MUSTANG ENGINEERS
& CONSTRUCTORS, L.P.

ENGINEERING GUIDELINE

GROUP:	CIVIL/STRUCTURAL ENGINEERING	**GUIDE NO.:**	EG-١٩٠٥
SUBJECT:	Pipe Supports Design	**ISSUE DATE:**	١٣ SEP ٠٦
RESPONSIBLE ENGINEER:	D. Mueller	**Approved:**	١٠DEC٩٩

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I. General

This guide presents a general approach for the analysis and design of pipe supports, including main racks, miscellaneous and “T” supports.

II. Design Loads

A. Vertical Loads

١. Piping

a. Main Rack – Vertical loads due to piping shall be the average unit loading at each level as determined from the piping layout drawings, but not less than ٣٥ psf (٢٢ psf dead load and ١٣ psf live load) per level.

b. Miscellaneous Racks and “T” Supports - Vertical loads due to piping shall be the average unit loading at each level as determined from the piping layout drawings, but not less than ٢٥ psf (١٦ psf dead load and ٩ psf live load) per level.

c. Pipes ١٤ inches and larger in diameter shall be considered as a concentrated load.

٢. Electrical

Use a minimum of ٢٠ psf (dead load) (for the width of the tray or area width of conduits) per level for conduits and single level cable trays. Use a minimum of ٤٠ psf for double level cable trays.

٣. Equipment

Loads should be obtained from vendor drawings for all equipment, such as air coolers with associated walkways and platforms.

٤. Live

Apply per the job specifications to all walkways, platforms, stairs, and ladders. A ٥٠ % reduction in live load is allowed when in combination with full wind or seismic. This reduction does not apply to piping live load (fluid load) or snow loads. Snow loading shall be included on platforms, cable trays, and equipment where applicable.

٥. Hydrotest

Combine the hydrotest load of vapor lines with dead load only from the other piping lines.

٦. Structure

Include the weight of all structural members, stairs, platforms and fireproofing in design.

B. Horizontal Loads

١. Wind

Apply wind loads to the structure, piping and equipment per *EG*-١٩٠١. Use ٨ in. diameter piping, minimum, if sizes are not known.

٢. Seismic

Calculate seismic loads to the structure, piping and equipment per *EG*-١٩٠٢. Use critical wind or seismic loads in design.

٣. Friction

Use a longitudinal friction force equal to ١٠ % of the applied piping vertical load at each support level.

٤. Anchor and Guide

Anchor and guide forces, provided by the pipe stress group, may require horizontal bracing in the affected bay and may control the placement of vertical bracing.

C. Load Combinations

١. Design pipe supports to accommodate the following load combinations:

a. Dead + Live

b. Dead + Wind (or Seismic)

c. Dead + Live + Wind (or Seismic)

d. Dead + Live + Friction (or Anchor and Guide)

e. Dead + Live + Anchor and Guide + Wind (or Seismic)

III. Structural Design

A. Design pipe racks as rigid frames in the transverse direction, with fixed bases. Struts transfer longitudinal loads to braced bays.

B. Use computer program such as Staad-Pro to perform a rigid frame analysis. (See example for typical input file.)

C. Make no allowance for future support levels unless specifically called for by the job scope. Apply minimum loads on empty areas of partially loaded supports per section II of this guide to account for future pipe loading.

D. Satisfy the applicable seismic requirements also, when other loads control design.

E. Limit lateral deflection of piperack bent to L/١٠٠

F. Limit lateral deflection at anchor points to ½ inch under anchor load only. Use ٥٠% of the moment of inertia of the beam when the anchor load is along the weak axis of the beam.

G. Following are some of the necessary parameters required for individual member design. Only those criteria, which are peculiar to pipe supports or have been known to cause confusion in their selection, are listed.

١. Columns

a. Strong direction (i.e. weak axis) oriented perpendicular to piping.

b. Effective Length Factor "K" :

TYPE OF SUPPORT	X-X (STRONG)	Y-Y (WEAK)
Piperack with struts And vertical bracing	١.٢*	١.٠
Single frame	١.٢*	١.٦**
"T" Support	٢.١	١.٨**

* For more accurate value use alignment charts, ASD ٩th Ed., pp ٥-١٣٧, Fig. C-C٢.٢
** Assumes partial restraint/support from piping

٢. Transverse Beams

a. Reduce weak axis section modulus by ٥٠ % when designing for Friction loads.

b. For calculating allowable strong axis bending (consider that the moment curve inflection points may be considered as locations of lateral support for the compression flange, use ½ span as the unbraced length. Otherwise, consider the whole span to be laterally unbraced.

c. Maintain as much uniformity as is reasonable in member selection and moment connection details.

٣. Longitudinal Struts

a. Design the strut beam for the larger of :

١. Actual loading from pipe.

٢. Pipe rack loadings as given in section II.A.١, multiplied by ½ of the piperack width. (ex. ٣٥ psf x ٠.٥ x ٢٠ ft for a ٢٠ ft wide rack).

b. Design all longitudinal struts to carry applied axial forces.

c. Strut load from pipe (dead + live) is not normally input into frame analysis of bent, but lead engineer may want to consider inputting ١ level on a multilevel strut rack.

d. To isolate a portion of the rack from existing structure or another rack, slot connections at strut ends

e. Use ٢/٣ of length for unbraced length when considering vertical beam load and/or axial load.

٤. Vertical Bracing (Longitudinal)

a. Bracing usually consists of WT or double angle sections in an inverted “V” (chevron bracing) configuration.

b. Locate braced bays at approximately ١٥٠ ft. intervals. Preferably provide two braced bays in each column row at every independent section of rack. But in no case should there be less than one braced bay in each column row, unless an alternate means of longitudinal support is provided.

c. Size bracing for the largest load applied by the following :

١. Accumulative force from friction.

٢. Longitudinal component of the wind acting at an angle of ٤٥° to the pipe rack.

٣. Anchor Forces.

٤. Longitudinal seismic forces.

٥. Moment Connections

a. Provide end-plate moment connections in transverse beams.

b. Consider using heavier column section in lieu of doubler plates when column web panel shear is exceeded.

c. Design beam moment connections for the full beam capacity (.٦٦Fy moment)

٦. Air Cooler Support Girders

a. Analyze as continuous beam spanning across tops of columns. Avoid lateral beams and horizontal bracing unless girder size becomes excessive.

b. Space air coolers to allow piperack column to extend above the air coolers for header pipe support.

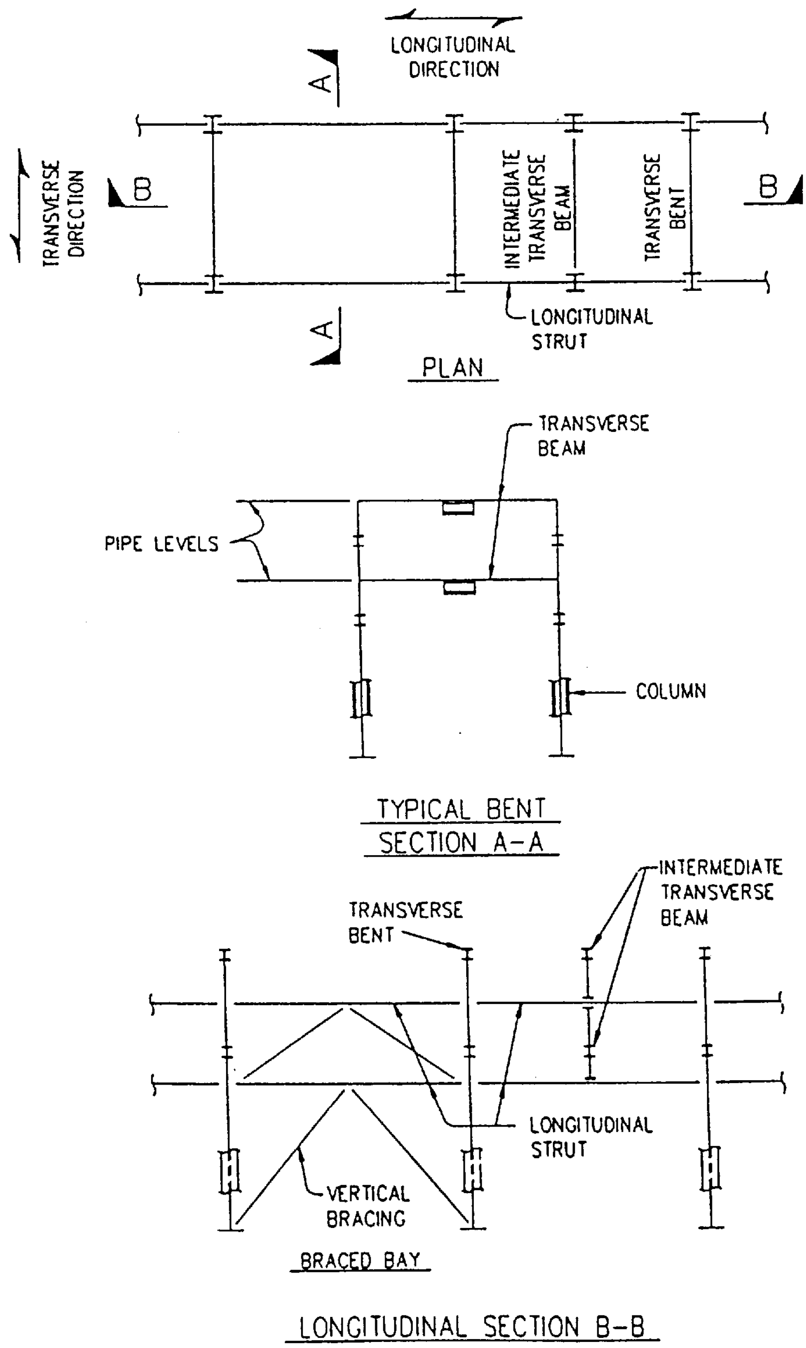
c. Use ١٤٠ psf for preliminary frame design without vendor weights. Base final design of girder on actual vendor provided weights, or use from ‘d’.

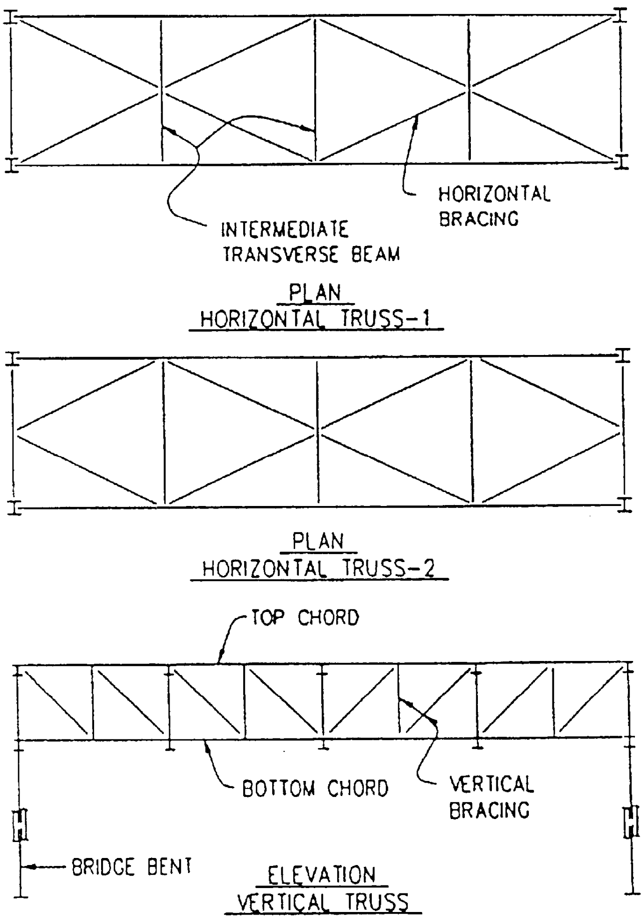
d. Typical Air Cooler Loads (For estimating only)
(Loads shown on pipe support column)

Piperack Width	٢٠’	٢٥’	٣٠’
Dead Load	٣٥ k/col	٤٢ k/col	٥٠ k/col
Live Load	٣.٥ k/col	٤ k/col	٥ k/col
Wind Load			
Traverse Shear	٥ k/col	٥.٥ k/col	٦ k/col
Wind Couple, Vertical	±٤.٥ k/col	±٤.٥ k/col	±٤.٥ k/col
Longitudinal Shear (at braced bay only)	١٨ k/bay	١٨ k/bay	١٨ k/bay

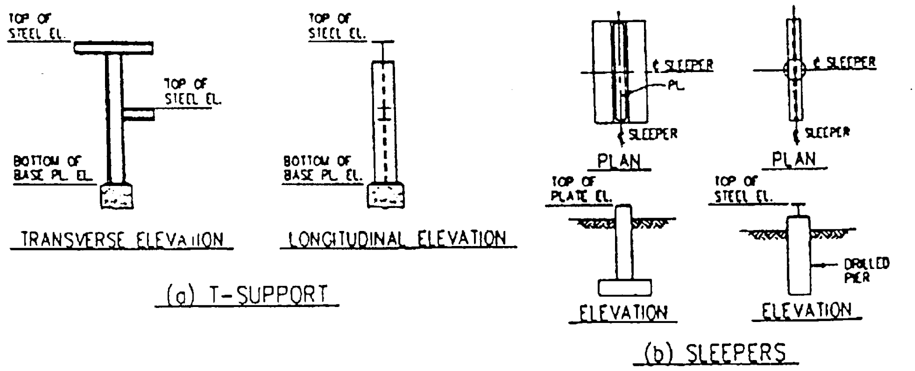
Note: Wind loads are based on a design wind speed of ١١٠ mph. For other design wind speed, V, multiply wind loads above by $V^{٢}/١١٠^{٢}$.

IV. Typical Piperack Configuration





TYPICAL PIPE BRIDGE
Figure ١



MISCELLANEOUS PIPE SUPPORTS
<u>Figure ٢</u>

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VIII. Design Example

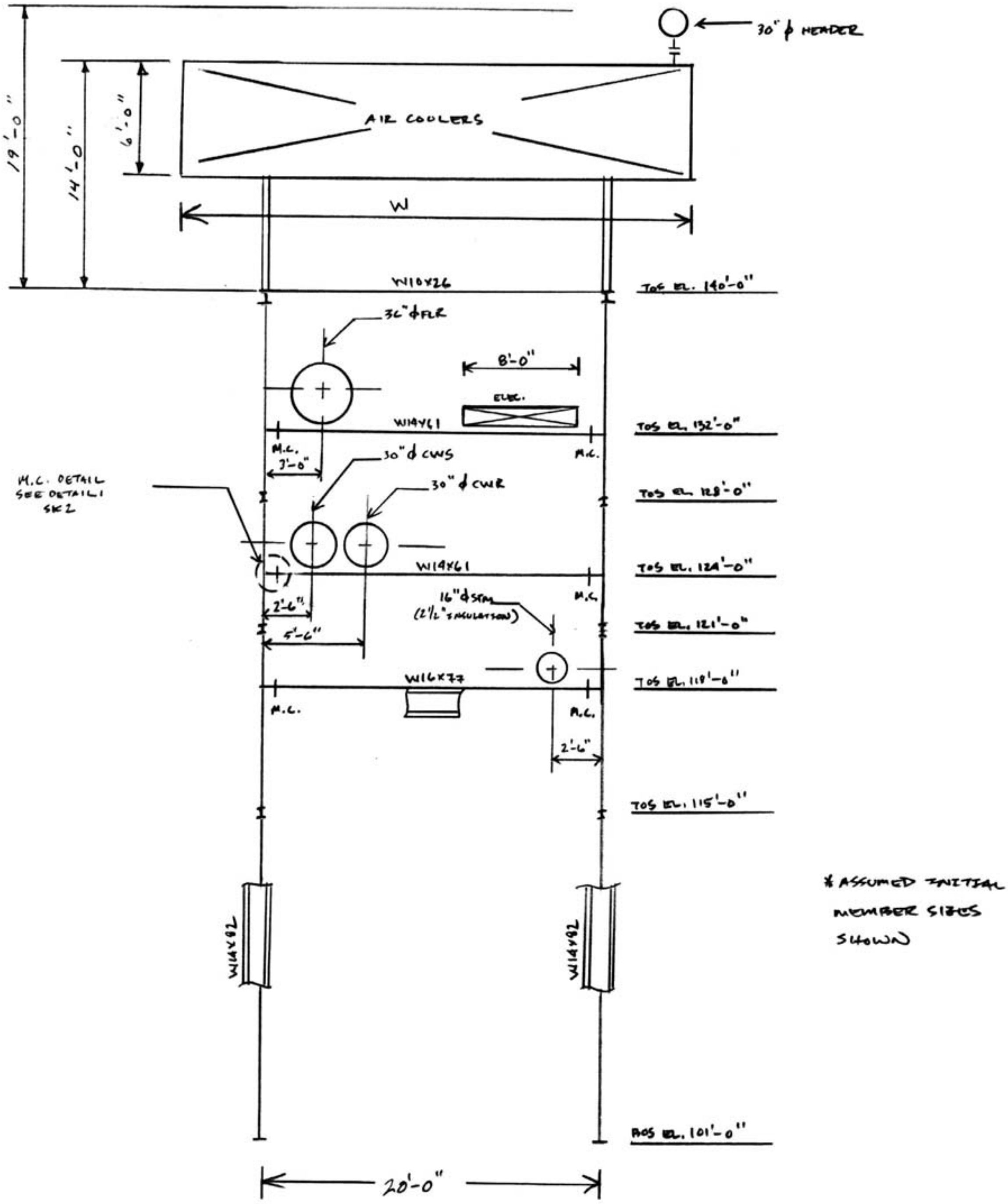


FIGURE 1

ELEVATION OF A TYPICAL BENT

LOOKING WEST

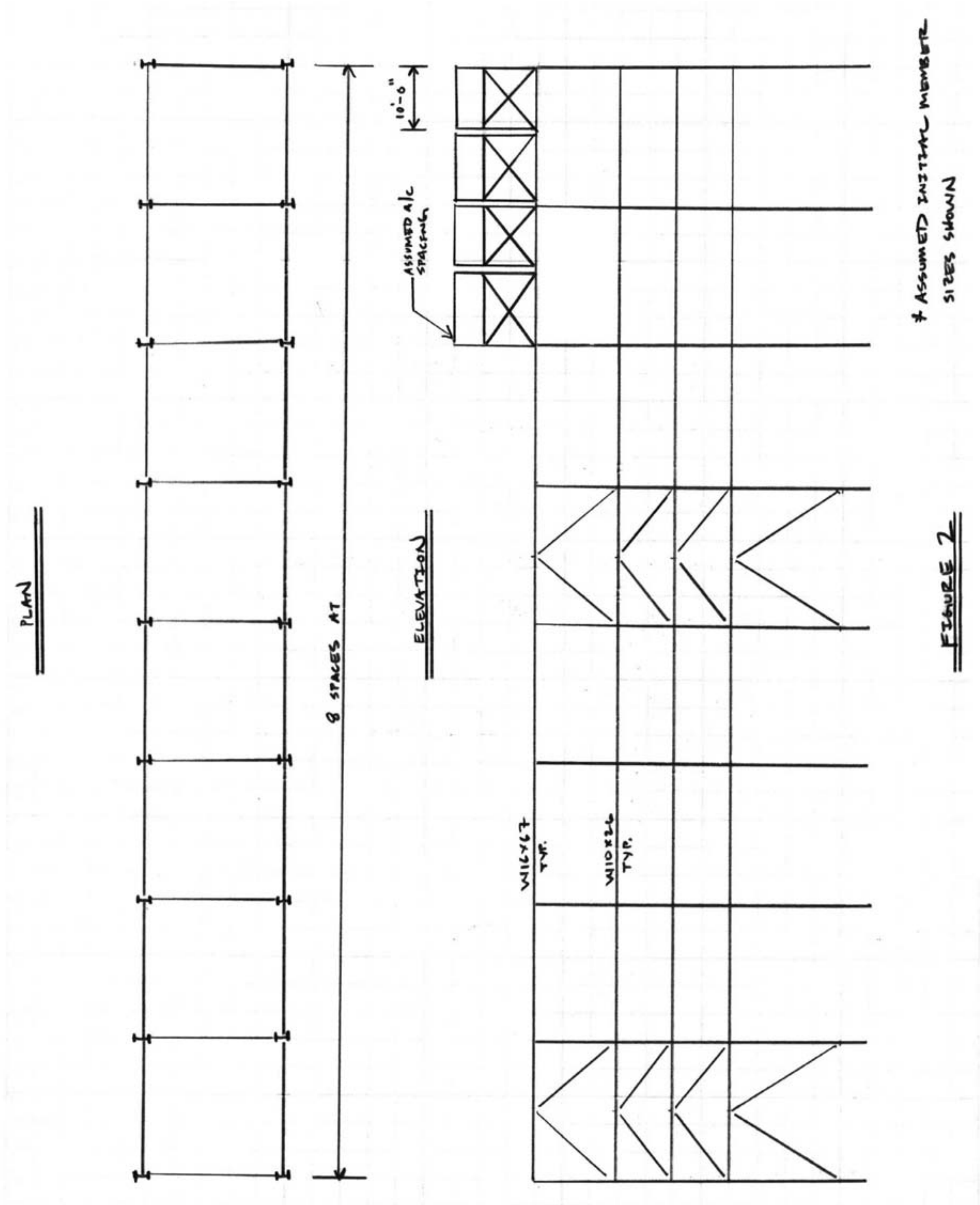
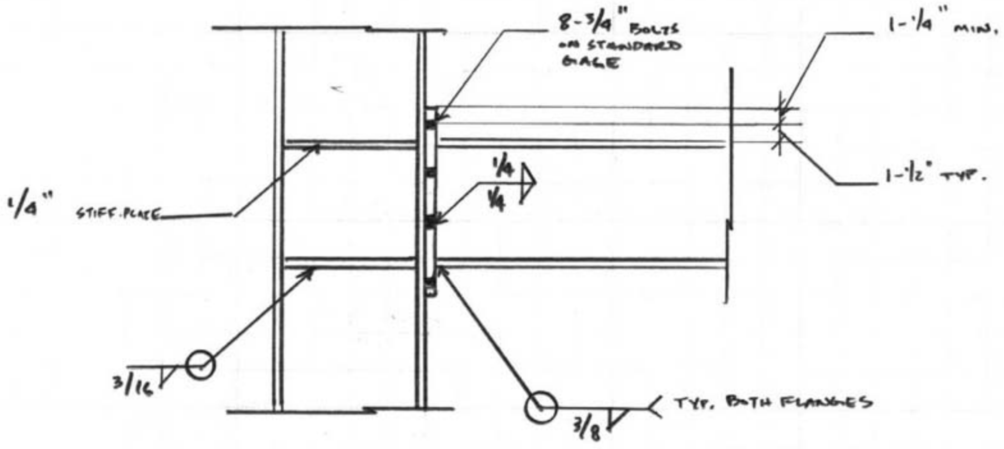

PLAN
ELEVATION
8 SPACES AT
10'-0"
ASSUMED A/C SPACING
W16X67 TYP.
W10X26 TYP.
* ASSUMED INITIAL MEMBER SIZES SHOWN

FIGURE 2


8-3/4" BOLTS ON STANDARD GAGE
1-1/4" MIN.
1-1/2" TYP.
1/4" STIFF. PLATE
1/4
1/4
3/16
3/8
TYP. BOTH FLANGES

DETAIL 1

Problem:

Design the pipe rack illustrated in figures ١ and ٢ using STAAD III. Figures ١ and ٢ show typical information available at the beginning of a job, usually provided by the Piping Department.

Given Design Criteria:

a) Wind ASCE ٧-٩٣ – ١١٠ mph, Exposure C, Importance Factor ١.٠.

b) Seismic Zone ٠

c) Air Cooler Loads (obtained from Mech/Equip. vendor drawings)

Dead Load	=	١٣٠	psf (based on plan area of rack)
Fluid Load	=	٢٠	psf (based on plan area of rack)
Live Load	=	١٠	psf (based on plan area of rack)

* Note: Actual Air Cooler loads should be used to check the final design when they become available.

d) No future expansion is considered in design.

e) All members are fireproofed except the longitudinal struts, and the top most transverse beam, which is included for platform support.

f) Engineering Guide *EG-*١٩٠٥

Load calculations for STAAD-III model:

Dead Loads

Air Coolers:

Air cooler load per column

$$= \frac{(20\,ft)^2}{2}\left(\frac{130lbs}{ft^2}\right) = 26kips$$

٣٠" Header Pipe $= \frac{118.8lbs}{ft}$ (Ref. EG-١٩٠٥ IV. Weight of Pipes)

Column load due to ٣٠" Header Pipe

$$= \frac{118.8lbs}{ft}(20\,ft) = 2.376kips$$

Structure:

Weight of each W١٠x٢٦ Longitudinal Strut on each column

$$= 20\,ft\left(\frac{26lbs}{ft}\right) = 0.52kips$$

Weight of W١٦x٦٧ A/C support beam plus fireproofing

$$= 20\,ft\left(\frac{67lbs + 251lbs}{ft}\right) = 6.8kips$$ (Ref.????)

Column fireproofing load $= \frac{244lbs}{ft} = 0.244\frac{kips}{ft}$ (Ref.????)

Traverse beam fireproofing load

W١٦x٧٧ $= \frac{252lbs}{ft} = 0.252\frac{kips}{ft}$ (Ref.????)

W١٤x٦١ $= \frac{213lbs}{ft} = 0.213\frac{kips}{ft}$ (Ref.????)

Upper level piping (Elevation ١٣٢'-٠"):

Minimum piping load on first ١٢ ft (Ref. EG-١٩٠٥, pg.٢, II.A.١.a)

$$= 20\,ft\left(\frac{22lbs}{ft^2}\right) = \frac{0.44kips}{ft}$$

Minimum load due cable tray on final ٨ ft (Ref. EG-١٩٠٥, pg.٢, II.A.٢)

$$= 20\,ft\left(\frac{20lbs}{ft^2}\right) = \frac{0.40kips}{ft}$$

Concentrated load due to ٣٦" FLR (Ref. EG-١٩٠٥ IV. Weight of Pipes)
(Ref. EG-١٩٠٥, pg.٢, II.A.١.c)

$$= \frac{142.8lbs}{ft} \times 20\,ft - \left(3\,ft \times \frac{0.44kips}{ft}\right) = 1.536kips$$

Mid level piping (Elevation ١٢٤'-٠"):

Minimum piping load

$$= 20\,ft\left(\frac{22lbs}{ft^2}\right) = \frac{0.44kips}{ft}$$

Concentrated loads due to ٣٠" CWS and ٣٠" CWR (Ref. EG-١٩٠٥ IV. Weight of Pipes)

$$= \frac{118.8lbs}{ft} \times 20\,ft - \left(2.5\,ft \times \frac{0.44kips}{ft}\right) = 1.276kips$$

Lower level piping (Elevation ١١٨'-٠")

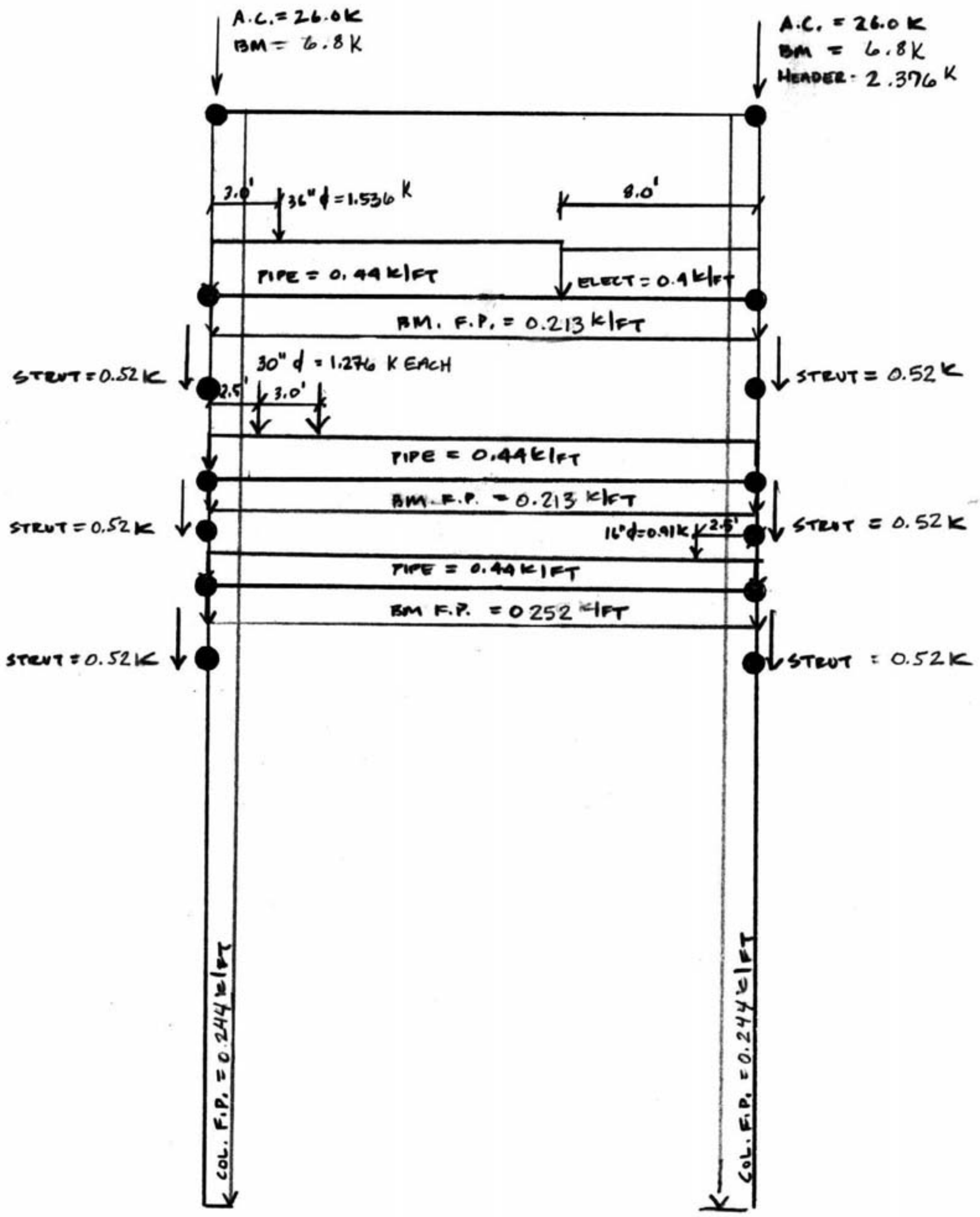
Minimum piping load

$$= 20\,ft\left(\frac{22lbs}{ft^2}\right) = \frac{0.44kips}{ft}$$

Concentrated loads due to Insulated ١٦" STM (Ref. EG-١٩٠٥ IV. Weight of Pipes)
(Ref. EG-١٩٠٥ V. Weight of Piping Insulation)

$$= \left(\frac{62.6lbs}{ft} + 1.01\,ft^2\left(12lbs/ft^3\right)\right) \times 20\,ft - \left(1.33\,ft \times \frac{440lbs}{ft}\right) = 0.909kips$$

DEAD LOAD


A.C. = 26.0K
BM = 6.8K
A.C. = 26.0K
BM = 6.8K
HEADER = 2.376K
3.0'
36" ϕ = 1.536K
8.0'
PIPE = 0.44 K/FT
ELECT = 0.4 K/FT
BM. F.P. = 0.213 K/FT
STRUT = 0.52K
30" ϕ = 1.276 K EACH
2.5'
3.0'
STRUT = 0.52K
PIPE = 0.44K/FT
BM. F.P. = 0.213 K/FT
STRUT = 0.52K
16" ϕ = 0.91K
2.5'
STRUT = 0.52K
PIPE = 0.44 K/FT
BM F.P. = 0.252 K/FT
STRUT = 0.52K
STRUT = 0.52K
COL. F.P. = 0.244 K/FT
COL. F.P. = 0.244 K/FT

Fluid Loads

Air Coolers:

Air cooler load per column

$$= \frac{(20\,ft)^2}{2}\left(\frac{20 lbs}{ft^2}\right) = 4 kips$$

٣٠" Header Pipe $= \frac{291.2 lbs}{ft}$ (Ref. EG-١٩٠٥ IV. Weight of Pipes)

Column load due to ٣٠" Header Pipe

$$= \frac{291.2 lbs}{ft}(20\,ft) = 5.824 kips$$

Upper level piping (Elevation ١٣٢'-٠"):

Minimum piping load on first ١٢ ft

$$= 20\,ft\left(\frac{13 lbs}{ft^2}\right) = \frac{0.26 kips}{ft}$$

Concentrated load due to ٣٦" FLR (Ref. EG-١٩٠٥ IV. Weight of Pipes)

$$= \frac{422.9 lbs}{ft} \times 20\,ft - \left(3\,ft \times \frac{0.26 kips}{ft}\right) = 7.678 kips$$

Mid level piping (Elevation ١٢٤'-٠"):

Minimum piping load

$$= 20\,ft\left(\frac{13 lbs}{ft^2}\right) = \frac{0.26 kips}{ft}$$

Concentrated loads due to ٣٠" CWS and ٣٠" CWR (Ref. EG-١٩٠٥ IV. Weight of Pipes)

$$= \frac{291.2 lbs}{ft} \times 20\,ft - \left(2.5\,ft \times \frac{0.26 kips}{ft}\right) = 5.174 kips$$

Lower level piping (Elevation ١١٨'-٠")

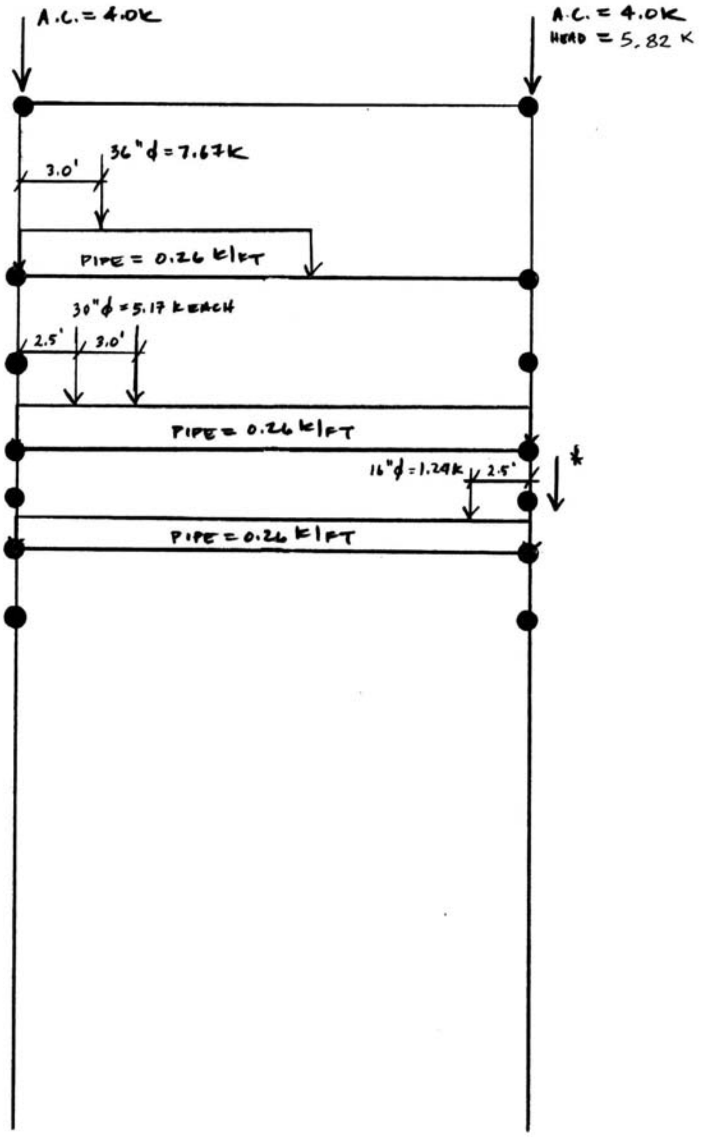
Minimum piping load

$$= 20\,ft\left(\frac{13 lbs}{ft^2}\right) = \frac{0.26 kips}{ft}$$

Concentrated loads due to Insulated ١٦" STM (Ref. EG-١٩٠٥ IV. Weight of Pipes)

$$= \frac{79.2 lbs}{ft} \times 20\,ft - \left(1.33\,ft \times \frac{0.26 kips}{ft}\right) = 1.238 kips$$

FLUID LOAD



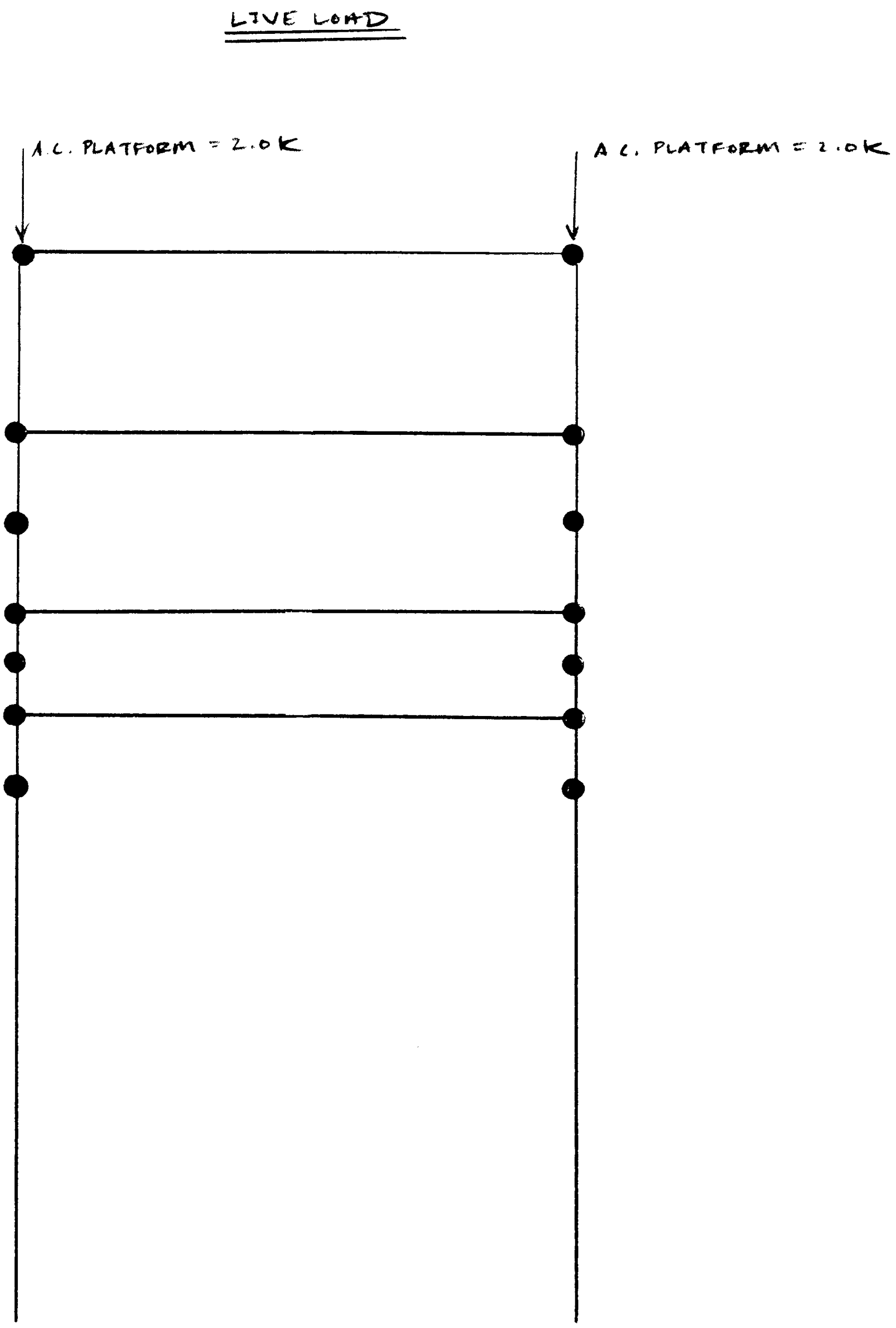
* ENGR MAY ELECT TO INPUT LIVE LOAD FROM PIPE ON STRUT.

Live Loads

Air Coolers:

Air cooler load per column

$$= \frac{(20\,ft)^2}{2}\left(\frac{10lbs}{ft^2}\right) = 2kips$$



Wind Loads
Note:

$F = A_f \times G_h \times C_f \times q$

Overall height $= 40\,ft + 19\,ft = 59\,ft$, implies $G_h = 1.20$ (Ref. EG-١٩٠١, pg.١٥, Table ١٧)

٠ *to* ٢٠ *ft* $q = \frac{26.9lbs}{ft^2}$ (Ref. EG-١٩٠١, pg.١٤, Table ٦)

٢٠ *to* ٤٠ *ft* $q = \frac{30.3lbs}{ft^2}$ (Ref. EG-١٩٠١, pg.١٤, Table ٦)

٤٠ *to* ٦٠ *ft* $q = \frac{35.0lbs}{ft^2}$ (Ref. EG-١٩٠١, pg.١٤, Table ٦)

Air Coolers:

For Wind on Equipment $C_f = 1.3$ (Ref. EG-١٩٠١, pg.٢٣, Table ١١)

Effective Height of air cooler

*h*e١ = Header Pipe Diameter = ٣٠ *in*
*h*e٢ = Actual Bundle height = ٦ *ft*
*h*e٣ = ٥٠% x Actual height of the coolers base support = ٥٠% *x* ٨ *ft* = ٤ *ft*
*H*eff = total effective height of the air cooler = *h*e١+*h*e٢+*h*e٣ = ١٢.٥ *ft*

Horizontal wind load per bent

$$F = 12.5\,ft \times 20\,ft \times 1.20 \times 1.3 \times 35lbs/ft^2 = 13.650kips$$

Value applied to the tops of each column.

$$= \frac{13.650kips}{2 \quad columns} = 6.825\frac{kips}{column}$$

Vertical wind load per column

Assume the horizontal wind force acts ٢/٣ of the effective height above the top most traverse beam.

$$= \frac{13.650kips \times (2/3)12.5\,ft}{20\,ft} = \pm 5.688kips$$

Value is positive (+) on the windward column and negative (-) on the leeward column.

Structure:

For Wind on Windward Steel $C_f = 1.8$ (Ref. EG-١٩٠١, pg.٢٣, Table ١١)
(Ref. EG-١٩٠١, pg.٢٥, Note ٣)

For Wind on Leeward Steel $C_f = 1.5$ (Ref. EG-١٩٠١, pg.٢٣, Table ١١)
(Ref. EG-١٩٠١, pg.٢٥, Note ٣)

Columns up to ٢٠ ft

Uniform load on the windward column:

$$F = \frac{(10in + 2in \times 2)\,ft}{12in} \times 1.20 \times 1.8 \times \frac{26.9lbs}{ft^2} = 0.068\frac{kips}{ft}$$

Uniform load on the leeward column:

$$F = \frac{(10in + 2in \times 2)\,ft}{12in} \times 1.20 \times 1.5 \times \frac{26.9lbs}{ft^2} = 0.056\frac{kips}{ft}$$

Columns ٢٠ ft to ٤٠ ft:

Uniform load on the windward column:

$$F = \frac{(10in + 2in \times 2)\,ft}{12in} \times 1.20 \times 1.8 \times \frac{30.3lbs}{ft^2} = 0.076\frac{kips}{ft}$$

Uniform load on the leeward column:

$$F = \frac{(10in + 2in \times 2)\,ft}{12in} \times 1.20 \times 1.5 \times \frac{30.3lbs}{ft^2} = 0.064\frac{kips}{ft}$$

Lower Strut (Elevation ١١٥'-٠"):

Concentrated load on the windward column at the strut elevation:

$$F = \frac{(10in)\,ft}{12in} \times 20\,ft \times 1.20 \times 1.8 \times \frac{26.9lbs}{ft^2} = 0.968kips$$

Concentrated load on the leeward column at the strut elevation:

$$F = \frac{(10in)\,ft}{12in} \times 20\,ft \times 1.20 \times 1.5 \times \frac{26.9lbs}{ft^2} = 0.807kips$$

Mid and Upper Strut (Elevation ١٢١'-٠" and ١٢٨'-٠"):

Concentrated load on the windward column at the strut elevation:

$$F = \frac{(10in)\,ft}{12in} \times 20\,ft \times 1.20 \times 1.8 \times \frac{30.3lbs}{ft^2} = 1.091kips$$

Concentrated load on the leeward column at the strut elevation:

$$F = \frac{(10in)\,ft}{12in} \times 20\,ft \times 1.20 \times 1.5 \times \frac{30.3lbs}{ft^2} = 0.909kips$$

Air Cooler Support Beams (Elevation ١٤٠'-٠"):

Concentrated load on the windward column at the beam elevation:

$$F = \frac{(16in)\,ft}{12in} \times 20\,ft \times 1.20 \times 1.8 \times \frac{30.3lbs}{ft^2} = 1.745kips$$

Concentrated load on the leeward column at the beam elevation:

$$F = \frac{(16in)\,ft}{12in} \times 20\,ft \times 1.20 \times 1.5 \times \frac{30.3lbs}{ft^2} = 1.454kips$$

Piping:

For Wind on Piping $C_f = 0.7$ (Ref. EG-١٩٠١, pg.٢٣, Table ١١)

The projected area for piping shall be based on the diameter of the largest pipe plus ١٠ percent of the width of the piperack times the lingth of the pipes. (Ref. EG-١٩٠١, pg.٢٥, Note J)

Lower Level Piping:

Concentrated load split between the windward and leeward column applied at the supporting beam elevation:

$$F = \left(\frac{16in + 2in \times 2}{12in/ft} + 10\% \times (20\,ft)\right) \times 20\,ft \times 1.20 \times 0.7 \times \frac{26.9lbs}{ft} = 1.657kips$$

Mid Level Piping:

Concentrated load split between the windward and leeward column applied at the supporting beam elevation:

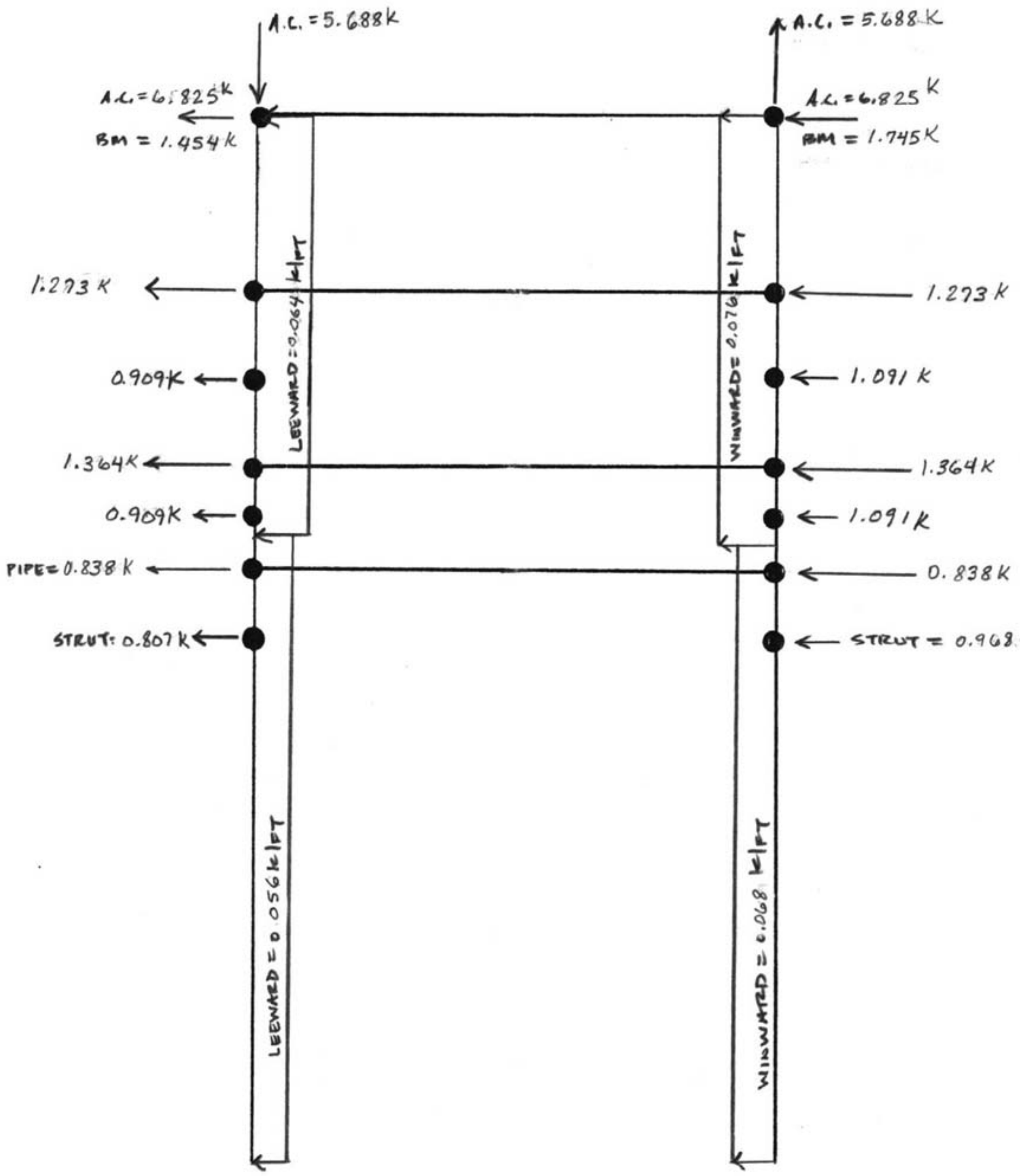
$$F = \left(\frac{30in}{12in/ft} + 10\% \times (20\,ft)\right) \times 20\,ft \times 1.20 \times 0.7 \times \frac{30.3lbs}{ft} = 2.727kips$$

Upper Level Piping:

Concentrated load split between the windward and leeward column applied at the supporting beam elevation:

$$F = \left(\frac{36in}{12in/ft} + 10\% \times (20\,ft)\right) \times 20\,ft \times 1.20 \times 0.7 \times \frac{30.3lbs}{ft} = 2.545kips$$

WIND LOAD NORTH TO SOUTH



Friction Load

Note: The load is doubled to account for reducing S_y by half. (Ref. EG-١٩٠٥, pg.٢, III.C.٢.a)
Use a longitudinal force equal to ١٠% of the applied piping vertical load at each support level. At points of concentrated pipe loads use ٣٠% of applied vertical load. (Ref. EG-١٩٠٥, II.B.٣)

Uniform load on each transverse beam:

$$\omega = 2\times(0.44\frac{kips}{ft}+0.26\frac{kips}{ft})\times 10\% = 0.140\frac{kips}{ft}$$

Concentrated Load due to ٣٦" FLR line on upper beam (no water):

$$F_1 = 2\times(1.536kips)\times 30\% = 0.922kips$$

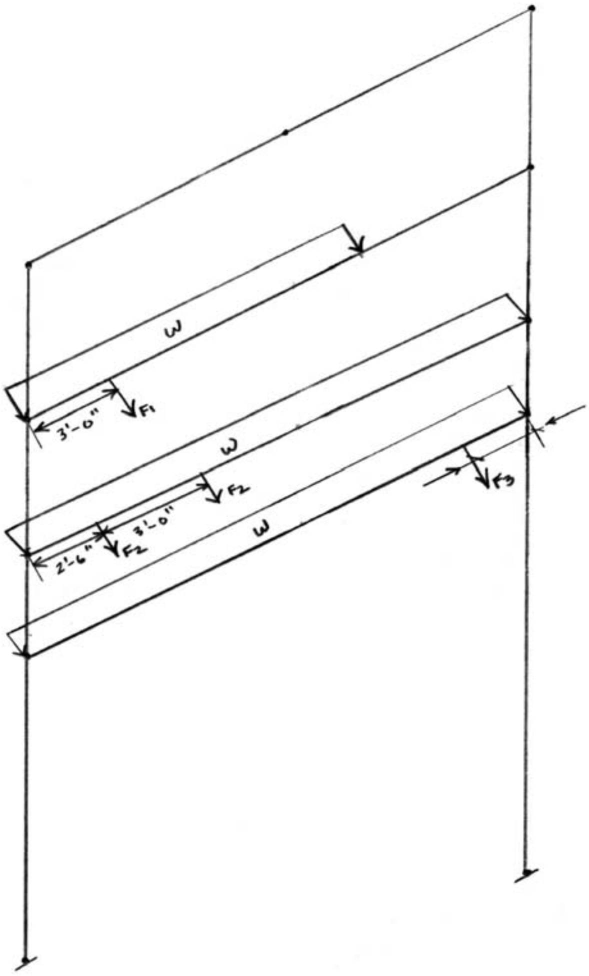
Concentrated Load due to ٣٠" CWS & ٣٠" CWR line on middle beam:

$$F_2 = 2\times(1.276kips + 5.174kips)\times 30\% = 3.87kips$$

Concentrated Load due to ١٦" STM line on upper beam (no water):

$$F_3 = 2\times(0.909kips)\times 30\% = 0.545kips$$

FRICTION LOAD



Design Calculations:

Verify Strut Design:

Strut size: W١٠x٢٦

Properties:

$r_t = 1.54 in$ $\quad \frac{d}{A_f} = 4.07$ $\quad S_x = 27.9 in^3$ $\quad S_y = 4.89 in^3$

$C_b = 1.0$ $\quad F_y = 36 ksi$ $\quad l = 20 ft$

Loads:

Vertical load

Self weight of the beam = ٢٦*lbs/ft*

Weight of pipe = ٣٦ *psf x* ٢٠ *ft x* ٠.٥ = ٣٥٠ *lbs/ft* (Ref. EG-١٩٠٥, pg.٢, III.G.٣)

Total vertical load = ٢٦ *lbs/ft* + ٣٥٠ *lbs/ft* = ٣٧٦ *lbs/ft*

Horizontal load

Friction Load = ١٠% x ٣٥٠ *lbs/ft* = ٣٥ *lbs/ft* (Ref. ????)

Calculations:

$$\frac{l}{r_t} = \frac{20\,ft}{1.54in} \times \frac{12in}{ft} = 155.844 \geq \sqrt{\frac{510 \times 10^3 C_b}{F_y}} = 119.02$$

$$F_{bx} = \frac{170 \times 10^3 C_b}{(l/r_t)^2} \leq 0.6F_y \quad F_{bx} = \frac{170 \times 10^3}{(119.02)^2} = 7ksi$$ (Ref. AISC-ASD F١-٧)

$$F_{bx} = \frac{12 \times 10^3 C_b}{(ld/A_f)} \leq 0.6F_y \quad F_{bx} = \frac{12 \times 10^3}{\left(20\,ft \times \frac{12in}{ft}\right) \times 4.07} = 12.285ksi$$ (Ref. AISC-ASD F١-٨)

$F_{bx} = 12.285ksi$ ....Controls

$F_{by} = 0.75F_y = 27ksi$ (Ref. AISC-ASD F٢-١)

$$M_x = \frac{(376lbs/ft) \times (20\,ft)^2}{8} = 18.8kip \cdot ft$$

$$M_y = \frac{(35lbs/ft) \times (20\,ft)^2}{8} = 1.75kip \cdot ft$$

$$f_{bx} = \frac{M_x \times \frac{12in}{ft}}{S_x} = 8.086ksi$$

$$f_{by} = \frac{M_y \times \frac{12in}{ft}}{S_y} = 4.294ksi$$

Stress Ratio $= \frac{f_{bx}}{F_{bx}} + \frac{f_{by}}{F_{by}} = \frac{8.086ksi}{12.285ksi} + \frac{4.294ksi}{27ksi} = 0.82 \leq 1.0$ .... O.K. (Ref. AISC-ASD H١-٣)

Preliminary Design Size W١٠x٢٦ for Struts

*Note: When the piping arrangement is finalized, individual struts may require further inspection, especially for axial loads from wind.

Verify Air Cooler Longitudinal Support Beam Design:

Beam size: W١٦x٦٧

Properties:

$r_t = 2.75in \qquad \frac{d}{A_f} = 2.4 \qquad S_x = 117.0in^3 \qquad S_y = 23.2in^3$

$C_b = 1.0 \qquad F_y = 36ksi \qquad l = 20\,ft$

Loads:

Horizontal load

Load due to the wind on the Air Cooler

$$F = 12.5\,ft \times 20\,ft \times 1.20 \times 1.3 \times 35 lbs/ft^2 = 13.650 kips$$ (Ref. Previous calculation)

Note: For the ٢٠ ft span between bents the Air Coolers have ٣ contact points along each longitudinal support beam

The component applied at the mid-span of the beam is

$$= \frac{13.650kips}{2 \quad beams} / 2 = 3.413kips$$

Vertical load

Self weight of the beam plus the fireproofing = ٦٧ *lbs/ft* + ٢٦١ *lbs/ft* = ٣٢٨ *lbs/ft*

Load due to the wind on the Air Cooler

$$= \frac{13.650kips \times (2/3) 12.5\,ft}{20\,ft} = \pm 5.688kips$$ (Ref. Previous calculation)

The component applied at the mid-span of the beam is

$$= \frac{5.688kips}{2 \quad beams} = 2.844kips$$

Weight of the Air Coolers (Dead+Fluid+Live) applied at mid-span of the support beam is

$$= \left(\frac{20\,ft}{2} \times \frac{20\,ft}{2}\right) \times (130 + 20 + 10)\frac{lbs}{ft^2} = 16kips$$

Calculations:

$$\sqrt{\frac{102 \times 10^3 C_b}{F_y}} = 53.23 \le \frac{l}{r_t} = \frac{20\,ft}{2.75in} \times \frac{12in}{ft} = 87.273 \le \sqrt{\frac{510 \times 10^3 C_b}{F_y}} = 119.02$$

$$F_{bx} = \left[\frac{2}{3} - \frac{F_y (l/r_t)^2}{1530 \times 10^3 C_b}\right] \le 0.6F_y \qquad F_{bx} = \left[\frac{2}{3} - \frac{36(87.237)^2}{1530 \times 10^3}\right] = 17.548ksi$$ (Ref. AISC-ASD F١-٦)

$$F_{bx} = \frac{12 \times 10^3 C_b}{(ld/A_f)} \le 0.6F_y \qquad F_{bx} = \frac{12 \times 10^3}{\left(20\,ft \times \frac{12in}{ft}\right) \times 2.4} = 20.833ksi$$ (Ref. AISC-ASD F١-٨)

$F_{bx} = 20.833ksi$ ….Controls

$F_{by} = 0.75F_y = 27ksi$ (Ref. AISC-ASD F٢-١)

a) Operating

$$M_x = \frac{16{,}000lbs \times 20\,ft}{4} + \frac{(328lbs/ft) \times (20\,ft)^2}{8} = 96.4kip \cdot ft$$

$$f_{bx} = \frac{M_x \times \frac{12in}{ft}}{S_x} = 9.877ksi$$ …less than F_{bx} <u>O.K.</u>

b) Operating + Wind

$$M_x = M_x + \frac{2.844lbs \times 20\,ft}{4} = 110.62kip \cdot ft$$

$$M_y = \frac{3.413kips \times 20\,ft}{4} = 17.07kips$$

$$f_{bx} = \frac{M_x \times \frac{12in}{ft}}{S_x} = 11.35ksi$$

$$f_{by} = \frac{M_y \times \frac{12in}{ft}}{S_y/2} = 17.65ksi$$

Stress Ratio $= \frac{f_{bx}}{F_{bx}} + \frac{f_{by}}{F_{by}} = \frac{11.35ksi}{20.833ksi} + \frac{17.65ksi}{27ksi} = 1.20 \le 1.33$ …. O.K. (Ref. AISC-ASD H١-٣)

Preliminary Design Size W١٦x٦٧ for Longitudinal Air Cooler Support Beams

Design the Longitudinal Bracing

To develop the quarter wind factor, assume the total wind on one bent is unity.
Take the longitudinal component of the wind at ٤٥ degrees to the rack.

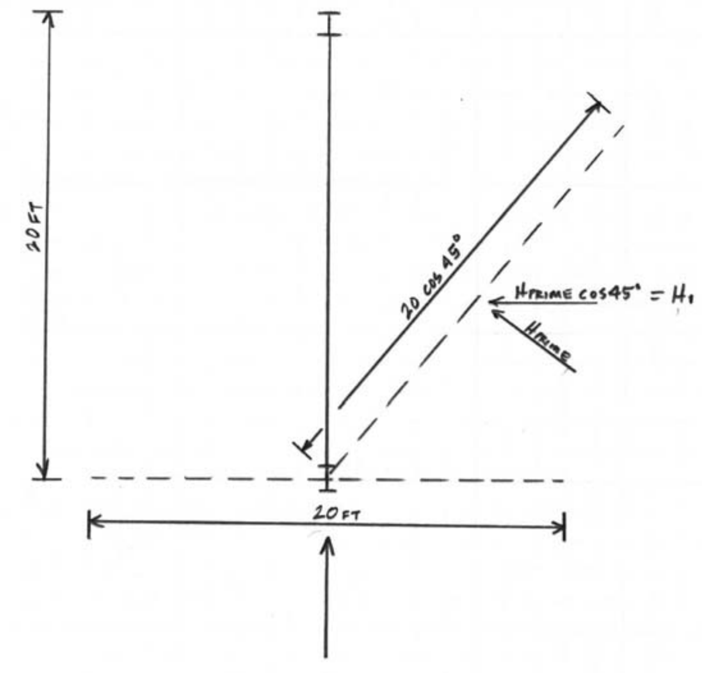


FIGURE 3

$Lateral\ Wind = 1kip/bent$ (Unity)

$$H_{prime} = \left(\frac{1kip/bent}{20\,ft}\right)\times\left(20\,ft\times Cos45^{\circ}\right) = 0.707kips/bent$$

$H_1 = H_{prime}\times Cos45^{\circ} = 0.5kips/bent$ Longitudinal component of the quarter wind

The horizontal wind at each column line is

$$H = \frac{H_1}{2} = 0.25kips/bent$$

The quarter wind factor for the total wind per braced bay is

$$F = H\times\frac{number\ of\ bents - 1}{number\ of\ braced\ bays} = 0.25\frac{kips}{bent}\times\frac{(9-1)bents}{2braced\ bays} = 1\frac{kip}{braced\ bay}$$

This is the force per kip of lateral wind.

Brace Lengths (Ref. Figure ١,٢, and ٤)

$$L_1 = \sqrt{(140\,ft - 128\,ft)^2 + (10\,ft)^2} = 15.62\,ft$$

$$L_2 = \sqrt{(128\,ft - 121\,ft)^2 + (10\,ft)^2} = 12.207\,ft$$

$$L_3 = \sqrt{(121\,ft - 115\,ft)^2 + (10\,ft)^2} = 11.662\,ft$$

$$L_4 = \sqrt{(115\,ft - 101\,ft)^2 + (10\,ft)^2} = 17.205\,ft$$

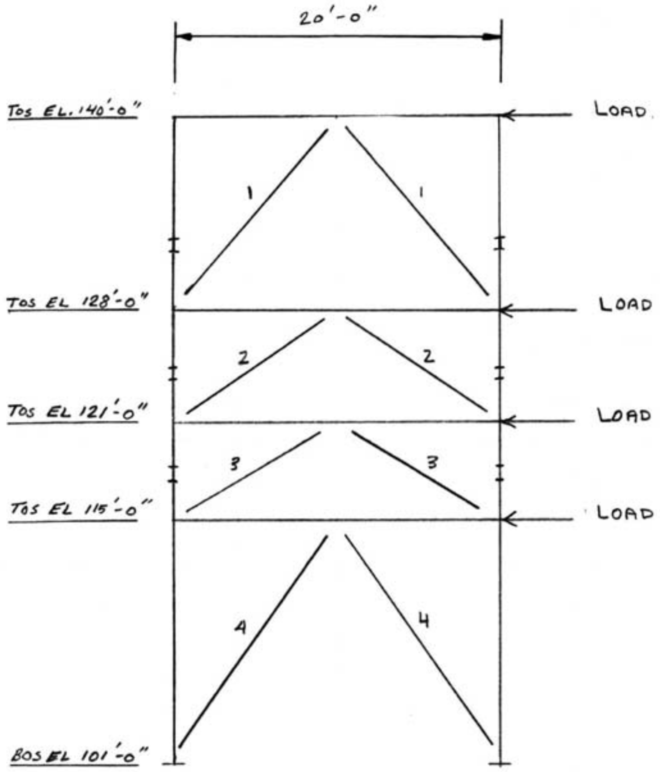


FIGURE 4
ELEVATION OF A TYPICAL BRACED BAY LOOKING SOUTH

Brace Loads (Ref. Wind Load Calculations)

$$Load = Hor.\,Wind\ on\ the\ Air\ Cooler + Wind\ on\ the\ Air\ Cooler\ Support\ Beams + Wind\ on\ the\ Columns$$

$$Load = 13.650 kips + (1.745 kips + 1.454 kips) + \left(0.076\frac{kips}{ft} + 0.064\frac{kips}{ft}\right) \times 6\,ft = 17.69 kips$$

$$Brace\ Load_1 = \frac{Load \times F}{2\ braces} \times \frac{15.62\,ft}{10\,ft} = 13.82 kips$$

$$Load = Load + Wind\ on\ the\ Upper\ Level\ Piping + Wind\ on\ the\ Upper\ Level\ Struts + Wind\ on\ the\ Columns$$

$$Load = 17.69 kips + 2.545 kips + (1.091 kips + 0.909 kips) + \left(0.076\frac{kips}{ft} + 0.064\frac{kips}{ft}\right) \times 9.5\,ft = 23.56 kips$$

$$Brace\ Load_2 = \frac{Load \times F}{2\ braces} \times \frac{12.207\,ft}{10\,ft} = 14.38 kips$$

$$Load = Load + Wind\ on\ the\ Mid\ Level\ Piping + Wind\ on\ the\ Mid\ Level\ Struts + Wind\ on\ the\ Columns$$

$$Load = 23.56kips + 2.727kips + (1.091kips + 0.909kips) + \left(0.076\frac{kips}{ft} + 0.064\frac{kips}{ft}\right) \times 6.5\,ft = 29.20kips$$

$$Brace\ Load_3 = \frac{Load \times F}{2\ braces} \times \frac{11.662\,ft}{10\,ft} = 17.03kips$$

$$Load = Load + Wind\ on\ the\ Lower\ Level\ Piping + Wind\ on\ the\ Lower\ Level\ Struts + Wind\ on\ the\ Columns$$

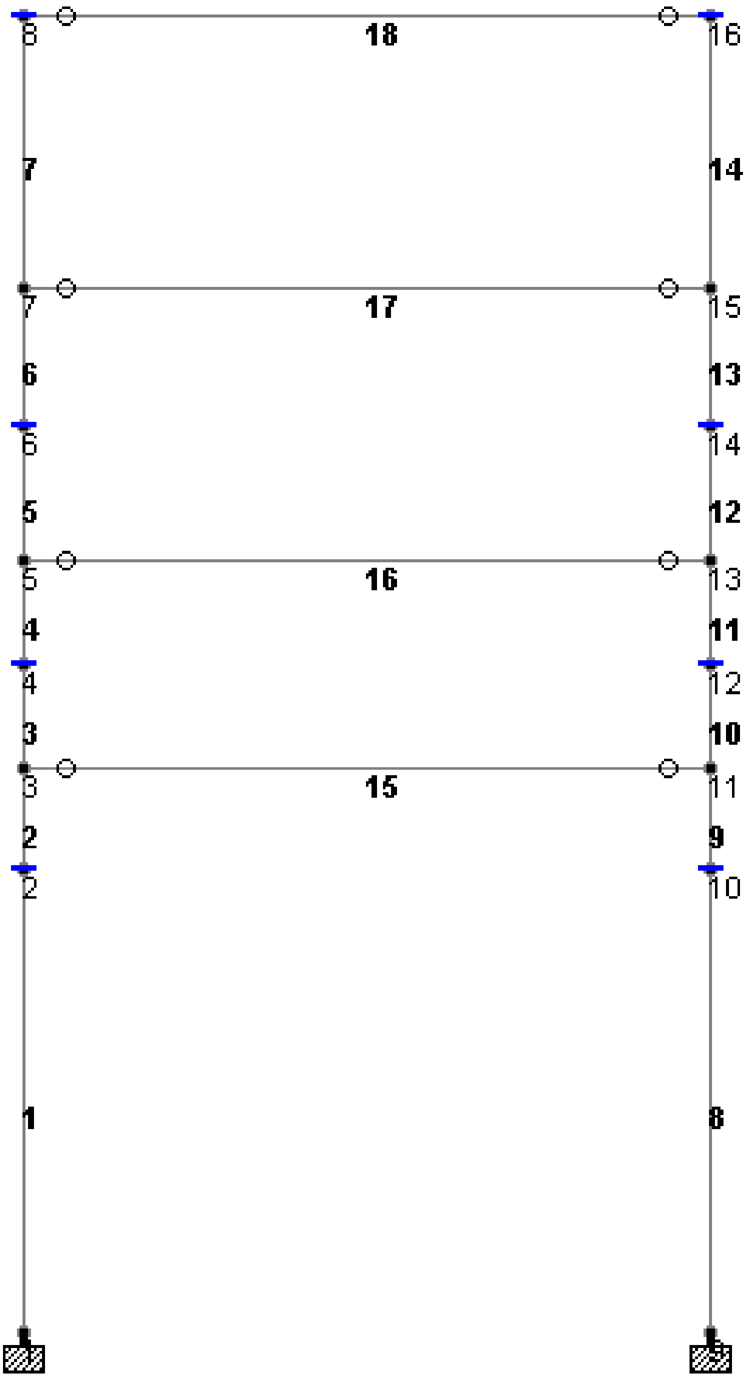
$$Load = 29.20kips + 1.657kips + (0.968kips + 0.807kips) + \left(0.068\frac{kips}{ft} + 0.056\frac{kips}{ft}\right) \times 10\,ft = 33.87kips$$

$$Brace\ Load_4 = \frac{Load \times F}{2\ braces} \times \frac{17.205\,ft}{10\,ft} = 29.14kips$$

To size braces, reference AISC Columns – Allowable Axial Loads, p. ٣-٨٥
(١/٣ increase allowable for wind)

For lengths ١,٢, and ٣ select WT٤x٩
For length ٤ select WT٥x١١

STAAD JOINT and MEMBER NUMBERS



STAAD ٢D INPUT FILE

```
STAAD SPACE EG-١٩٠٥ STANDARD PIPERACK DESIGN EXAMPLE
INPUT WIDTH ٧٢
*MUSTANG ENGINEERS AND CONSTRUCTORS, INC.
*FILE .... EG١٩٠٥.STD
OUTPUT WIDTH ٧٢
UNIT FEET KIP
JOINT COORDINATES
   ١      .٠٠٠      .٠٠٠      .٠٠٠
   ٢      .٠٠٠    ١٣.٥٠٠      .٠٠٠
   ٣      .٠٠٠    ١٦.٥٠٠      .٠٠٠
   ٤      .٠٠٠    ١٩.٥٠٠      .٠٠٠
   ٥      .٠٠٠    ٢٢.٥٠٠      .٠٠٠
   ٦      .٠٠٠    ٢٦.٥٠٠      .٠٠٠
   ٧      .٠٠٠    ٣٠.٥٠٠      .٠٠٠
   ٨      .٠٠٠    ٣٨.٥٠٠      .٠٠٠
   ٩    ٢٠.٠٠٠      .٠٠٠      .٠٠٠
  ١٠    ٢٠.٠٠٠    ١٣.٥٠٠      .٠٠٠
  ١١    ٢٠.٠٠٠    ١٦.٥٠٠      .٠٠٠
  ١٢    ٢٠.٠٠٠    ١٩.٥٠٠      .٠٠٠
  ١٣    ٢٠.٠٠٠    ٢٢.٥٠٠      .٠٠٠
  ١٤    ٢٠.٠٠٠    ٢٦.٥٠٠      .٠٠٠
  ١٥    ٢٠.٠٠٠    ٣٠.٥٠٠      .٠٠٠
  ١٦    ٢٠.٠٠٠    ٣٨.٥٠٠      .٠٠٠
MEMBER INCIDENCES
     ١     ١     ٢
     ٢     ٢     ٣
     ٣     ٣     ٤
     ٤     ٤     ٥
     ٥     ٥     ٦
     ٦     ٦     ٧
     ٧     ٧     ٨
     ٨     ٩    ١٠
     ٩    ١٠    ١١
    ١٠    ١١    ١٢
    ١١    ١٢    ١٣
    ١٢    ١٣    ١٤
    ١٣    ١٤    ١٥
    ١٤    ١٥    ١٦
    ١٥     ٣    ١١
    ١٦     ٥    ١٣
    ١٧     ٧    ١٥
    ١٨     ٨    ١٦
MEMBER PROPERTY AMERICAN
* TRAVERSE BEAMS
١٨ TABLE ST W١٠X٢٦
١٦ ١٧ TABLE ST W١٤X٦١
١٥ TABLE ST W١٦X٧٧
* COLUMNS
```

```
١ TO ١٤ TABLE ST W١٤X٨٢
MEMBER RELEASE
* RELEASE WEAK AXIS MOMENT ON TRAVERSE BEAMS
١٥ TO ١٧ START MY



١٥ TO ١٧ END MY
* RELEASE STRONG AND WEAK AXIS MOMENTS ON TOP MOST BEAM
١٨ START MY MZ
١٨ END MY MZ
SUPPORT
* BASES ARE FIXED
١ ٩ FIXED
* PROVIDE SUPPORT IN THE Z DIRECTION WHERE STRUTS ARE LOCATED
٢ ٤ ٦ ٨ ١٠ ١٢ ١٤ ١٦ FIXED BUT FX FY MX MY MZ
CONSTANT
E STEEL ALL
DENSITY STEEL ALL
POISSON STEEL ALL
LOAD ١ DEAD LOAD
SELFWEIGHT Y -١.
JOINT LOAD
*AIR COOLERS
٨ ١٦ FY -٢٦.
* ٣٠" HEADER ON AIR COOLER
١٦ FY -٢.٣٧٦
* STRUTS
٢ ٤ ٦ ١٠ ١٢ ١٤ FY -.٥٢
* AIR COOLER LONGITUDINAL SUPPORT BEAMS
٨ ١٦ FY -٦.٨
MEMBER LOAD
* FIREPROOFING - COLUMNS
١ TO ١٤ UNI GY -.٢٤٤
* FIREPROOFING - TRAVERSE BEAMS
١٥ UNI GY -.٢٥٢
١٦ ١٧ UNI GY -.٢١٣
* UPPER LEVEL PIPING AND ELECTRICAL
١٧ UNI GY -.٤٤ ٠. ١٢.
١٧ UNI GY -.٤ ١٢. ٢٠.
١٧ CON GY -١.٥٣٦ ٣.
* MID LEVEL PIPING
١٦ UNI GY -.٤٤
١٦ CON GY -١.٢٧٦ ٢.٥
١٦ CON GY -١.٢٧٦ ٥.٥
* LOWER LEVEL PIPING
١٥ UNI GY -.٤٤
١٥ CON GY -.٩٠٩ ١٧.٥
LOAD ٢ FLUID LOAD
JOINT LOAD
* AIR COOLERS
٨ ١٦ FY -٤.
*٣٠" HEADER ON AIR COOLER
١٦ FY -٥.٨٢
* UPPER PIPING LEVEL
MEMBER LOAD
```

١٧ UNI GY -.٢٦ ٠. ١٢.
١٧ CON GY -٧.٦٧ ٣.
* MID PIPING LEVEL
١٦ UNI GY -.٢٦
١٦ CON GY -٥.١٧٤ ٢.٥
١٦ CON GY -٥.١٧٤ ٥.٥
* LOWER LEVEL PIPING

١٥ UNI GY -.٢٦
١٥ CON GY -١.٢٣٨ ١٧.٥
LOAD ٣ LIVE LOADS
*AIR COOLER PLATFORMS
JOINT LOAD
٨ ١٦ FY -٢.٠
LOAD ٤ NORTH WIND
*AIR COOLER JOINT LOAD
JOINT LOAD
٨ FY -٥.٦٨٨
١٦ FY ٥.٦٨٨
٨ ١٦ FX -٦.٨٢٥
MEMBER LOAD
* COLUMNS LEEWARD
١ ٢ UNI GX -.٠٥٧
٣ UNI GX -.٠٥٧ ٠. ٢.٥
٣ UNI GX -.٠٦٤ ٢.٥ ٣.
٤ TO ٧ UNI GX -.٠٦٤
* COLUMNS WINDWARD
٨ ٩ UNI GX -.٠٦٨
١٠ UNI GX -.٠٦٨ ٠. ٢.٥
١٠ UNI GX -.٠٧٦ ٢.٥ ٣.
١١ TO ١٤ UNI GX -.٠٧٦
JOINT LOAD
* LOWER STRUT LEEWARD
٢ FX -.٨٠٧
* LOWER STRUT WINDWARD
١٠ FX -.٩٦٨
* MID AND UPPER STRUT LEEWARD
٤ ٦ FX -.٩٠٩
* MID AND UPPER STRUT WINDWARD
١٢ ١٤ FX -١.٠٩١
* AIR COOLER LONGITUDINAL SUPPORT BEAM LEEWARD
٨ FX -١.٤٥٤
* AIR COOLER LONGITUDINAL SUPPORT BEAM WINDWARD
١٦ FX -١.٧٤٥
* LOWER LEVEL PIPING
٣ ١١ FX -.٨٢٩
* MID LEVEL PIPING
٥ ١٣ FX -١.٣٦٤
* UPPER LEVEL PIPING
٧ ١٥ FX -١.٢٧٣
LOAD ٥ SOUTH WIND
*AIR COOLER JOINT LOAD
JOINT LOAD
٨ FY ٥.٦٨٨

١٦ FY -٥.٦٨٨
٨ ١٦ FX ٦.٨٢٥
MEMBER LOAD
* COLUMNS LEEWARD
٨ ٩ UNI GX .٠٥٧
١٠ UNI GX .٠٥٧ ٠. ٢.٥
١٠ UNI GX .٠٦٤ ٢.٥ ٣.
١١ TO ١٤ UNI GX .٠٦٤
* COLUMNS WINDWARD
١ ٢ UNI GX .٠٦٨

٣ UNI GX .٠٦٨ ٠. ٢.٥
٣ UNI GX .٠٧٦ ٢.٥ ٣.
٤ TO ٧ UNI GX .٠٧٦
JOINT LOAD
* LOWER STRUT LEEWARD
١٠ FX .٨٠٧
* LOWER STRUT WINDWARD
٢ FX .٩٦٨
* MID AND UPPER STRUT LEEWARD
١٢ ١٤ FX .٩٠٩
* MID AND UPPER STRUT WINDWARD
٤ ٦ FX ١.٠٩١
* AIR COOLER LONGITUDINAL SUPPORT BEAM LEEWARD
١٦ FX ١.٤٥٤
* AIR COOLER LONGITUDINAL SUPPORT BEAM WINDWARD
٨ FX ١.٧٤٥
* LOWER LEVEL PIPING
٣ ١١ FX .٨٢٩
* MID LEVEL PIPING
٥ ١٣ FX ١.٣٦٤
* UPPER LEVEL PIPING
٧ ١٥ FX ١.٢٧٣
LOAD ٦ FRICTION
* DOUBLE LOAD TO ACCOUNT FOR REDUCING SY OF THE BEAM BY HALF.
* REMEMBER TO REDUCE BEAM END REACTION BY HALF IF LOADS ARE USED FOR
* VERTICAL BRACING DESIGN.
MEMBER LOAD
* UNIFORM PIPE FRICTION ١٠% OF OPERATING PIPE LOAD
١٥ ١٦ UNI GZ .١٤
١٧ UNI GZ .١٤ ٠. ١٢.
* CONCENTRATED LOAD USE ٣٠%
* ٣٦" DIA. FLR
١٧ CON GZ .٩٢٢ ٣.
* ٣٠" DIA. CWS
١٦ CON GZ ٣.٨٧ ٢.٥
* ٣٠" DIA. CWR
١٦ CON GZ ٣.٨٧ ٥.٥
* ١٦" DIA. STM
١٥ CON GZ .٥٤٥ ١٧.٥
LOAD COMB ٧ DEAD + LIVE
١ ١. ٢ ١. ٣ ١.
LOAD COMB ٨ DEAD + NORTH WIND

١ .٧٥ ٤ .٧٥
LOAD COMB ٩ DEAD + SOUTH WIND
١ .٧٥ ٥ .٧٥
LOAD COMB ١٠ DEAD + LIVE + NORTH WIND
١ .٧٥ ٢ .٧٥ ٣ .٧٥ ٤ .٧٥
LOAD COMB ١١ DEAD + LIVE + SOUTH WIND
١ .٧٥ ٢ .٧٥ ٣ .٧٥ ٥ .٧٥
LOAD COMB ١٢ DEAD + LIVE + FRICTION
١ ١. ٢ ١. ٣ ١. ٦ ١.
PERFORM ANALYSIS
SECTION ٠. .٢٥ .٥ .٧٥ ١. ALL
PARAMETER
CODE AISC
* NOTE: IT IS IMPORTANT TO SUPPLY ALL REQUIRED PARAMETERS IF A

*   CORRECT DESIGN IS EXPECTED.
* COLUMNS
KZ ١.٣ MEMB ١ ٢ ٨ ٩
KZ ٢. MEMB ٧ ١٤
LY ٦. MEMB ٢ ٣ ٩ ١٠
LY ٦. MEMB ٤ ٥ ١١ ١٢
LY ١٢. MEMB ٦ ٧ ١٣ ١٤
LZ ١٦.٥ MEMB ١ ٢ ٨ ٩
LZ ٦. MEMB ٣ ٤ ١٠ ١١
LZ ٨. MEMB ٥ ٦ ١٢ ١٣
UNL ٦. MEMB ٢ ٣ ٩ ١٠
UNL ٧. MEMB ٤ ٥ ١١ ١٢
UNL ١٢. MEMB ٦ ٧ ١٣ ١٤
* BEAMS
CMY ١. ALL
* CMZ DEFAULTS TO ٠.٨٥ & CB DEFAULTS TO ١.٠ FOR ALL MEMBERS.
LOAD LIST ١ ٦ TO ١٢
PRINT SUPPORT REACTIONS
CHECK CODE ALL
FINISH