-Q-005 "Concrete Foundations".

8.2 The type of foundation to be used for piperacks shall be established based on the soil report recommendations.

8.3 In piperack foundation design, buoyant load shall be considered when applicable. The buoyant load included in the design shall be based on project water table elevations (permanent or temporary), which produce the most unfavorable effect on the foundation.

Revision Summary

31 August, 2002 New Saudi Aramco Best Practice (SABP-007).

Attachment 1

PIPERACK DESIGN - EXAMPLE 1

Design typical piperack bent in Uthmaniyah Gas Plant. The piperack configuration shall be as shown in example 1 (Figures 1 through 6), and with a 3-sec. Gust wind speed of ***96 mph per*** SAES-A-112. Earthquake zone is 0, therefore seismic loads need not be considered in the analysis and design.

Assumptions:

The main beams shall be W10X33 for the cable tray support and W12X40 and W12X45 for the pipe supports. The beam levels are 20.00, 25.00 and 20.00. The beams are rigidly connected to the columns (i.e., moment connection)

The columns are W14X53 and fixed at the base.

The longitudinal struts (W10X33) located at levels 17.50, 22.50 and 30.00 acts as struts to transfer thermal load to the vertical bracing of the rack. These levels will be considered as braced in the longitudinal direction. Refer to Figure 2 for Bent Framing arrangement.

Primary loads to be considered are as follows:

D, P_L, FF, TF & W (assume no anchor loads and no pipes will be tested at this bent)

Load Combinations to be considered are as follows:

D + P_L + FF + TF	Load Combination 101
0.75 (D + P_L + W)	Load Combination 102
0.75 (0.9 D + W)	Load Combination 103

Member Loads:

Dead Loads (D) & Product Loads (P_L). Refer to Figures 1, 3 & 5.

<u>Members 11 and 12</u>

Dead Load: W_D = 23 psf x 20 ft = 460 #/ft = 0.46 K/ft (per Section 4.1.2.a)
Product Load: W_{PL} = 17 psf x 20 ft = 340 #/ft = 0.34 K/ft (per Section 4.2.2.a)

Concentrated Pipe Loads (per Sections 4.1.2.a and 4.2.2.b)

24" O.D. Pipe Schedule 40 $D = 125.49$ #/ft, $P_L = 179.87$ #/ft
18" O.D. Pipe Schedule 40 $D = 104.67$ #/ft, $P_L = 96.93$ #/ft

For pipe weight and product load (P_L), refer to Table 1.

Member 12 concentrated Dead Load

$$P_{DL} = S\,(W_{DL} - p_{DL}\,D)$$

$P_{1DL} = 20 \text{ ft } (125.49 - 23*2)/1000 = 1.59$ kips

Member 12 concentrated Product Load

$$P_{PL} = S\,(W_{PL} - p_{PL}\,D)$$

$P_{1PL} = 20 \text{ ft } (179.87 - 17*2)/1000 = 2.917$ kips

$P_{1\ Total} = 1.59 + 2.917 = 4.507$ kips

Member 11 concentrated Dead Load

$$P_{DL} = S\,(W_{DL} - p_{DL}\,D)$$

$P_{2DL} = 20 \text{ ft } (104.67 - 23*1.5)/1000 = 1.403$ kips

Member 11 concentrated Product Load

$$P_{PL} = S\,(W_{PL} - p_{PL}\,D)$$

$P_{2PL} = 20 \text{ ft } (96.93 - 17*1.5)/1000 = 1.428$ kips

$P_{2\ Total} = 1.403 + 1.428 = 2.831$ kips

Member 13
Dead Load: $W_D = 20$ psf x 20 ft = 400 #/ft = 0.40 K/ft

Thermal Loads – Frictional Force FF (in the longitudinal direction)

Members 11 and 12
FF (Uniform) = (0.04 x 20) x 0.1 = 0.08 k/ft (FF = 10% of Operating Load)

Concentrated load in the longitudinal direction - 10% of concentrated load

Member 11
FF2 = 0.1 (2.831) = 0.283 kips

Member 12
FF1 = 0.1 (4.507) = 0.451 kips

Temperature Loads:

Structural steel shall be designed based on SAES-A-112. The Design Temperature shall be the difference the highest and lowest one-day mean temperature. For Uthmaniyah it will be 106-43 = 63°F plus metal temperature for the sunhearting effects on structural steel which can be estimated at about 36°F or (20°C).

Design Temperature = (63 + 36) = 99°F (103°F is used in this example – say ok)

Wind Loads

Design wind forces are determined by the equation listed below, where F is the force per unit length of the piping or cable tray (For Force Coefficients and details, refer to Structural Design Best Practices Guidelines for "Wind Loads on Piperacks and Open Frame Structures"):

$F = q_z G C_f A_e$ ASCE 7 Table 6-1

Design wind pressure, for 30 ft elevation from Table 1

qz = 26.59 psf

Gust effect factor, G = 0.85 **(ASCE 7, Section 6.6.1)**

Force Coefficients

For structural members	$C_f = 1.8$	(Section 4.1)
For columns	$C_f = 2.0$	(Section 4.1)
For pipes	$C_f = 0.7$	(Section 4.1.3)
For cable trays	$C_f = 2.0$	(Section 4.1.4)

Projected Area

Projected Area per foot of piperack, A_e = Largest pipe diameter or cable tray height + 10% of piperack width. (Sections 4.1.1 and 4.1.2)

WIND LOAD ON PIPING AND CABLE TRAY

The guidelines require the consideration of the piping or cable trays separately from the structural members. The following calculations are only for piping and cable trays without the structural support members:

Force	Calculation	Force (Pounds)
F1	***Cable Tray 6" Deep***	
	$C_f = 2.0$	
	$A_e = 0.5 + (10\% * 25\ ft) = 3.0\ ft^2$	
	F1 = [(26.59 psf) * (0.85) * (2.0) * (3.0)] * 20.0 bent spacing	F1 = 2712.2
F2	***Pipe Level 25 ft – 24" Max. O.D.***	
	$C_f = 0.7$	
	$A_e = 2.0 + (10\% * 25\ ft) = 4.5\ ft^2$	
	F2 = [(26.59 psf) * (0.85) * (0.7) * (4.5)] * 20.0 bent spacing	F2 = 1423.9
F3	***Pipe Level 20 ft – 18" Max. O.D.***	
	$C_f = 0.7$	
	$A_e = 1.5 + (10\% * 25\ ft) = 4.0\ ft^2$	
	F3 = [(26.59 psf) * (0.85) * (0.7) * (4.0)] * 20.0 bent spacing	F3 = 1265.7

WIND LOAD ON STRUCTURAL MEMBERS

For structural members, assume 25 ft wide rack with bent spacing of 20 ft centers, all stringers not shielded.

Stringers at elevations 30.0, 22.5 and 17.5

Assume qz = 26.59 psf for all 3 levels of stringers (conservative)
$C_f = 1.8$
$A_e = 9.73/12$ ft (beam depth) * 20 ft (beam length) = 16.22 ft^2

F4=F5=F6= (26.59 psf) * 0.85 *1.8 * 16.22 ft^2 = 659.9 pounds = 0.66 kips

Columns

qz = 26.59 psf at elev. 30 ft
qz = 25.50 psf at elev. 25 ft
qz = 24.42 psf at elev. 20 ft

Use qz = 26.59 psf for the whole column (conservative)
$C_f = 2.0$

A_e = 8/12 ft (column width) * 1 ft = 0.67 ft²/linear foot

Force per column = (26.59 psf) * 0.85 * 2.0 * 0.67 = 30.3 pounds/foot = 0.0303 kips/ft

Kz (effective length factor about the column local z-axis) calculations for columns

Refer to detailed calculations in Figure 6

$$G = \frac{\Sigma I_C/L_C}{\Sigma I_B/L_B}$$

Column Member	Elevation	G	Kz
	30.0	**15.82**	
5, 10			3.8
	25.0	17.51	
3, 4, 8, 9			3.5
	20.0	9.63	
1, 2, 6, 7			***1.9***
	0.0	1.0	

Check the critical Kz for the governing bottom portion of column:

Col. W14X53 (members 1, 2, 6 & 7) per Figure 5

W14X53 Ix = 541 IN^4
W12X45 Ix = 350 IN^4

G_B = 1.0 Fixed Base

$$G_T = \frac{\Sigma I_C/L_C}{\Sigma I_B/L_B}$$

$\Sigma I_C/L_C$ = (541/20x12) + (541/5x12) = 2.25 + 9.02 = 11.27

$\Sigma I_B/L_B$ = 350/25x12 = 1.17

G_T = 11.27/1.17 = 9.63

With G_B = 1.0 & G_T = 9.63 Kz = 1.9 Per AISC Steel Manual Figure 1 Page 3-4.

Piperack Bent is designed per attached STAAD III input and output file.

Check STAAD III output for the following:

Unity Check:
Ensure that unity check for all structural members are less than ***1.0***

Beam Deflection:
Ensure that maximum beams vertical deflection is less than ***L/240***
where L = span length

Lateral Drift:
Ensure that maximum lateral drift for the piperack is less than ***H/150*** for load combinations with wind load and ***H/100*** for earthquake case.

Connections & Columns Base Plate:
Design Beam/Column moment connection based on AISC Steel Manual procedure.
Design vertical and horizontal bracings connections based on member loads and in accordance with the AISC Steel Manual procedure.
Design Columns Base Plates based on AISC Steel Manual procedure.

Foundations:
Design columns Foundations in accordance with the requirements of SAES-Q005 and the Saudi Aramco Best Practices SABP-002 "Spread Footings Design".

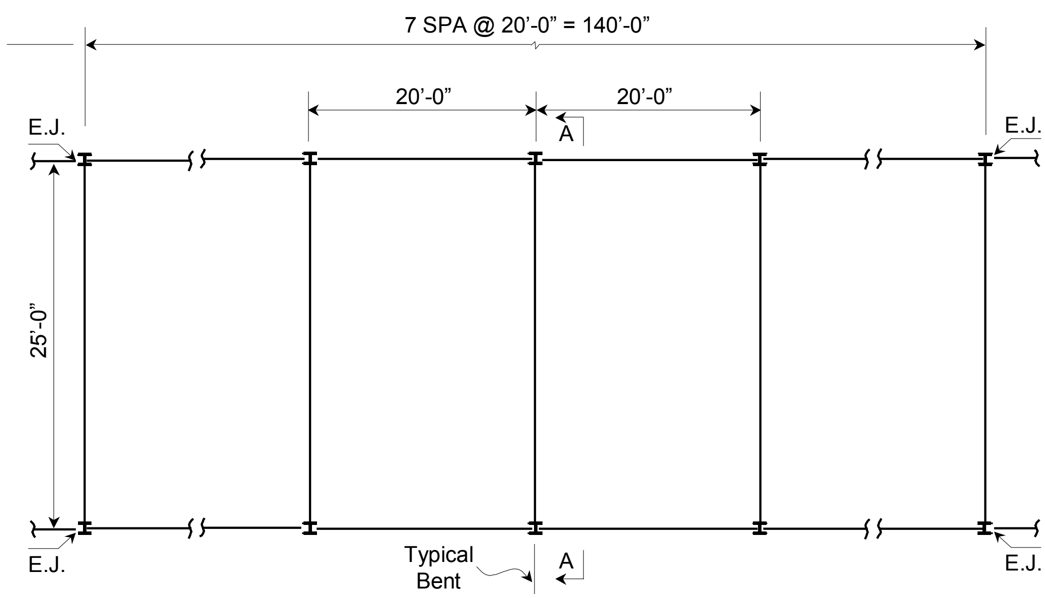


Figure 1 PIPE RACK – PLAN LAYOUT
Example 1

Attach. 1

MEMBER PROPERTIES

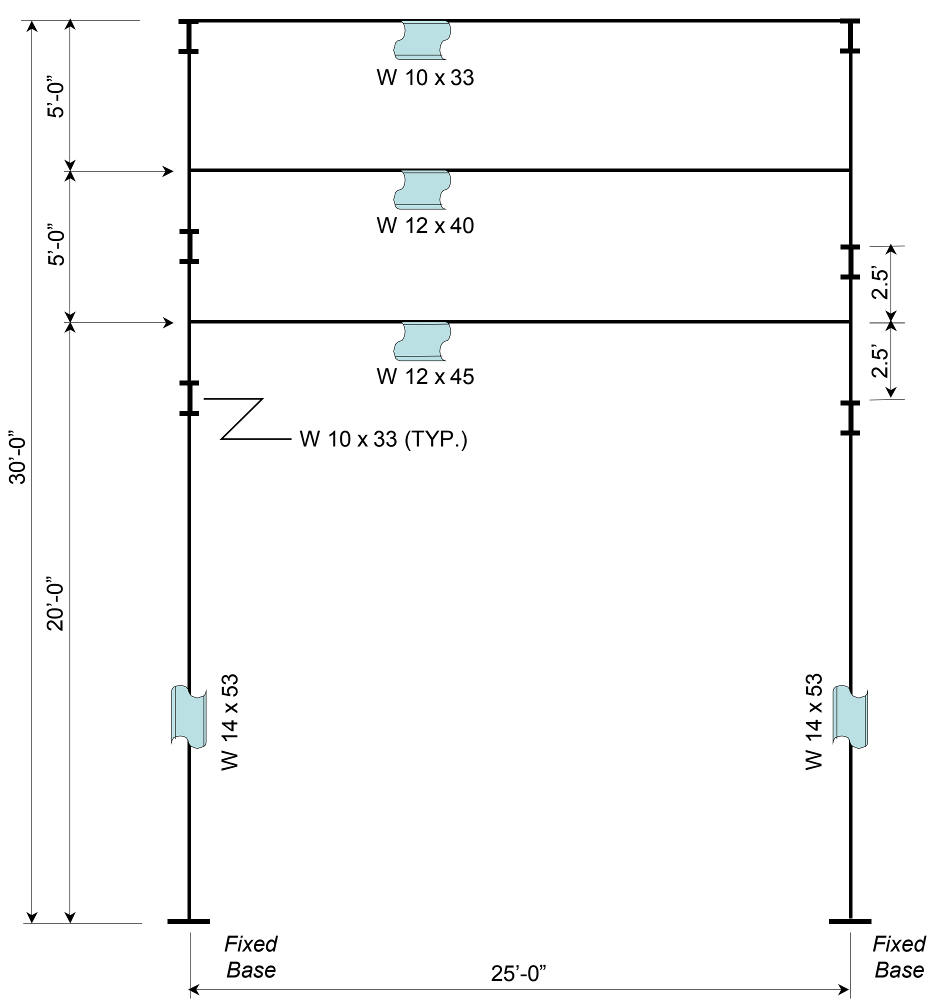


Figure 2

Typical Bent
Section A-A

Attach. 1

Example 1

WIND LOAD ON PIPE & STEEL MEMBERS

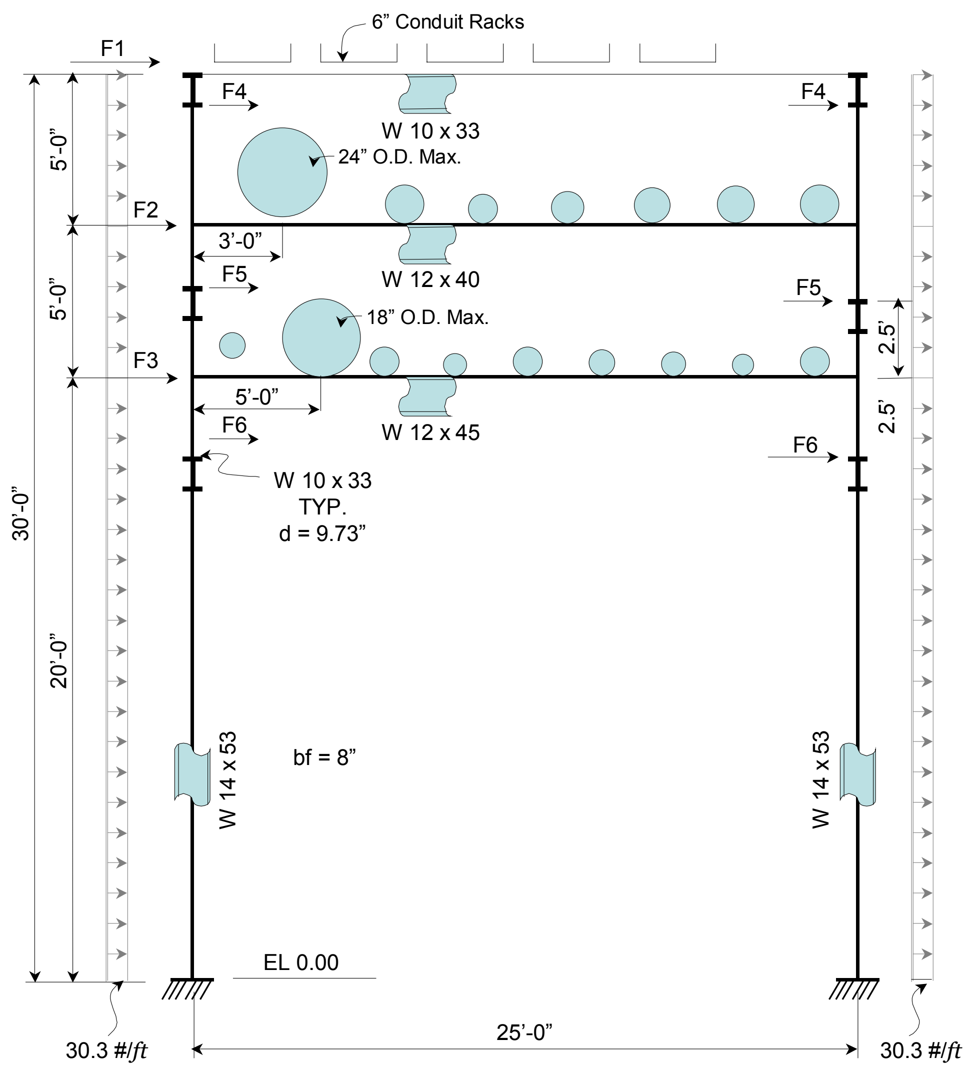


Figure 3

Typical Bent

Section A-A

Attach. 1

Example 1

WIND LOAD FOR STAAD III COMPUTER INPUT

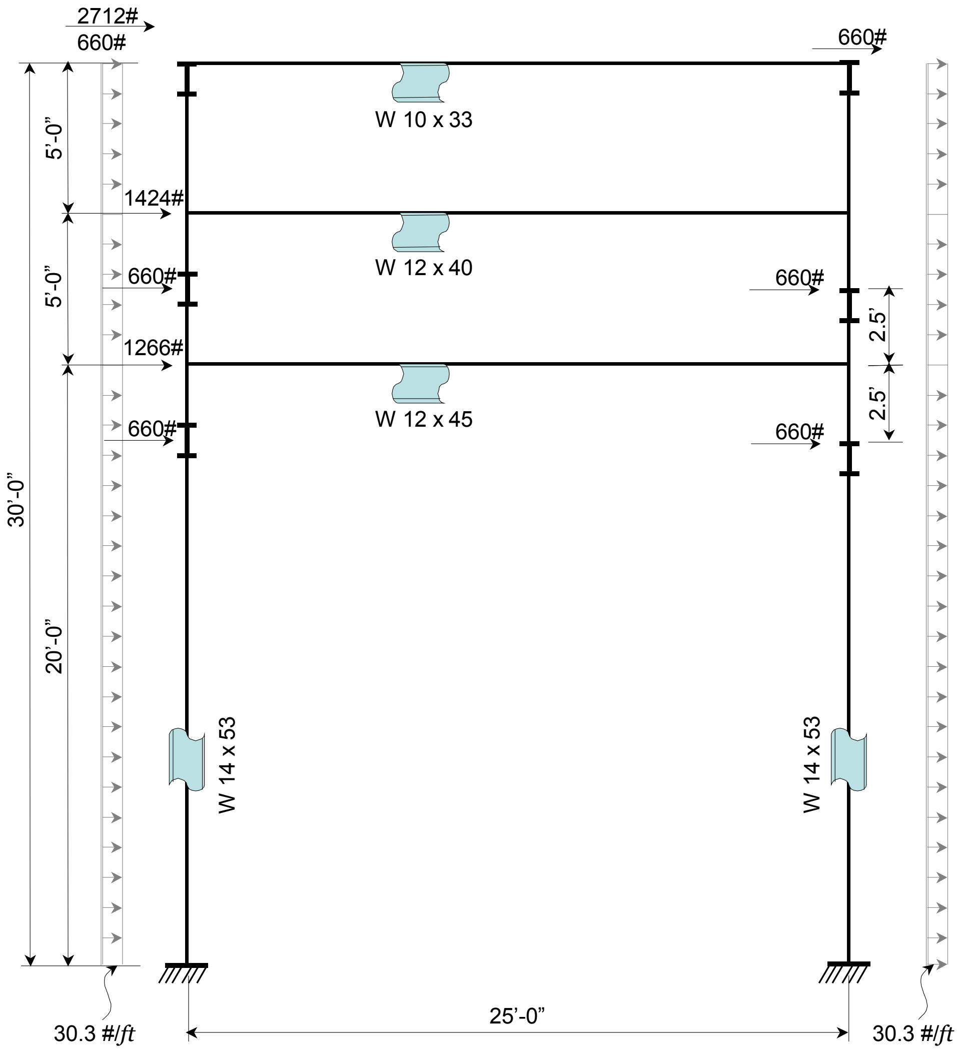


Figure 4

Typical Bent
Section A-A

Attach. 1

Example 1

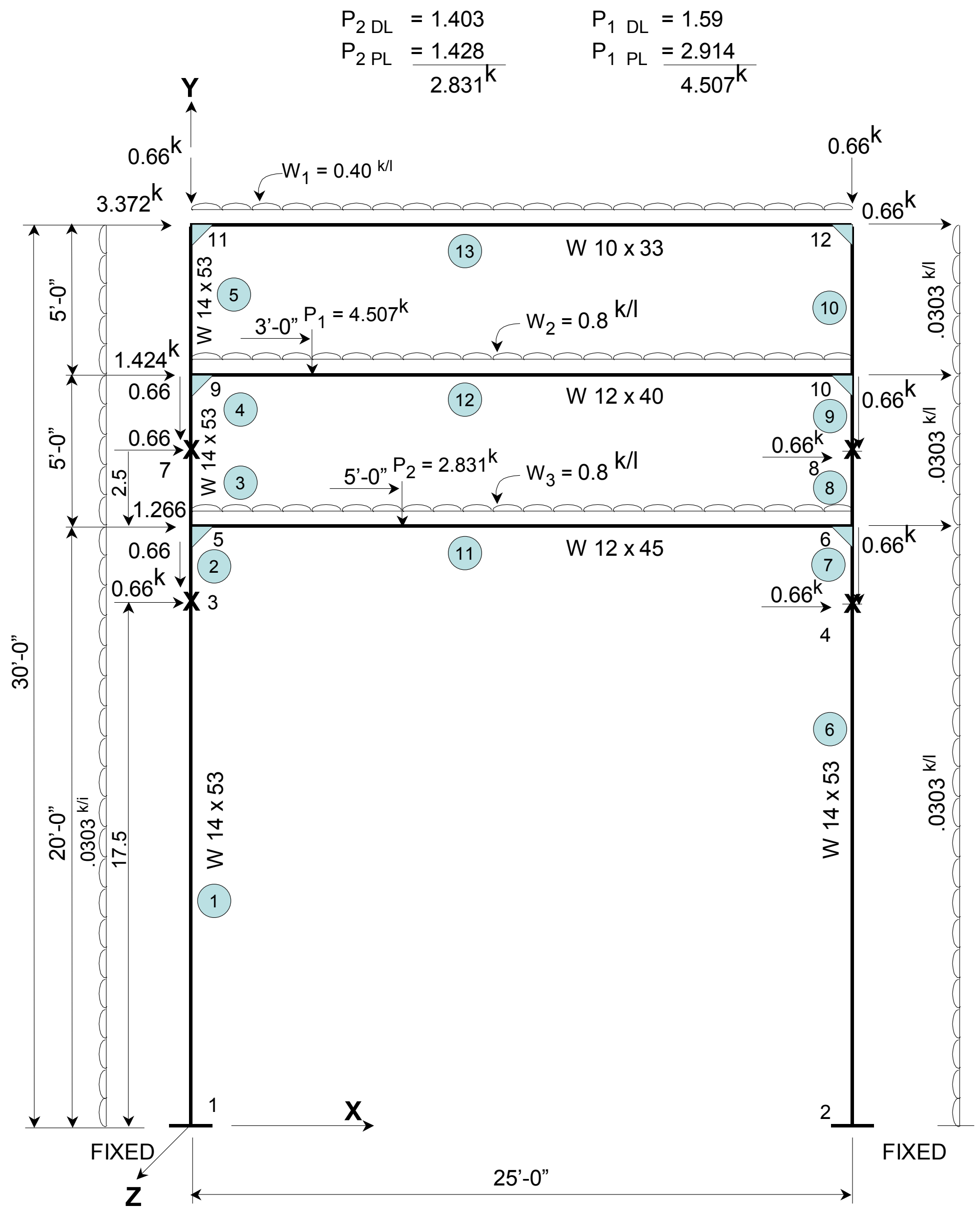


Figure 5

DL + OPER LD + WL

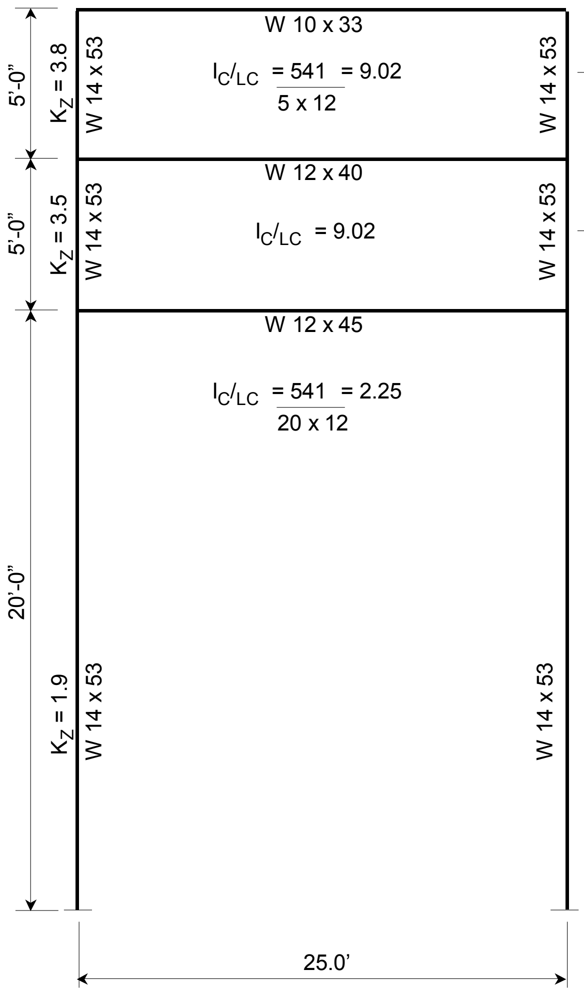
DESIGN LOADS

Attach. 1

Example 1

W 10 x 33 Ix = 170 IN^4
W 12 x 40 Ix = 310 IN^4
W 12 x 45 Ix = 350 IN^4
W 14 x 53 Ix = 541 IN^4

$$G = \frac{\Sigma Ic/Lc}{\Sigma I_B/L_B}$$



$$G = \frac{9.02}{0.57} = 15.82$$

$$\frac{I_B}{L_B} = \frac{170}{25 \times 12} = 0.57 \quad \underline{K_Z = 3.8}$$

$$G = \frac{9.02 \times 9.02}{1.03} = 17.51$$

$$\frac{I_B}{L_B} = \frac{310}{25 \times 12} = 1.03 \quad \underline{K_Z = 3.5}$$

$$G = \frac{2.25 \times 9.02}{1.17} = 9.63$$

$$\frac{I_B}{L_B} = \frac{3.50}{25 \times 12} = 1.17$$

$\underline{K_Z = 1.9}$

Elev.	G	K_Z
30.0	15.82	
		3.8
25.0	17.51	
		3.5
20.0	9.63	
		1.9
0.0	1.0	

Figure 6 Columns K_Z Factors

Example 1

Attach. 1

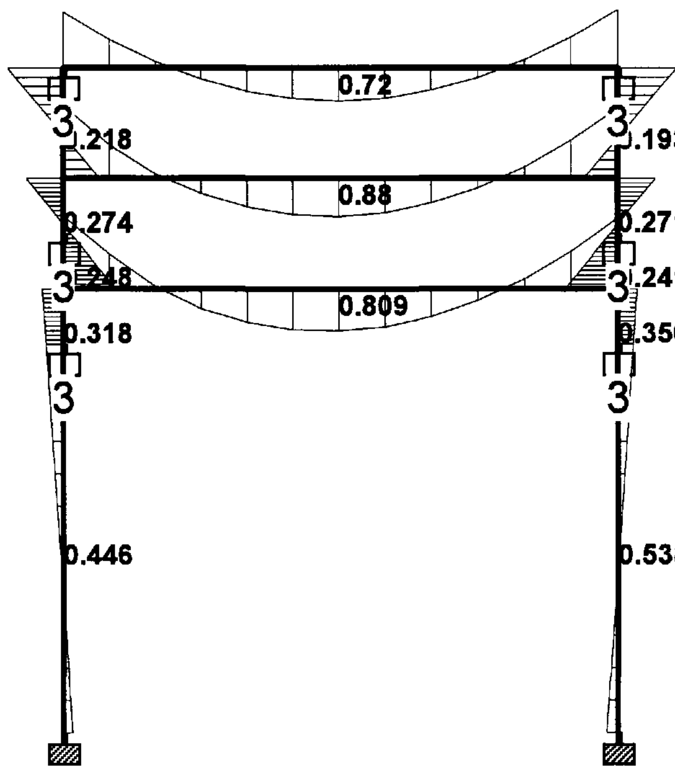


Figure 7 Typical Bent – Computer Output-Member Unity Check & Moment Diagram

Attachment 2

STAAD III Computer Input & Output for Example 1

```
                                                              PAGE NO.    1

          **************************************************
          *                                                *
          *            STAAD.Pro                           *
          *            Version  2001    Build 1004         *
          *            Proprietary Program of              *
          *            RESEARCH ENGINEERS, Intl.           *
          *            Date=    JUL  1, 2002               *
          *            Time=     9:55:30                   *
          *                                                *
          *       USER ID: CSD/Saudi Aramco                *
          **************************************************

 1. STAAD SPACE - PIPERACK DESIGN - EXAMPLE 1 - DESIGN GUIDELINES BEST
    PRACTICES
 2. OUTPUT WIDTH 72
 3. * DESIGN  BY : H.ABU-ADAS        CHECK  BY :      DATE:01/15/2002
 4. * FILE: BP-PR-EX1.STD
 5. UNIT FEET KIP
 6. JOINT COORDINATES
 7. 1 0 0 0; 2 25 0 0; 3 0 17.5 0; 4 25 17.5 0; 5 0 20 0; 6 25 20 0
 8. 7 0 22.5 0; 8 25 22.5 0; 9 0 25 0; 10 25 25 0; 11 0 30 0; 12 25 30 0
 9. MEMBER INCIDENCES
10. 1 1 3; 2 3 5; 3 5 7; 4 7 9; 5 9 11; 6 2 4; 7 4 6; 8 6 8; 9 8 10
11. 10 10 12; 11 5 6; 12 9 10; 13 11 12
12. SUPPORTS
13. 1 2 FIXED
14. 3 4 7 8 11 12 FIXED BUT FX FY MX MY MZ
15. MEMBER PROPERTY AMERICAN
16. 1 TO 10 TABLE ST W14X53
17. 11 TABLE ST W12X45
18. 12 TABLE ST W12X40
19. 13 TABLE ST W10X33
20. UNIT INCHES KIP
21. CONSTANTS
22. E STEEL ALL
23. DENSITY STEEL ALL
24. POISSON STEEL ALL
25. ALPHA 70E-7 ALL
26. UNIT FEET KIP
27. LOAD 1 DEAD LOAD (DL)
28. SELFWEIGHT Y -1
29. JOINT LOAD
30. 3 4 7 8 11 12 FY -0.66
31. MEMBER LOAD
32. 11 12 UNI GY -0.46
```

```
 - PIPERACK DESIGN - EXAMPLE 1 - DESIGN GUIDELINES BEST P -- PAGE NO.   2

 33. 13 UNI GY -0.4
 34. 11 CON GY -1.403 5
 35. 12 CON GY -1.59 3
 36. LOAD 2 PRODUCT LOAD (PL)
 37. MEMBER LOAD
 38. 11 12 UNI GY -0.34
 39. 11 CON GY -1.428 5
 40. 12 CON GY -2.914 3
 41. LOAD 3 THERMAL LOAD (FF + TF)
 42. * FRICTIONAL LOAD
 43. MEMBER LOAD
 44. 11 12 UNI GZ 0.08
 45. 11 CON GZ 0.283 5
 46. 12 CON GZ 0.451 3
 47. * TEMPERATURE LOAD
 48. TEMP LOAD
 49. 1 TO 13 TEMP 103
 50. LOAD 4 WIND LOAD (WL) FROM LEFT TO RIGHT (NORTH TO SOUTH)
 51. JOINT LOAD
 52. 3 4 7 8 12 FX 0.66
 53. 5 FX 1.266
 54. 9 FX 1.424
 55. 11 FX 3.372
 56. *WIND LOAD ON COLUMNS
 57. MEMBER LOAD
 58. 1 TO 10 UNI GX 0.0303
 59. *SERVICE LOADING COMB. FOR STEEL DESIGN
 60. LOAD COMB 101 OPERATING LOAD (DL + PL + FF)
 61. 1 1.0 2 1.0 3 1.0
 62. LOAD COMB 102 75 PERCENT DL + PL + WL(E-W)
 63. 1 0.75 2 0.75 4 0.75
 64. LOAD COMB 103 MIN. LOAD 0.75(0.9 DL + WL)
 65. 1 0.68 4 0.75
 66. PERFORM ANALYSIS


         P R O B L E M   S T A T I S T I C S
         -----------------------------------

  NUMBER OF JOINTS/MEMBER+ELEMENTS/SUPPORTS =    12/    13/     8
  ORIGINAL/FINAL BAND-WIDTH=     2/     2/     17 DOF
  TOTAL PRIMARY LOAD CASES =    4, TOTAL DEGREES OF FREEDOM =     54
  SIZE OF STIFFNESS MATRIX =       1 DOUBLE  KILO-WORDS
  REQRD/AVAIL. DISK SPACE  =    12.0/  1345.2 MB,  EXMEM =    0.1 MB

++ Processing Element Stiffness Matrix.                9:55:30
++ Processing Global Stiffness Matrix.                 9:55:30
++ Processing Triangular Factorization.                9:55:30
++ Calculating Joint Displacements.                    9:55:30
++ Calculating Member  Forces.                         9:55:30
```

```
- PIPERACK DESIGN - EXAMPLE 1 - DESIGN GUIDELINES BEST P -- PAGE NO.   3

67. LOAD LIST ALL
68. PRINT ANALYSIS RESULTS
```

JOINT DISPLACEMENT (INCH RADIANS) STRUCTURE TYPE = SPACE

JOINT	LOAD	X-TRANS	Y-TRANS	Z-TRANS	X-ROTAN	Y-ROTAN	Z-ROTAN
1	1	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
	2	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
	3	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
	4	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
	101	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
	102	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
	103	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
2	1	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
	2	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
	3	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
	4	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
	101	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
	102	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
	103	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
3	1	-0.00329	-0.01097	0.00000	0.00000	0.00000	-0.00025
	2	0.00126	-0.00569	0.00000	0.00000	0.00000	-0.00022
	3	-0.09764	0.15141	0.00000	0.00004	-0.00524	0.00039
	4	0.58305	0.00244	0.00000	0.00000	0.00000	-0.00287
	101	-0.09968	0.13475	0.00000	0.00004	-0.00524	-0.00009
	102	0.43577	-0.01066	0.00000	0.00000	0.00000	-0.00251
	103	0.43506	-0.00563	0.00000	0.00000	0.00000	-0.00233
4	1	0.01690	-0.00999	0.00000	0.00000	0.00000	0.00013
	2	0.01610	-0.00422	0.00000	0.00000	0.00000	0.00006
	3	0.09764	0.15141	0.00000	0.00004	0.00499	-0.00039
	4	0.58265	-0.00244	0.00000	0.00000	0.00000	-0.00287
	101	0.13065	0.13720	0.00000	0.00004	0.00499	-0.00020
	102	0.46174	-0.01249	0.00000	0.00000	0.00000	-0.00201
	103	0.44848	-0.00862	0.00000	0.00000	0.00000	-0.00207
5	1	0.00648	-0.01246	0.00000	0.00000	0.00000	-0.00042
	2	0.00963	-0.00650	0.00000	0.00000	0.00000	-0.00035
	3	-0.10706	0.17304	0.00080	-0.00002	-0.00598	0.00019
	4	0.66062	0.00279	0.00000	0.00000	0.00000	-0.00211
	101	-0.09095	0.15408	0.00080	-0.00002	-0.00598	-0.00058
	102	0.50755	-0.01212	0.00000	0.00000	0.00000	-0.00216
	103	0.49988	-0.00638	0.00000	0.00000	0.00000	-0.00187
6	1	0.01129	-0.01134	0.00000	0.00000	0.00000	0.00027
	2	0.01305	-0.00482	0.00000	0.00000	0.00000	0.00016
	3	0.10706	0.17304	0.00087	-0.00002	0.00570	-0.00019
	4	0.66015	-0.00279	0.00000	0.00000	0.00000	-0.00210
	101	0.13140	0.15688	0.00087	-0.00002	0.00570	0.00024
	102	0.51337	-0.01421	0.00000	0.00000	0.00000	-0.00125
	103	0.50279	-0.00980	0.00000	0.00000	0.00000	-0.00139

- PIPERACK DESIGN - EXAMPLE 1 - DESIGN GUIDELINES BEST P -- PAGE NO. 4

JOINT DISPLACEMENT (INCH RADIANS) STRUCTURE TYPE = SPACE

JOINT	LOAD	X-TRANS	Y-TRANS	Z-TRANS	X-ROTAN	Y-ROTAN	Z-ROTAN
7	1	0.01083	-0.01344	0.00000	0.00000	0.00000	-0.00017
	2	0.01459	-0.00695	0.00000	0.00000	0.00000	-0.00019
	3	-0.10948	0.19467	0.00000	0.00007	-0.00630	0.00004
	4	0.72305	0.00296	0.00000	0.00000	0.00000	-0.00190
	101	-0.08407	0.17428	0.00000	0.00007	-0.00630	-0.00031
	102	0.56135	-0.01308	0.00000	0.00000	0.00000	-0.00169
	103	0.54965	-0.00692	0.00000	0.00000	0.00000	-0.00153
8	1	0.01139	-0.01224	0.00000	0.00000	0.00000	0.00002
	2	0.01406	-0.00513	0.00000	0.00000	0.00000	-0.00002
	3	0.10948	0.19467	0.00000	0.00005	0.00596	-0.00004
	4	0.72252	-0.00296	0.00000	0.00000	0.00000	-0.00189
	101	0.13493	0.17730	0.00000	0.00005	0.00596	-0.00005
	102	0.56098	-0.01524	0.00000	0.00000	0.00000	-0.00142
	103	0.54964	-0.01054	0.00000	0.00000	0.00000	-0.00141
9	1	0.01324	-0.01437	0.00000	0.00000	0.00000	-0.00029
	2	0.01881	-0.00741	0.00000	0.00000	0.00000	-0.00030
	3	-0.10888	0.21630	0.00469	0.00011	-0.00662	-0.00001
	4	0.77589	0.00312	0.00000	0.00000	0.00000	-0.00150
	101	-0.07682	0.19452	0.00469	0.00011	-0.00662	-0.00061
	102	0.60596	-0.01399	0.00000	0.00000	0.00000	-0.00157
	103	0.59092	-0.00743	0.00000	0.00000	0.00000	-0.00132
10	1	0.01342	-0.01309	0.00000	0.00000	0.00000	0.00015
	2	0.01642	-0.00543	0.00000	0.00000	0.00000	0.00007
	3	0.10888	0.21630	0.00338	0.00008	0.00621	0.00001
	4	0.77522	-0.00312	0.00000	0.00000	0.00000	-0.00149
	101	0.13871	0.19778	0.00338	0.00008	0.00621	0.00023
	102	0.60379	-0.01623	0.00000	0.00000	0.00000	-0.00095
	103	0.59054	-0.01125	0.00000	0.00000	0.00000	-0.00102
11	1	0.02081	-0.01519	0.00000	0.00000	0.00000	-0.00046
	2	0.02462	-0.00740	0.00000	0.00000	0.00000	-0.00004
	3	-0.10817	0.25956	0.00000	-0.00017	-0.00031	-0.00001
	4	0.86380	0.00323	0.00000	0.00000	0.00000	-0.00128
	101	-0.06274	0.23697	0.00000	-0.00017	-0.00031	-0.00052
	102	0.68192	-0.01452	0.00000	0.00000	0.00000	-0.00134
	103	0.66200	-0.00791	0.00000	0.00000	0.00000	-0.00127
12	1	0.01346	-0.01392	0.00000	0.00000	0.00000	0.00036
	2	0.02243	-0.00544	0.00000	0.00000	0.00000	-0.00012
	3	0.10817	0.25956	0.00000	-0.00012	0.00031	0.00001
	4	0.86238	-0.00323	0.00000	0.00000	0.00000	-0.00126
	101	0.14406	0.24020	0.00000	-0.00012	0.00031	0.00025
	102	0.67370	-0.01694	0.00000	0.00000	0.00000	-0.00077
	103	0.65594	-0.01189	0.00000	0.00000	0.00000	-0.00070

- PIPERACK DESIGN - EXAMPLE 1 - DESIGN GUIDELINES BEST P -- PAGE NO. 5

Allowable Piperack Drift Limit

$$\Delta_{max} = \frac{H}{150} = \frac{30 \times 12}{150} = 2.40 \text{ inches} > 0.6819 \quad \text{o.k.}$$

SUPPORT REACTIONS -UNIT KIP FEET STRUCTURE TYPE = SPACE

JOINT	LOAD	FORCE-X	FORCE-Y	FORCE-Z	MOM-X	MOM-Y	MOM Z
1	1	0.57	24.10	0.00	0.00	0.00	-3.39
	2	0.42	12.25	0.00	0.00	0.00	-2.29
	3	1.08	0.00	0.01	0.05	0.04	-11.86
	4	-5.59	-5.26	0.00	0.00	0.00	65.26
	101	2.07	36.34	0.01	0.05	0.04	-17.54
	102	-3.45	23.31	0.00	0.00	0.00	44.68
	103	-3.81	12.44	0.00	0.00	0.00	46.64
2	1	-0.57	21.98	0.00	0.00	0.00	4.20
	2	-0.42	9.09	0.00	0.00	0.00	3.32
	3	-1.08	0.00	0.01	0.05	-0.04	11.86
	4	-5.59	5.26	0.00	0.00	0.00	65.22
	101	-2.07	31.08	0.01	0.05	-0.04	19.37
	102	-4.93	27.25	0.00	0.00	0.00	54.55
	103	-4.58	18.89	0.00	0.00	0.00	51.77
3	1	0.00	0.00	0.00	0.00	0.00	0.00
	2	0.00	0.00	0.00	0.00	0.00	0.00
	3	0.00	0.00	-0.33	0.00	0.00	0.00
	4	0.00	0.00	0.00	0.00	0.00	0.00
	101	0.00	0.00	-0.33	0.00	0.00	0.00
	102	0.00	0.00	0.00	0.00	0.00	0.00
	103	0.00	0.00	0.00	0.00	0.00	0.00
4	1	0.00	0.00	0.00	0.00	0.00	0.00
	2	0.00	0.00	0.00	0.00	0.00	0.00
	3	0.00	0.00	-0.31	0.00	0.00	0.00
	4	0.00	0.00	0.00	0.00	0.00	0.00
	101	0.00	0.00	-0.31	0.00	0.00	0.00
	102	0.00	0.00	0.00	0.00	0.00	0.00
	103	0.00	0.00	0.00	0.00	0.00	0.00
7	1	0.00	0.00	0.00	0.00	0.00	0.00
	2	0.00	0.00	0.00	0.00	0.00	0.00
	3	0.00	0.00	-2.05	0.00	0.00	0.00
	4	0.00	0.00	0.00	0.00	0.00	0.00
	101	0.00	0.00	-2.05	0.00	0.00	0.00
	102	0.00	0.00	0.00	0.00	0.00	0.00
	103	0.00	0.00	0.00	0.00	0.00	0.00
8	1	0.00	0.00	0.00	0.00	0.00	0.00
	2	0.00	0.00	0.00	0.00	0.00	0.00
	3	0.00	0.00	-1.62	0.00	0.00	0.00
	4	0.00	0.00	0.00	0.00	0.00	0.00

- PIPERACK DESIGN - EXAMPLE 1 - DESIGN GUIDELINES BEST P -- PAGE NO. 6

SUPPORT REACTIONS -UNIT KIP FEET STRUCTURE TYPE = SPACE

JOINT	LOAD	FORCE-X	FORCE-Y	FORCE-Z	MOM-X	MOM-Y	MOM Z
	101	0.00	0.00	-1.62	0.00	0.00	0.00
	102	0.00	0.00	0.00	0.00	0.00	0.00
	103	0.00	0.00	0.00	0.00	0.00	0.00
11	1	0.00	0.00	0.00	0.00	0.00	0.00
	2	0.00	0.00	0.00	0.00	0.00	0.00
	3	0.00	0.00	-0.25	0.00	0.00	0.00
	4	0.00	0.00	0.00	0.00	0.00	0.00
	101	0.00	0.00	-0.25	0.00	0.00	0.00
	102	0.00	0.00	0.00	0.00	0.00	0.00
	103	0.00	0.00	0.00	0.00	0.00	0.00
12	1	0.00	0.00	0.00	0.00	0.00	0.00
	2	0.00	0.00	0.00	0.00	0.00	0.00
	3	0.00	0.00	-0.19	0.00	0.00	0.00
	4	0.00	0.00	0.00	0.00	0.00	0.00
	101	0.00	0.00	-0.19	0.00	0.00	0.00
	102	0.00	0.00	0.00	0.00	0.00	0.00
	103	0.00	0.00	0.00	0.00	0.00	0.00

- PIPERACK DESIGN - EXAMPLE 1 - DESIGN GUIDELINES BEST P -- PAGE NO. 7

MEMBER END FORCES STRUCTURE TYPE = SPACE

ALL UNITS ARE -- KIP FEET

MEMBER	LOAD	JT	AXIAL	SHEAR-Y	SHEAR-Z	TORSION	MOM-Y	MOM-Z
1	1	1	24.10	-0.57	0.00	0.00	0.00	-3.39
		3	-23.17	0.57	0.00	0.00	0.00	-6.56
	2	1	12.25	-0.42	0.00	0.00	0.00	-2.29
		3	-12.25	0.42	0.00	0.00	0.00	-5.08
	3	1	0.00	-1.08	0.01	0.04	-0.05	-11.86
		3	0.00	1.08	-0.01	-0.04	-0.11	-7.05
	4	1	-5.26	5.59	0.00	0.00	0.00	65.26
		3	5.26	-5.06	0.00	0.00	0.00	27.95
	101	1	36.34	-2.07	0.01	0.04	-0.05	-17.54
		3	-35.42	2.07	-0.01	-0.04	-0.11	-18.69
	102	1	23.31	3.45	0.00	0.00	0.00	44.68
		3	-22.62	-3.05	0.00	0.00	0.00	12.23
	103	1	12.44	3.81	0.00	0.00	0.00	46.64
		3	-11.81	-3.41	0.00	0.00	0.00	16.50
2	1	3	22.51	-0.57	0.00	0.00	0.00	6.56
		5	-22.38	0.57	0.00	0.00	0.00	-7.98
	2	3	12.25	-0.42	0.00	0.00	0.00	5.08
		5	-12.25	0.42	0.00	0.00	0.00	-6.13
	3	3	0.00	-1.08	-0.32	0.04	0.11	7.05
		5	0.00	1.08	0.32	-0.04	0.69	-9.75
	4	3	-5.26	4.40	0.00	0.00	0.00	-27.95
		5	5.26	-4.33	0.00	0.00	0.00	38.86
	101	3	34.76	-2.07	-0.32	0.04	0.11	18.69
		5	-34.62	2.07	0.32	-0.04	0.69	-23.87
	102	3	22.12	2.56	0.00	0.00	0.00	-12.23
		5	-22.02	-2.50	0.00	0.00	0.00	18.55
	103	3	11.36	2.91	0.00	0.00	0.00	-16.50
		5	-11.27	-2.86	0.00	0.00	0.00	23.71
3	1	5	14.91	-6.70	0.00	0.00	0.00	-19.56
		7	-14.78	6.70	0.00	0.00	0.00	2.80
	2	5	6.85	-4.79	0.00	0.00	0.00	-13.04
		7	-6.85	4.79	0.00	0.00	0.00	1.07
	3	5	0.00	1.70	0.91	0.02	-0.69	8.66
		7	0.00	-1.70	-0.91	-0.02	-1.59	-4.40
	4	5	-2.52	3.67	0.00	0.00	0.00	-4.60
		7	2.52	-3.59	0.00	0.00	0.00	13.67
	101	5	21.76	-9.79	0.91	0.02	-0.69	-23.95
		7	-21.63	9.79	-0.91	-0.02	-1.59	-0.53
	102	5	14.43	-5.87	0.00	0.00	0.00	-27.90
		7	-14.33	5.92	0.00	0.00	0.00	13.16

- PIPERACK DESIGN - EXAMPLE 1 - DESIGN GUIDELINES BEST P -- PAGE NO. 8

MEMBER END FORCES STRUCTURE TYPE = SPACE

ALL UNITS ARE -- KIP FEET

MEMBER	LOAD	JT	AXIAL	SHEAR-Y	SHEAR-Z	TORSION	MOM-Y	MOM-Z
	103	5	8.25	-1.81	0.00	0.00	0.00	-16.75
		7	-8.16	1.86	0.00	0.00	0.00	12.16
4	1	7	14.12	-6.70	0.00	0.00	0.00	-2.80
		9	-13.99	6.70	0.00	0.00	0.00	-13.96
	2	7	6.85	-4.79	0.00	0.00	0.00	-1.07
		9	-6.85	4.79	0.00	0.00	0.00	-10.90
	3	7	0.00	1.70	-1.14	0.02	1.59	4.40
		9	0.00	-1.70	1.14	-0.02	1.27	-0.14
	4	7	-2.52	2.93	0.00	0.00	0.00	-13.67
		9	2.52	-2.86	0.00	0.00	0.00	20.91
	101	7	20.97	-9.79	-1.14	0.02	1.59	0.53
		9	-20.84	9.79	1.14	-0.02	1.27	-25.00
	102	7	13.84	-6.42	0.00	0.00	0.00	-13.16
		9	-13.74	6.48	0.00	0.00	0.00	-2.96
	103	7	7.71	-2.36	0.00	0.00	0.00	-12.16
		9	-7.62	2.42	0.00	0.00	0.00	6.19
5	1	9	6.30	-6.90	0.00	0.00	0.00	-13.55
		11	-6.04	6.90	0.00	0.00	0.00	-20.97
	2	9	-0.06	-2.05	0.00	0.00	0.00	-10.87
		11	0.06	2.05	0.00	0.00	0.00	0.60
	3	9	0.00	0.04	0.25	-0.19	-1.27	0.18
		11	0.00	-0.04	-0.25	0.19	0.00	0.03
	4	9	-0.80	2.20	0.00	0.00	0.00	0.54
		11	0.80	-2.05	0.00	0.00	0.00	10.07
	101	9	6.24	-8.91	0.25	-0.19	-1.27	-24.24
		11	-5.98	8.91	-0.25	0.19	0.00	-20.34
	102	9	4.08	-5.07	0.00	0.00	0.00	-17.91
		11	-3.88	5.18	0.00	0.00	0.00	-7.72
	103	9	3.68	-3.05	0.00	0.00	0.00	-8.81
		11	-3.50	3.16	0.00	0.00	0.00	-6.71
6	1	2	21.98	0.57	0.00	0.00	0.00	4.20
		4	-21.05	-0.57	0.00	0.00	0.00	5.76
	2	2	9.09	0.42	0.00	0.00	0.00	3.32
		4	-9.09	-0.42	0.00	0.00	0.00	4.05
	3	2	0.00	1.08	0.01	-0.04	-0.05	11.86
		4	0.00	-1.08	-0.01	0.04	-0.11	7.05
	4	2	5.26	5.59	0.00	0.00	0.00	65.22
		4	-5.26	-5.06	0.00	0.00	0.00	27.94
	101	2	31.08	2.07	0.01	-0.04	-0.05	19.37
		4	-30.15	-2.07	-0.01	0.04	-0.11	16.86
	102	2	27.25	4.93	0.00	0.00	0.00	54.55
		4	-26.56	-4.54	0.00	0.00	0.00	28.31

- PIPERACK DESIGN - EXAMPLE 1 - DESIGN GUIDELINES BEST P -- PAGE NO. 9

MEMBER END FORCES STRUCTURE TYPE = SPACE

ALL UNITS ARE -- KIP FEET

MEMBER	LOAD	JT	AXIAL	SHEAR-Y	SHEAR-Z	TORSION	MOM-Y	MOM-Z
	103	2	18.89	4.58	0.00	0.00	0.00	51.77
		4	-18.26	-4.18	0.00	0.00	0.00	24.87
7	1	4	20.39	0.57	0.00	0.00	0.00	-5.76
		6	-20.26	-0.57	0.00	0.00	0.00	7.18
	2	4	9.09	0.42	0.00	0.00	0.00	-4.05
		6	-9.09	-0.42	0.00	0.00	0.00	5.11
	3	4	0.00	1.08	-0.30	-0.04	0.11	-7.05
		6	0.00	-1.08	0.30	0.04	0.65	9.75
	4	4	5.26	4.40	0.00	0.00	0.00	-27.94
		6	-5.26	-4.32	0.00	0.00	0.00	38.84
	101	4	29.49	2.07	-0.30	-0.04	0.11	-16.86
		6	-29.36	-2.07	0.30	0.04	0.65	22.03
	102	4	26.06	4.04	0.00	0.00	0.00	-28.31
		6	-25.96	-3.98	0.00	0.00	0.00	38.34
	103	4	17.81	3.69	0.00	0.00	0.00	-24.87
		6	-17.72	-3.63	0.00	0.00	0.00	34.01
8	1	6	13.70	6.70	0.00	0.00	0.00	19.56
		8	-13.57	-6.70	0.00	0.00	0.00	-2.80
	2	6	4.56	4.79	0.00	0.00	0.00	13.93
		8	-4.56	-4.79	0.00	0.00	0.00	-1.96
	3	6	0.00	-1.70	0.75	-0.02	-0.65	-8.66
		8	0.00	1.70	-0.75	0.02	-1.24	4.40
	4	6	2.52	3.71	0.00	0.00	0.00	-4.60
		8	-2.52	-3.64	0.00	0.00	0.00	13.79
	101	6	18.27	9.79	0.75	-0.02	-0.65	24.83
		8	-18.14	-9.79	-0.75	0.02	-1.24	-0.36
	102	6	15.59	11.40	0.00	0.00	0.00	21.67
		8	-15.49	-11.35	0.00	0.00	0.00	6.77
	103	6	11.21	7.34	0.00	0.00	0.00	9.85
		8	-11.12	-7.29	0.00	0.00	0.00	8.44
9	1	8	12.91	6.70	0.00	0.00	0.00	2.80
		10	-12.78	-6.70	0.00	0.00	0.00	13.96
	2	8	4.56	4.79	0.00	0.00	0.00	1.96
		10	-4.56	-4.79	0.00	0.00	0.00	10.01
	3	8	0.00	-1.70	-0.87	-0.02	1.24	-4.40
		10	0.00	1.70	0.87	0.02	0.93	0.14
	4	8	2.52	2.98	0.00	0.00	0.00	-13.79
		10	-2.52	-2.90	0.00	0.00	0.00	21.14
	101	8	17.48	9.79	-0.87	-0.02	1.24	0.36
		10	-17.34	-9.79	0.87	0.02	0.93	24.11

- PIPERACK DESIGN - EXAMPLE 1 - DESIGN GUIDELINES BEST P -- PAGE NO. 10

MEMBER END FORCES STRUCTURE TYPE = SPACE

ALL UNITS ARE -- KIP FEET

MEMBER	LOAD	JT	AXIAL	SHEAR-Y	SHEAR-Z	TORSION	MOM-Y	MOM-Z
	102	8	15.00	10.85	0.00	0.00	0.00	-6.77
		10	-14.90	-10.80	0.00	0.00	0.00	33.83
	103	8	10.67	6.79	0.00	0.00	0.00	-8.44
		10	-10.58	-6.74	0.00	0.00	0.00	25.35
10	1	10	6.37	6.90	0.00	0.00	0.00	12.63
		12	-6.11	-6.90	0.00	0.00	0.00	21.89
	2	10	0.06	2.05	0.00	0.00	0.00	9.45
		12	-0.06	-2.05	0.00	0.00	0.00	0.83
	3	10	0.00	-0.04	0.19	0.18	-0.93	-0.18
		12	0.00	0.04	-0.19	-0.18	0.00	-0.03
	4	10	0.80	2.14	0.00	0.00	0.00	0.27
		12	-0.80	-1.99	0.00	0.00	0.00	10.03
	101	10	6.43	8.91	0.19	0.18	-0.93	21.89
		12	-6.17	-8.91	-0.19	-0.18	0.00	22.68
	102	10	5.43	8.32	0.00	0.00	0.00	16.76
		12	-5.23	-8.21	0.00	0.00	0.00	24.56
	103	10	4.94	6.30	0.00	0.00	0.00	8.79
		12	-4.76	-6.18	0.00	0.00	0.00	22.41
11	1	5	-6.13	7.47	0.00	0.00	0.00	27.54
		6	6.13	6.56	0.00	0.00	0.00	-26.73
	2	5	-4.37	5.40	0.00	0.00	0.00	19.18
		6	4.37	4.53	0.00	0.00	0.00	-19.04
	3	5	2.78	0.00	-1.23	0.00	0.03	1.09
		6	-2.78	0.00	-1.06	0.00	-0.03	-1.09
	4	5	0.61	-2.74	0.00	0.00	0.00	-34.26
		6	-0.61	2.74	0.00	0.00	0.00	-34.25
	101	5	-7.72	12.86	-1.23	0.00	0.03	47.81
		6	7.72	11.09	-1.06	0.00	-0.03	-46.86
	102	5	-7.42	7.59	0.00	0.00	0.00	9.35
		6	7.42	10.37	0.00	0.00	0.00	-60.01
	103	5	-3.72	3.02	0.00	0.00	0.00	-6.97
		6	3.72	6.52	0.00	0.00	0.00	-43.86
12	1	9	-0.20	7.69	0.00	0.00	0.00	27.51
		10	0.20	6.41	0.00	0.00	0.00	-26.59
	2	9	2.73	6.91	0.00	0.00	0.00	21.77
		10	-2.73	4.51	0.00	0.00	0.00	-19.46
	3	9	-1.66	0.00	-1.40	0.00	0.21	-0.04
		10	1.66	0.00	-1.05	0.00	-0.19	0.04
	4	9	0.77	-1.71	0.00	0.00	0.00	-21.45
		10	-0.77	1.71	0.00	0.00	0.00	-21.41
	101	9	0.87	14.59	-1.40	0.00	0.21	49.24
		10	-0.87	10.91	-1.05	0.00	-0.19	-46.00

```
 - PIPERACK DESIGN - EXAMPLE 1 - DESIGN GUIDELINES BEST P -- PAGE NO.   11


 MEMBER END FORCES    STRUCTURE TYPE = SPACE
 -----------------
 ALL UNITS ARE -- KIP  FEET

MEMBER  LOAD  JT     AXIAL   SHEAR-Y  SHEAR-Z   TORSION     MOM-Y      MOM-Z

       102     9      2.47      9.66     0.00      0.00      0.00      20.87
              10     -2.47      9.47     0.00      0.00      0.00     -50.59
       103     9      0.44      3.94     0.00      0.00      0.00       2.62
              10     -0.44      5.64     0.00      0.00      0.00     -34.14

  13     1    11      6.90      5.38     0.00      0.00      0.00      20.97
              12     -6.90      5.45     0.00      0.00      0.00     -21.89
         2    11      2.05     -0.06     0.00      0.00      0.00      -0.60
              12     -2.05      0.06     0.00      0.00      0.00      -0.83
         3    11     -0.04      0.00     0.00      0.00     -0.19      -0.03
              12      0.04      0.00     0.00      0.00      0.18       0.03
         4    11      1.33     -0.80     0.00      0.00      0.00     -10.07
              12     -1.33      0.80     0.00      0.00      0.00     -10.03
       101    11      8.91      5.32     0.00      0.00     -0.19      20.34
              12     -8.91      5.51     0.00      0.00      0.18     -22.68
       102    11      7.71      3.39     0.00      0.00      0.00       7.72
              12     -7.71      4.73     0.00      0.00      0.00     -24.56
       103    11      5.69      3.05     0.00      0.00      0.00       6.71
              12     -5.69      4.31     0.00      0.00      0.00     -22.41


 ************** END OF LATEST ANALYSIS RESULT **************


  69. LOAD LIST 101 TO 103
  70. PARAMETER
  71. CODE AISC
  72. BEAM 1 ALL
  73. NSF 0.85 ALL
  74. TRACK 1 ALL
  75. RATIO 1 ALL
  76. *DEFINE COLUMNS
  77. LZ 20 MEMB 1 2 6 7
  78. LZ 5 MEMB 3 4 8 9
  79. LZ 5 MEMB 5 10
  80. KZ 1.9 MEMB 1 2 6 7
  81. KZ 3.5 MEMB 3 4 8 9
  82. KZ 3.8 MEMB 5 10
  83. LY 17.5 MEMB 1 6
  84. LY 5 MEMB 2 3 7 8
  85. LY 7.5 MEMB 4 5 9 10
  86. CHECK CODE ALL
```

```
   - PIPERACK DESIGN - EXAMPLE 1 - DESIGN GUIDELINES BEST P -- PAGE NO.  12


                        STAAD.Pro CODE CHECKING - (AISC)
                        ***********************

 ALL UNITS ARE - KIP  FEET (UNLESS OTHERWISE NOTED)

 MEMBER     TABLE       RESULT/   CRITICAL COND/     RATIO/     LOADING/
                          FX            MY             MZ       LOCATION
 =======================================================================


      1  ST   W14 X53      PASS     AISC- H1-3         0.446       102
                        23.31 C         0.00          44.68        0.00

  -----------------------------------------------------------------------
 | MEM=     1, UNIT KIP-INCH,  L= 210.0  AX= 15.60  SZ=  77.7  SY=  14.3 |
 | KL/R-Y= 109.2  CB=  1.00  YLD= 36.00  ALLOWABLE STRESSES:  FCZ= 21.60 |
 | FTZ= 21.60  FCY= 27.00  FTY= 27.00  FA= 11.78  FT= 21.60  FV= 14.40   |
  -----------------------------------------------------------------------

      2  ST   W14 X53      PASS     AISC- H1-3         0.318       101
                        34.62 C        -0.69          23.87        2.50

  -----------------------------------------------------------------------
 | MEM=     2, UNIT KIP-INCH,  L=  30.0  AX= 15.60  SZ=  77.7  SY=  14.3 |
 | KL/R-Z=  77.4  CB=  1.00  YLD= 36.00  ALLOWABLE STRESSES:  FCZ= 23.76 |
 | FTZ= 23.76  FCY= 27.00  FTY= 27.00  FA= 15.64  FT= 21.60  FV= 14.40   |
  -----------------------------------------------------------------------

      3  ST   W14 X53      PASS     AISC- H1-3         0.248       101
                        21.76 C        -0.69         -23.95        0.00

  -----------------------------------------------------------------------
 | MEM=     3, UNIT KIP-INCH,  L=  30.0  AX= 15.60  SZ=  77.7  SY=  14.3 |
 | KL/R-Z=  35.7  CB=  1.00  YLD= 36.00  ALLOWABLE STRESSES:  FCZ= 23.76 |
 | FTZ= 23.76  FCY= 27.00  FTY= 27.00  FA= 19.52  FT= 21.60  FV= 14.40   |
  -----------------------------------------------------------------------
```

```
   - PIPERACK DESIGN - EXAMPLE 1 - DESIGN GUIDELINES BEST P -- PAGE NO.  13


 ALL UNITS ARE - KIP  FEET (UNLESS OTHERWISE NOTED)

 MEMBER     TABLE       RESULT/   CRITICAL COND/     RATIO/     LOADING/
                          FX            MY             MZ       LOCATION
 =======================================================================

      4  ST   W14 X53      PASS     AISC- H1-3         0.274       101
                        20.84 C        -1.27         25.00        2.50

  -----------------------------------------------------------------------
 | MEM=     4, UNIT KIP-INCH,  L=  30.0  AX= 15.60  SZ=  77.7  SY=  14.3 |
 | KL/R-Y=  46.8  CB=  1.00  YLD= 36.00  ALLOWABLE STRESSES:  FCZ= 23.76 |
 | FTZ= 23.76  FCY= 27.00  FTY= 27.00  FA= 18.63  FT= 21.60  FV= 14.40   |
  -----------------------------------------------------------------------

      5  ST   W14 X53      PASS     AISC- H1-3         0.218       101
                         6.24 C        -1.27        -24.24        0.00

  -----------------------------------------------------------------------
 | MEM=     5, UNIT KIP-INCH,  L=  60.0  AX= 15.60  SZ=  77.7  SY=  14.3 |
 | KL/R-Y=  46.8  CB=  1.00  YLD= 36.00  ALLOWABLE STRESSES:  FCZ= 23.76 |
 | FTZ= 23.76  FCY= 27.00  FTY= 27.00  FA= 18.63  FT= 21.60  FV= 14.40   |
  -----------------------------------------------------------------------

      6  ST   W14 X53      PASS     AISC- H1-3         0.538       102
                        27.25 C         0.00         54.55        0.00

  -----------------------------------------------------------------------
 | MEM=     6, UNIT KIP-INCH,  L= 210.0  AX= 15.60  SZ=  77.7  SY=  14.3 |
 | KL/R-Y= 109.2  CB=  1.00  YLD= 36.00  ALLOWABLE STRESSES:  FCZ= 21.60 |
 | FTZ= 21.60  FCY= 27.00  FTY= 27.00  FA= 11.78  FT= 21.60  FV= 14.40   |
  -----------------------------------------------------------------------

      7  ST   W14 X53      PASS     AISC- H1-3         0.356       102
                        25.96 C         0.00        -38.34        2.50
```

```
   - PIPERACK DESIGN - EXAMPLE 1 - DESIGN GUIDELINES BEST P -- PAGE NO.  14


 ALL UNITS ARE - KIP  FEET (UNLESS OTHERWISE NOTED)

 MEMBER     TABLE       RESULT/   CRITICAL COND/     RATIO/     LOADING/
                          FX            MY              MZ      LOCATION
 =======================================================================



  -----------------------------------------------------------------------
 | MEM=     7, UNIT KIP-INCH,  L=  30.0  AX= 15.60  SZ=  77.7  SY=  14.3 |
 | KL/R-Z=  77.4  CB=  1.00  YLD= 36.00  ALLOWABLE STRESSES:  FCZ= 23.76 |
 | FTZ= 23.76  FCY= 27.00  FTY= 27.00  FA= 15.64  FT= 21.60  FV= 14.40   |
  -----------------------------------------------------------------------

      8  ST   W14 X53      PASS     AISC- H1-3         0.241       101
                        18.27 C        -0.65         24.83       0.00

  -----------------------------------------------------------------------
 | MEM=     8, UNIT KIP-INCH,  L=  30.0  AX= 15.60  SZ=  77.7  SY=  14.3 |
 | KL/R-Z=  35.7  CB=  1.00  YLD= 36.00  ALLOWABLE STRESSES:  FCZ= 23.76 |
 | FTZ= 23.76  FCY= 27.00  FTY= 27.00  FA= 19.52  FT= 21.60  FV= 14.40   |
  -----------------------------------------------------------------------

      9  ST   W14 X53      PASS     AISC- H1-3         0.271       102
                        14.90 C         0.00        -33.83       2.50

  -----------------------------------------------------------------------
 | MEM=     9, UNIT KIP-INCH,  L=  30.0  AX= 15.60  SZ=  77.7  SY=  14.3 |
 | KL/R-Y=  46.8  CB=  1.00  YLD= 36.00  ALLOWABLE STRESSES:  FCZ= 23.76 |
 | FTZ= 23.76  FCY= 27.00  FTY= 27.00  FA= 18.63  FT= 21.60  FV= 14.40   |
  -----------------------------------------------------------------------

     10  ST   W14 X53      PASS     AISC- H1-3         0.193       101
                         6.43 C        -0.93         21.89       0.00
```

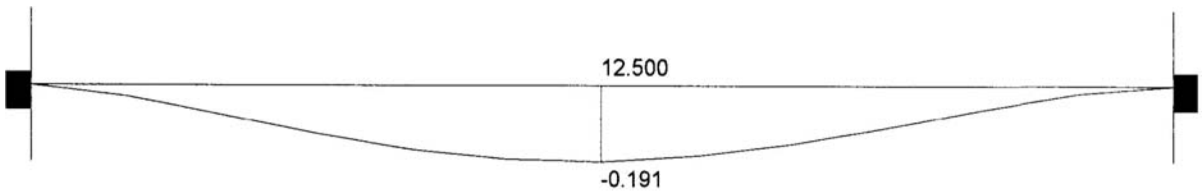
```
   - PIPERACK DESIGN - EXAMPLE 1 - DESIGN GUIDELINES BEST P -- PAGE NO.  15


 ALL UNITS ARE - KIP  FEET (UNLESS OTHERWISE NOTED)

 MEMBER     TABLE       RESULT/   CRITICAL COND/     RATIO/     LOADING/
                          FX            MY             MZ       LOCATION
 =======================================================================



  -----------------------------------------------------------------------
 | MEM=    10, UNIT KIP-INCH,  L=  60.0  AX= 15.60  SZ=  77.7  SY=  14.3 |
 | KL/R-Y=  46.8  CB=  1.00  YLD= 36.00  ALLOWABLE STRESSES:  FCZ= 23.76 |
 | FTZ= 23.76  FCY= 27.00  FTY= 27.00  FA= 18.63  FT= 21.60  FV= 14.40   |
  -----------------------------------------------------------------------

    11  ST   W12 X45      PASS     AISC- H2-1         0.809       102
                        7.42 T         0.00          60.01      25.00

  -----------------------------------------------------------------------
 | MEM=    11, UNIT KIP-INCH,  L= 300.0  AX= 13.20  SZ=  58.0  SY=  12.4 |
 | KL/R-Y= 154.1  CB=  1.00  YLD= 36.00  ALLOWABLE STRESSES:  FCZ= 15.34 |
 | FTZ= 21.60  FCY= 27.00  FTY= 27.00  FA=  6.28  FT= 21.60  FV= 14.40   |
  -----------------------------------------------------------------------

    12  ST   W12 X40      PASS     AISC- H1-3         0.880       102
                        2.47 C         0.00          50.59      25.00

  -----------------------------------------------------------------------
 | MEM=    12, UNIT KIP-INCH,  L= 300.0  AX= 11.80  SZ=  51.9  SY=  11.0 |
 | KL/R-Y= 155.2  CB=  1.00  YLD= 36.00  ALLOWABLE STRESSES:  FCZ= 13.81 |
 | FTZ= 21.60  FCY= 27.00  FTY= 27.00  FA=  6.20  FT= 21.60  FV= 14.40   |
  -----------------------------------------------------------------------

    13  ST   W10 X33      PASS     AISC- H1-3         0.720       102
                        7.71 C         0.00          24.56      25.00
```

```
   - PIPERACK DESIGN - EXAMPLE 1 - DESIGN GUIDELINES BEST P -- PAGE NO.  16


 ALL UNITS ARE - KIP  FEET (UNLESS OTHERWISE NOTED)

 MEMBER     TABLE       RESULT/   CRITICAL COND/     RATIO/     LOADING/
                          FX            MY             MZ       LOCATION
 =======================================================================


  -----------------------------------------------------------------------
 | MEM=    13, UNIT KIP-INCH,  L= 300.0  AX=  9.71  SZ=  34.9  SY=   9.2 |
 | KL/R-Y= 154.5  CB=  1.00  YLD= 36.00  ALLOWABLE STRESSES:  FCZ= 14.23 |
 | FTZ= 21.60  FCY= 27.00  FTY= 27.00  FA=  6.25  FT= 21.60  FV= 14.40   |
  -----------------------------------------------------------------------

   87. LOAD LIST ALL
   88. FINISH

            *************** END OF STAAD.Pro ***************

              **** DATE= JUL  1,2002   TIME=  9:55:30 ****

        *********************************************************
        *     For questions on STAAD.Pro, please contact :      *
        *    Research Engineers by email : support@reiusa.com   *
        *  US West Coast: Ph-(714) 974-2500, Fax-(714) 974-4771 *
        *  US East Coast: Ph-(781) 890-7677  Fax-(781) 895-1117 *
        *********************************************************
```

Staad.Pro Query Deflection Result

Beam no. 11

Deflection in Local Y axis. Load case 101.



Dist□ft	Y(in)	Z(in)
0.000000	0.0000	0.0000
2.083333	-0.0291	0.1475
4.166667	-0.0753	0.2830
6.250000	-0.1231	0.3960
8.333333	-0.1618	0.4796
10.416667	-0.1856	0.5299
12.500000	-0.1910	0.5448
14.583333	-0.1777	0.5240
16.666667	-0.1478	0.4690
18.750000	-0.1061	0.3831
20.833333	-0.0603	0.2714
22.916667	-0.0206	0.1408
25.000000	0.0000	0.0000

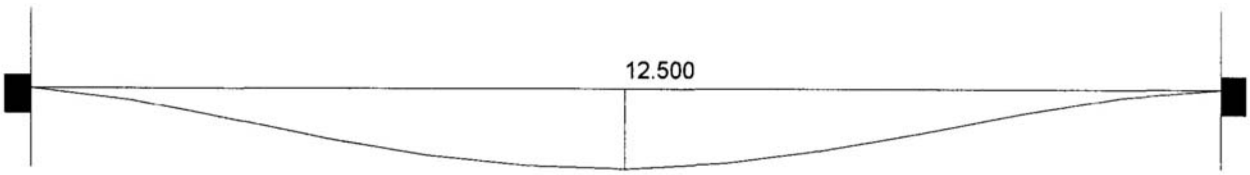
Allowable Beam Deflection:

$$\Delta_{max} = \frac{L}{240} = \frac{25 \times 12}{240} = 1.25 \text{ inch} > 0.191 \quad \text{o.k.}$$

Staad.Pro Query Deflection Result

Beam no. 12

Deflection in Local Y axis. Load case 101.



Dist□ft	Y(in)	Z(in)
0.000000	0.0000	0.0000
2.083333	-0.0317	0.1636
4.166667	-0.0811	0.3126
6.250000	-0.1317	0.4361
8.333333	-0.1734	0.5276
10.416667	-0.1993	0.5826
12.500000	-0.2057	0.5986
14.583333	-0.1917	0.5754
16.666667	-0.1594	0.5146
18.750000	-0.1143	0.4199
20.833333	-0.0646	0.2970
22.916667	-0.0217	0.1538
25.000000	0.0000	0.0000

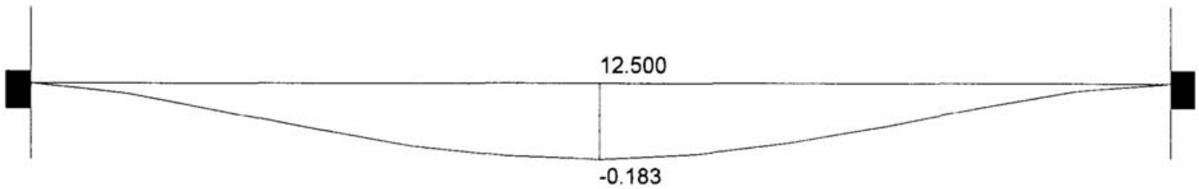
Allowable Beam Deflection:

$$\Delta_{max} = \frac{L}{240} = \frac{25 \times 12}{240} = 1.25 \text{ inch} > 0.206 \quad \text{o.k.}$$

Staad.Pro Query Deflection Result

Beam no. 13

Deflection in Local Y axis. Load case 101.



Dist□ft	Y(in)	Z(in)
0.000000	0.0000	0.0000
2.083333	-0.0259	0.0072
4.166667	-0.0675	0.0131
6.250000	-0.1123	0.0176
8.333333	-0.1505	0.0208
10.416667	-0.1754	0.0227
12.500000	-0.1829	0.0233
14.583333	-0.1719	0.0227
16.666667	-0.1442	0.0207
18.750000	-0.1042	0.0174
20.833333	-0.0595	0.0129
22.916667	-0.0204	0.0071
25.000000	0.0000	0.0000

Allowable Beam Deflection:

$$\Delta_{max} = \frac{L}{240} = \frac{25 \times 12}{240} = 1.25 \text{ inch} > 0.183 \quad \text{o.k.}$$

Attachment 3

Weights of Standard (STD) and Extra Strong (XS) Pipes

Table 1 – *Weight of Standard (Std) Pipes

Nomial Pipe Size Inches	SCH. No. API	Wall Thickness Inches	Weight Pipe Pound per ft	Weight Water Pound per ft	Weight Total Pound per ft	Outside Diam. Inches
0.5	40	0.109	0.85	0.13	0.98	0.840
1	40	0.133	1.68	0.38	2.06	1.315
1.5	40	0.145	2.72	0.88	3.60	1.900
2	40	0.154	3.65	1.45	5.10	2.375
2.5	40	0.203	5.79	2.07	7.86	2.875
3	40	0.216	7.58	3.20	10.78	3.500
3.5	40	0.226	9.11	4.29	13.40	4.000
4	40	0.237	10.79	5.50	16.29	4.500
5	40	0.258	14.62	8.67	23.29	5.563
6	40	0.280	18.97	12.51	31.48	6.625
8	40	0.322	28.55	21.70	50.25	8.625
10	40	0.365	40.48	34.20	74.68	10.750
12	40	0.406	53.52	48.50	102.02	12.750
14	40	0.438	63.44	58.64	122.08	14.000
16	40	0.375	62.58	79.12	141.70	16.000
18	30	0.438	82.15	99.84	181.99	18.000
20	20	0.375	78.60	125.67	204.27	20.000
22	20	0.375	86.61	153.68	240.29	22.000
24	20	0.375	94.62	183.95	278.57	24.000
26		0.375	102.63	216.99	319.62	26.000
28		0.375	110.64	252.73	363.37	28.000
30		0.375	118.65	291.18	409.83	30.000
32		0.375	126.66	332.36	459.02	32.000
34		0.375	134.67	376.27	510.94	34.000
36		0.375	142.68	422.89	565.57	36.000
42		0.375	167.00	579.30	746.30	42.000

***Shaded area are the most common pipes used. However, weights of actual pipe should be used based on piping drawings.**

Table 1A – *Weight of Heavy (Extra Strong - XS) Pipes

Nomial Pipe Size Inches	SCH. No. API	Wall Thickness Inches	Weight Pipe Pound per ft	Weight Water Pound per ft	Weight Total Pound per ft	Outside Diam. Inches
0.5	80	0.147	1.09	0.10	1.19	0.840
1	80	0.179	2.17	0.31	2.48	1.315
1.5	80	0.200	3.63	0.77	4.40	1.900
2	80	0.218	5.02	1.28	6.30	2.375
					0.00	
2.5	80	0.276	7.66	1.87	9.53	2.875
3	80	0.300	10.25	2.86	13.11	3.500
3.5	80	0.318	12.50	3.84	16.34	4.000
4	80	0.337	14.98	4.98	19.96	4.500
5	80	0.375	20.78	7.88	28.66	5.563
6	80	0.432	28.57	11.29	39.86	6.625
8	80	0.500	43.39	19.78	63.17	8.625
10	80	0.594	64.43	31.13	95.56	10.750
12	80	0.688	88.63	44.04	132.67	12.750
14	80	0.750	106.13	53.18	159.31	14.000
16	80	0.844	136.61	69.73	206.34	16.000
18	80	0.938	170.92	88.50	259.42	18.000
20	40	0.594	123.11	120.46	243.57	20.000
22	30	0.500	114.81	150.09	264.90	22.000
24	40	0.688	171.29	174.23	345.52	24.000
26	20	0.500	136.17	212.71	348.88	26.000
28	20	0.500	146.85	252.73	399.58	28.000
30	20	0.500	157.53	291.18	448.71	30.000
32	20	0.500	168.21	327.06	495.27	32.000
34	20	0.500	178.89	370.63	549.52	34.000
36	20	0.500	189.68	416.91	606.59	36.000
42		0.500	222.00	572.30	794.30	42.000

***Shaded area are the most common pipes used. However, weights of actual pipe should be used based on piping drawings.**