THESIS

INVESTIGATION OF EAST LANSING WATER TOWER

C. H. PETERSON & A. L. SAYLES

1915

East Lansing - Water - supply

Water - storage

This thesis was contributed by

Mr. C. H. Peterson

under the date indicated by the department stamp, to replace the original which was destroyed in the fire of March 5, 1916.

Civil engineering Sanitary engineering

FEB 1925

INVESTIGATION OF STRESSES

IN

EAST LANSING WATER TOWER.

* * *

A THESIS SUBMITTED TO

THE FACULTY OF

MICHIGAN AGRICULTURAL COLLEGE

by

C. H. Petersen A. L. Sayles

Candidates for the Degree of

BACHELOR OF SCIENCE.

June, 1915.

THESIS

I N D E X

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OUTLINE OF PROCEDURE.

A. History.

B. Specified Loads.

C. Specified Unit Stressed.

D. Loads -

1. Tankfull - square wind
2. Tankfull - diagonal wind
3. Tank empty - square wind
4. Tank empty - diagonal wind

E. Stresses -

1. Column, maximum
2. Horizontal Bracing
3. Vertical Bracing
4. Anchor Bolts
5. Masonry -
   - Bearing on
   - Resist to uplift
   - Press on soil
6. Side Plate Pl.
7. Spherical Bottom Plates P_2

F. Make-up of Design -

1. Column 2. Horizontal Bracing 3. Vertical Bracing 4. Anchor Bolts 5. Masonry 6. Side Plates P_1 7. Spherical Bottom plates	a. Main section b. Riveted connections c. Lacing

G. Maximum Unit Stressed -

1. Column 2. Horizontal Bracing 3. Vertical Bracing 4. Anchor Bolts 5. Masonry 6. Side Plates P_1 7. Spherical Bottom Plates	a. On main sections. b. Riveted connections c. Lacing

Outline of Procedure, Contd.

H. Summary -

1. Based on Original Sections
    a. Members overstrained
    b. Percent. excess overstrained
    c. Loading producing excess.
2. General Conditions and Workmanship

I. Acknowledgments and Technical references.

J. Miscellaneous.

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This work of analysis was undertaken not in any spirit of fault finding or of criticising the design or construction but in order to gain knowledge of steel construction and experience in analysis.

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INTRODUCTION.

Prior to 1909 the City of East Lansing had no public water supply but depended on the individual system installed in private residences or from the College. Mr. Chase had erected a private tower and from this supplied a few in the immediate vicinity, but this was entirely inadequate to supply more than a very few surrounding him. As the city expanded the need of an adequate water supply for domestic and fire purposes became very pressing. A number of small fires alarmed the city council and they realized that they could not depend on the City of Lansing for their water as they had done for their lights.

They first tried to obtain water from the College, as Mr. Bird on Grand River Avenue had done, but failed, as Mr. Bird had no legal right to use the College water.

A committee was appointed by the council to investigate the various systems in use and authorized to submit plans for a system to be used in East Lansing.

Professor Hadden, then of the Civil Engineering Department of the College, was secured to draw up design of tower. These plans were submitted for bids and the contract for building was let to Whitehead and Kales

Iron Works of Detroit, Michigan, in January, 1909.

The original site of this tower was the present location of the pumping station, but before the erection was started the present location was secured on Forest Hill Avenue. This had been originally selected as the building site but the price asked by the owners was almost prohibitory. By changing the location to the top of the hill an increase in head of about thirty feet was gained, but necessitated the pumping of the water about three hundred feet further and thirty feet higher.

Construction was started on the tower late in the spring of 1909 and finished in the summer of the same year. The system had so far been entirely satisfactory.

Other improvements were made after the tower was erected which depended on a good water supply, the chief being an extensive sewer system.

The tower is 118 feet high and has a capacity of 10,000 gallons.

SPECIFIED LOADS.

Dead Loads.

Weight of structure.

Columns	8 - 6" Channels @ 8# / ft. 102¾' high	= 6600#
	4 - 8"x ¼" plates @ 6.8#/ft 51' "	= 710#
	1504- 1¼"x ¼" bars @ .65# ea. 7 5/16" long	= 1000#
	Total ------	8310#
Ladder	200' L 1¼"x 1¼" x 3/16" @ 1.8#/ft	= 360#
	100 round bars @ 1.2# ea.	= 120#
	Total -----	480#
Hori-zontal Bracing	16 Ls 2½"x 2" x ¼" @ 3.62#/ft60.5	= 980#
	144 bars 1¼" x ¼" x 14" @ 1.6# ea.	= 230#
	1 frame ----	1210#
		3
	Total frames ---	3630#

Vertical and lateral brace rods. --------	8 - 1" Rods	30'	long	@ 2.6#/ft	= 620#
	8 - 1" "	28'	"	@ 2.6#/ft	= 580#
	8 - 7/8" "	26'	"	@ 2 # /ft	= 415#
	8 - 7/8" "	25'	"	@ 2 # /ft	= 400#
	4 - 3/4" "	13'	"	@ 1.5#/ft	= 78#
	4 - 3/4" "	10'	"	@ 1.5#/ft	= 60#
	4 - 3/4" "	8'	"	@ 1.5#/ft	= 48#
				T o t a l ----	2201#

Tank Drum	12 plates 8'x48"x3/16"	@ 30.6#/ft	=2950#
	4 " 8'x28"x3/16"	@ 17.85#/ft	= 560#
		T o t a l ------	3510#

Tank Roof	18 plates No.12 gauge, 60"x24"x1/10"	@ 490#/Cu ft	= 410#

Tank Bell	1 Plate 73"x3/16"x6'3"	@ 46.8#/ft	= 300#
	8 " 48"x3/16"x4'	@ 30.6#/ft	= 980#
		T o t a l ----	1280#

__Total Weight of Tank__ ---------------------- 5200#

Total Dead Load Estimates -

4 Columns	8310#
1 Ladder	480#
3 Cross Frames	3630#
Vertical & Lateral rods	2201#
Tank	5200#
Total ------	19821#
Use ------	20000#
Add 20% for rivets, etc. --	4000#
Total Dead Load ----	24000#

<u>Weight of Contained Water in Tank.</u>

$\frac{10000 \text{ Gals.}}{7.48}$ = 1340 Cu ft. @ 62½#/cu ft. = 84000#

Total Dead Load of Structure and Contained Water = 108000#

$\frac{108000}{4}$ = 27000# D.L. on each column

<u>Wind Loads</u>

30#/sq.ft. of exposed area

150#/ Lin.ft. of height

Specified Unit Stresses.

Tension in Tank plates 12000#/sq.in. net area

Tension in other parts of structure 16000#/ Sq.in.net area

Compression 16000#/sq.in. (reduced)

Shear on shop rivets	12000#/ sq.in.
" " filled "	9000#/sq.in
" in plates	10000#/sq.in. (Gross area)

For compression members the permissible unit stress of 16000# shall be reduced by the formula

$$P = 16000 - \frac{70\,L}{r}$$ where

P = permissible working stess in compression in pounds / sq.in.

L = length of member from center to center of connections in inches.

r = least radius of gyration of section in inches.

The ratio L/r shall not exceed 120 for main members and 180 for struts and roof construction members.

Unit compression on concrete sub-structures = 350#/ sq in.

Unit masonry bearing on soil = 2 tons/sq.ft.

Loads.

Wind on roofs - (Print No.2)

2/3 b h x 30#/sq.ft.

2/3 x 12 x 4 x 30 = 960#

Wind on Drum

2/3 bh x 30#/sq.ft.

2/3 x 10 x 13 x 30 = 2600#

Wind on Bell

2/3 bh x 30#/sq ft

2/3 x 10 x 5 x 30 = 1000#

Wind on Tower (Prints Nos. 2 and 3)

Diagonally per foot of vertical height

Area = 8"+ 8"+ 6"+ 6" = 2 1/3' + 2.84 = 5.17'

5.17 x 30 x 1 = 154#/ft of height.

Squarely on Tower.

Area = $\frac{4 \times 10}{12}$ = 3.33' + 2' = 5.33'

5.33 x 30 x 1 = 160#/ft of height.

Load on each section (Print No.3)

25 x 160 = 4000#

Wind Loads on Tank. See Print No.3.

Tank Empty.

Forces	Sq. Wind	Diag.Wind.
AB	960	960
BC	2600	2600
CD	2000	1925
DE	1000	1000
EF	4000	3850
FG	4000	3850
GH	4000	3850
HI	2000	1925

With tank full, the loads on leeward side are increased by the weight of the water in the tank

STRESSES.

Stresses in Column

Analytical Solution.

Stress due to wind = $M/2r$ for four column structure where M is maximum moment of each section due to wind and r is the radius of a circle passing through the center of the columns.

Thus:

ΣM_o about base in the plane about the diagonal of the structure = 0

$$S = [(4000 \times 25)+(4000 \times 50)+(4000 \times 75)+(2000 \times 100)+(2600 \times 106.5)+(960 \times 114.33)+(1000 \times 98)] \div (15 \times 2)$$

S = 42833# due to wind.

S = 27000# due to weight of structure and water

Total stress- 69833#

This compares favorably with wind stresses as shown in graphical solution in Print No.3, that giving max. stress as 45000 + 27000 = 72000#. This being slightly greater the graphical solution was used for final results.

Column Stresses.

Member	Wind Stress	Dead Load Stress	Max. Stress
C1, C2	45000	27000	72000
C3, C4	32500	26000	58500
C5, C6	20800	25000	45800
C7, C8	10200	24000	34200

Horizontal Bracing

Member	Max. Stress.
S1.	7000
S2.	5750
S3.	4450

Vertical Bracing

Member	Max. Stress.
D1	11000
D2	10000
D3	8600
D4	6750

Anchor Bolts

Two anchor bolts in each pier take the tension due to wind on empty tank, minus 1/4 weight of tank.

$$\text{Max. Stress} = \frac{45000 - 6000}{2} = 19500$$

Masonry Bearing.

The masonry takes both the compression on the lee-ward side and the dead load coming on it from one leg, or

$$\text{Max. Stress} = 45000 + 27000 = 72000\#$$

Bearing on Soil

45000 + 27000 = 72000# Bearing due to tower

157 Cu ft @ 150#/cu ft= 23500# Wt. of one pier

95500#

88 cu ft Earth @ 100# /cu ft = 8800# Wt. of earth above

104300#

Slide Plates - Pl. (See Print No.4)

Stress is that due to tank full of water.

Stress per sq. in. of plate

$$S = \frac{2.6\ hd}{t.}$$

h = height in feet = 14'

d = Diameter of Tank in feet = 10'

t = Thickness of plates in inches = .1875"

$$S = \frac{2.6 \times 14 \times 10}{.1875} = 1940\#/\text{square inch.}$$

Spherical Plates

Stress T. = $\frac{2.6\ hr}{t}$ /Sq.In.

h = height in feet = 19'

r = radius of tank = 5'

t = thickness in inches = .1875"

$$T = \frac{2.6 \times 19 \times 5}{.1875} = 1320\#/\text{Sq in.}$$

MAKE UP OF DESIGN.

Columns. (Plate No.5)

The columns are made up of two 6" channels, the two lower ones having a 3/8" x 8" plate on one side and single laced on the other side by 1-1/2" x 1/4" bars. The two upper ones are single laced on each side. 5/8" rivets are used in all columns.

Horizontal Bracing. (Plate No.6)

The horizontal bracing is made up of four angles 2-1/2" x 2 x 1/4", two in each set and joined by 1-1/4" x 1/4" laced work, 5/8" rivets.

The tie rods of the horizontal bracing are of 3/4" round rods, bolted to the columns.

Vertical Bracing. (Plate No.5).

The vertical bracing in the two lower panels are of 1" round rods; that in the two upper panels are of 7/8" round rods.

Anchor Bolts. (Plate No.6)

These are of 1-1/4" x 4' long stock firmly imbedded in concrete.

Masonry. (Plate No.6)

The piers are of solid concrete made in three stages, the lower one being 7' x 7' x 2', middle one 5' x 5' x 2', and the top one 3' x 3' x 1'.

Side Plate - P_1. (Plate #5)

These are of 3/16" O.H.Steel, all rivets 1/2". The plates are bent to the radius of the tank.

Spherical Bottom Plates. (Plate No.7)

These are also of 3/16" O.H. steel, using 1/2" rivets, stamped to conform to their spherical shape.

MAXIMUM UNIT STRESSES.

Columns. (Refer to Plate No.8)

Stress in C1 - C2 - C3 - C4.

$$S = \frac{P}{A} + \frac{P.e.c.}{I}$$

P = 72000#

A = 4.76 +3 = 7.76 sq.in.

C = 4.35"

e = 1.35"

I_y = 4.19

r_y = 2.32"

$$S = \frac{72000}{7.76} + \frac{72000 \times 1.35 \times 4.35}{41.9} = 19500\#/\text{sq.in.}$$

Unit Compressive stress = $16000 - \frac{70\ l}{r_y}$, where l is length (unsupported) in inches and r_y is least radius of gyration = $16000 - \frac{70 \times 25 \times 12}{2.32}$

allowed stress = 16000 - 9000 = 7000#/sq.in.

$\frac{l}{r_y}$ should not exceed 120 but in this case it is in excess of that amount.

$\frac{l}{r_y} = \frac{300}{2.32} = 129$

Stress in column C5 - C6 - C7 - C8.

$S = \frac{P}{A}$ P = 45800#
A = 4.76 sq.in.

$= \frac{45800}{4.76} = 9600\#/\text{sq in.}$

$r = \sqrt{\frac{I}{A}}$ I = 25.9 r = 2.34
A = 4.76

$\frac{l}{r} = \frac{300}{2.34} = 128$

Should not exceed 120

Allowed Unit Compression = $16000 - \frac{70\ l}{r}$

= 16000 - 9000 = 7000#/sq in.

Lacing on Columns (Print No.9)

$9000 = \frac{70\ \cancel{L}\ \ell}{\cancel{R}\ r}$

Lace bar Shear = $\frac{9000\ Ar^2}{d/2} \times \frac{4}{L}$

Max. Stress in Lacing = $\frac{9000\ Ar^2}{d/2} \times \frac{4}{L} \times \text{Sec } \theta$

where $A = 7.76$ sq.in.

$r = 2.32"$

$d = 7.5"$

$L = 300"$

θ = Angle between lace bar and horizontal

Sec. $\theta = 1.33$

$$\text{Shear} = \frac{9000 \times 7.76 \times \overline{2.32}^2}{7.5/2} \times \frac{4}{300} = 1180\#$$

Stress in bar = $1180 \times 1.33 = 1570\#$

Divide by area of bar 1-1/2" x 1/4" = 3/8"

$8/3 \times 1570 = 4200\#$/sq.in.

Check (From Ketchums)

$$\text{Stress} = \frac{280\ Ar}{C}\ \text{Csc}\ \theta,$$

$A = 7.76$ sq.in.

$r = 2.32"$

$C = 4.35"$

Csc $\theta = 1.33$

θ is angle between lacing and vertical.

$$\text{Stress} = \frac{280 \times 7.76 \times 2.32 \times 1.33}{4.35} = 1540\#/\text{sq.in.}$$

Horizontal Bracing (Print No.3)

4∠s 2-1/2" x 2" x 1/4"   Area = 1.06 x 4 = 4.24 sq.in.

Unit Stress $= \frac{P}{A}$

$P = 7000$

$A = 4.24$

$= \frac{7000}{4.24} = 1650\#/\text{sq.in.}$

Allowed Unit $= 16000 - 70\,\frac{L}{R}$

$L = 17.75 \times 12 = 212''$

Least radius of gyration = 1.21"

Allowed Unit $= 16000 - \frac{70 \times 212}{1.21} = 16000 - 12250 = 3750\#/\text{sq.in.}$

$\frac{L}{R} = \frac{212}{1.21} = 175$ Allowed 180

Lacing on Horizontal Bar (Print No.9)

Stress $= \frac{70L}{R}\left(\frac{Ar^2}{d/2}\right)\frac{4}{L}\sec\theta$

$\frac{70L}{R} = 12250$

$A = 4.24$

$r = 1.21$

$d = 16''$

$L = 212''$

$\sec\theta = \frac{17.25}{13.75} = 1.26$

Stress in bar $\dfrac{12250 \times 4.24 \times \overline{1.21}^2}{16/2} \times \dfrac{4}{212} \times 1.26 = 225\#$

$$\frac{225\#}{\text{area}} = \frac{225}{8/3} = 600\#/\text{sq.in.}$$

Checked by Ketchum's formula giving

$$227\# \text{ or } \frac{227}{8/3} = 600\#$$

Vertical Bracing

D_1 and D_2

Maximum Stress = 11000#

Area of 1" rod = .7854 sq.in.

Unit Stress = $\dfrac{11000}{.7854}$ = 14000#/ sq.in.

D_3 and D_4

Maximum Stress = 8600#

Area of 7/8" rod = .6013 sq.in.

Unit Stress = $\dfrac{8600}{.6013}$ = 14300#/sq.in.

Anchor Bolts

Maximum Stress = 19500#

Area of 1-1/4"bolt = 1.2272 sq.in.

Unit Stress = $\dfrac{19500}{1.2272}$ = 15400#/sq.in.

Test for bond.

Bond stress = 80 x surface area

= 80 x 4 x 12 x 3.927 = 15100#

15100 x 2 = 30200#

Masonry

Column bearing on Pier

Maximum Stress = 72000#

Area = 14" x 16" = 224 sq.in.

Unit Stress = $\frac{72000}{224}$ = 320#/sq.in.

Pier on Soil

Maximum Stress = 104300#

Area = 7' x 7' = 49 sq.ft. = 2100#/sq.ft.

Side Plate P 1. Riveted Joints.

Rivet spacing = 1-1/2"

Diameter Rivet 1/2", Diam. hole 9/16"

Stress per lin. in. of vert. height = 1940#

Load for 1-1/2" = 1-1/2 x 1940 = 2910# = P.

a = pitch of rivet = 1-1/2"

d = Diam. of rivet hole = 9/16"

S_t = Unit tensile stress in plate

S_c = " compression in plate

S_s = " shear on rivet.

d_1 = Diam. rivet = 1/2"

$S_t = \frac{P}{(a-d)}$ $\qquad S_c = \frac{P}{a}$ $\qquad S_s = \frac{P}{1/4\pi d^2}$

$S_t = \frac{2910}{(1.5-.5625)} = 3100$#/sq.in.

$$S_c = \frac{2910}{.5625} = 5200\#/\text{sq.in.}$$

$$S_s = \frac{2910}{1/4\pi\, d^2} = \frac{2910}{.1963} = 14700\#$$

Spherical Plates

Unit stress in spherical plates = 1320#/sq.in as shown on page 13.

As this is smaller than that above used in finding stresses on joints, the stresses on rivets and joints will be smaller.

Riveted Connection

Between plates of tank and legs.(Print No.10)

Weight of tank plates = 5200#
plus 33% for incidentals = 1700
Wt. of contained water = 84000
Total = 90900#

1/4 on each leg or 22725# borne by rivets
Value of 5/8" rivet in single shear at 10000# = 3068#
16 rivets at 3068 = 49088# rivets can takein single shear.

Bearing value of single 5/8" rivet on 3/16" plate

Unit bearing stress = 20000# =

Diam. of rivet x thickness of plate x

allowed unit bearing stress.

Bearing value of rivet = .625 x .1875 x 20000 = 2344
16 rivets at 2344 = 37504# rivets can take in bearing on plate.

SUMMARY.

Based on original section.

All members show sufficient strength except the columns. These appear to have been designed without taking into consideration the eccentric loading due to the plate on the inside or to the large value of the item L/R. In the case of the lower half of the columns, this reduces the allowed unit compressive strength from 16000# to 7000#. The addition of the plate in this case was a detriment. Instead of strengthening the column it weakened it by increasing unit stress from 15100#/sq.in. to 19500 #/sq.in.

The main columns are overstressed 180%

The upper columns are overstressed 36%

The calibrated corrosion on the tower was found to be so small that it could be neglected altogether. That on the plate, for instance, was found to be .0005 inches and none on the channels.

The corrosion on the tank was much greater but could not be calibrated on account of its inaccessibility. The rivets in the north side of the bell were nearly eaten away by the rust. This is probably due to the running over of the tank and to excess of carbon dioxide in the water.

GENERAL CONDITIONS AND WORKMANSHIP.

This design appears to have been rather hasty and incomplete. The action of the couple due to the wind on the tank seems to have been neglected and also that of eccentric loading of the columns.

This, coupled with lax attention and poor upkeep, has rendered the structure unsafe for excessive loads. The tank was repainted this spring <u>for the first time since it was erected in 1909</u>, and has suffered from inattention in that manner. We had the good fortune to interview a skilled structural iron worker at the time of examination of the tank and from him learned of the unsafe condition of the bell. In his opinion the rivets will have to be renewed within two years or the bell will fail.

ACKNOWLEDGMENTS.

In the solution of this work, we are indebted to Prof. C. A. Melick for advice and help and to the "American Handbook," Ketchum's "Structural Handbook," Morris' "Design and Detail of Steel Structures," "The Report of the Royal Commission on Quebec Bridge," and the "Theory and Practice of Modern Framed Structures," by Johnson, Bryan and Turneaure, for formulas, information and general knowledge of steel structures.

* * *

East Lansing
Water Tower

A.L.Sayles
C.H.Peterson

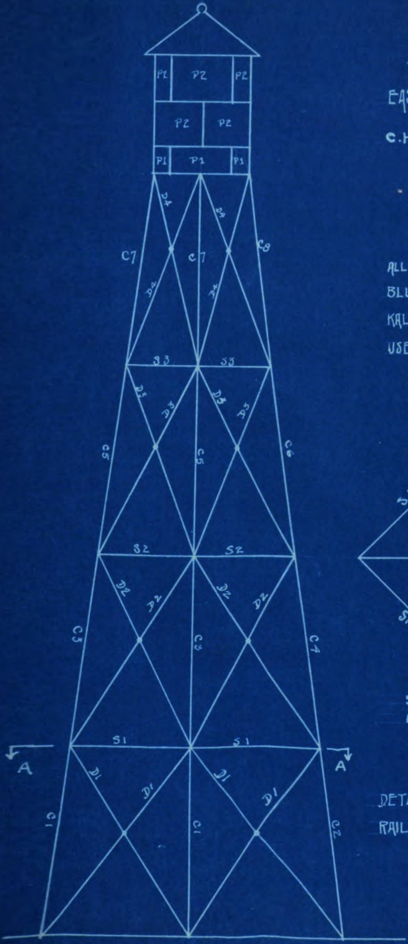
A.L.Sayles
C.H.Peterson

C.H.Peterson A.L.Sayles L.P.Dingham

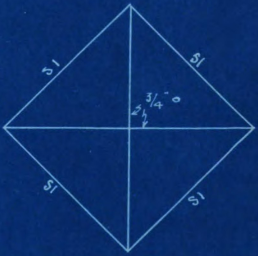
Strut L.P.Dingham

Column M.S.Fuller

ERECTION DRAWING
OF
EAST LANSING, MICH., WATER TOWER
THESIS OF
C.H. PETERSON - A.L. SAYLES
1915



ALL ERECTION MARKS TAKEN FROM BLUE PRINTS OF WHITEHEAD & KALES IRON WORKS AND WILL BE USED IN ALL REFERENCES.



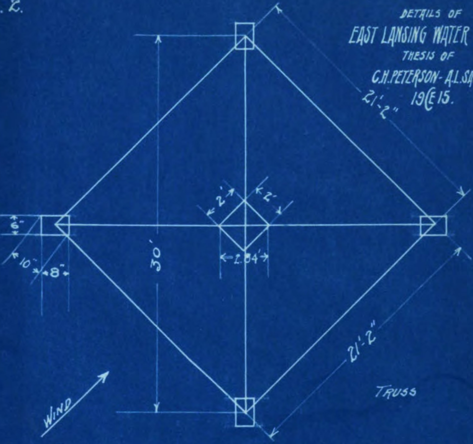
SECTION ON A-A, SHOWING HORIZONTAL TIE RODS

DETAILS NOT USED, SUCH AS: LADDERS, RAILINGS, ROOF PLATES, ETC., OMMITTED

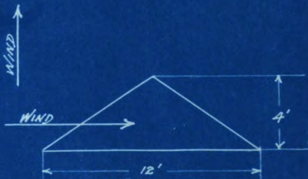
PRINT NO. 2.

DETAILS OF
EAST LANSING WATER TOWER
THESIS OF

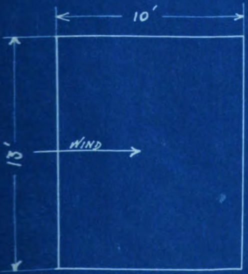
C.H. PETERSON - A.L. SAYLES,
19 CE 15.



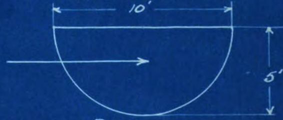
TRUSS



ROOF



DRUM.



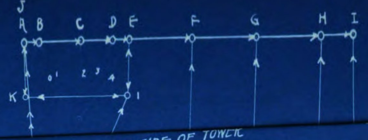
BELL

FROM KETCHUM'S "STRUCTURAL HANDBOOK"

WIND LOAD OF 30# /SQ.FT. ACTING IN ANY DIRECTION OR ON CYLINDERS CONICAL OR SPHERICAL SURFACES, THE WIND LOAD SHALL BE 2/3 OF HEIGHT X DIAMETER X 30#/□' APPLIED AT CENTRE OF GRAVITY.

GRAPHICAL SOLUTION OF WIND LOADS ON TOWER

THESIS OF
C.H. PETERSON - A.L. SAYLES.
19CE15



25' x 13' x 4'

WIND TAKEN AS BLOWING SQUARE AGAINST SIDE OF TOWER
MAX. STRESS IN COLUMNS WITH WIND BLOWING DIAGONALLY.

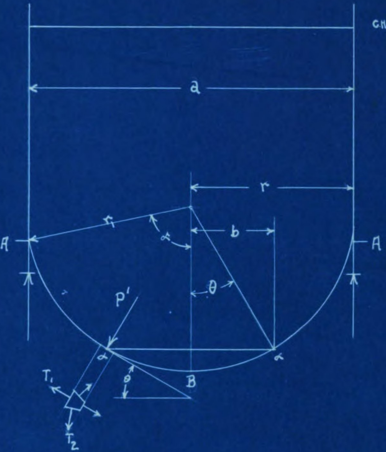
③

SAYLES

⑤

FORMULAS FOR STRESSES IN ELEVATED TANK

THESIS OF
G.H. PETERSON - A.L. SAYLES
1915.



STRESSES ON RADIAL JOINTS

FOR HEMISPHERICAL BOTTOM; $T_1 = \frac{2.6\, ha}{2t} = \frac{2.6\, hr}{t}$

FOR SEGMENTAL BOTTOM (B) $T_1 = \frac{W \csc^2\theta}{24\pi\, r_1 t}$

$W = 62.5\, h\pi\, r_1^2 \sin^2\theta$, and $T_1 = \frac{62.5\, hr_1}{24t} = \frac{2.6\, hr_1}{t}$

But $r_1 = r$, $\therefore$ $T_1 = \frac{2.6\, hr}{t}$

STRESSES IN CIRCUMFERENCIAL JOINTS.

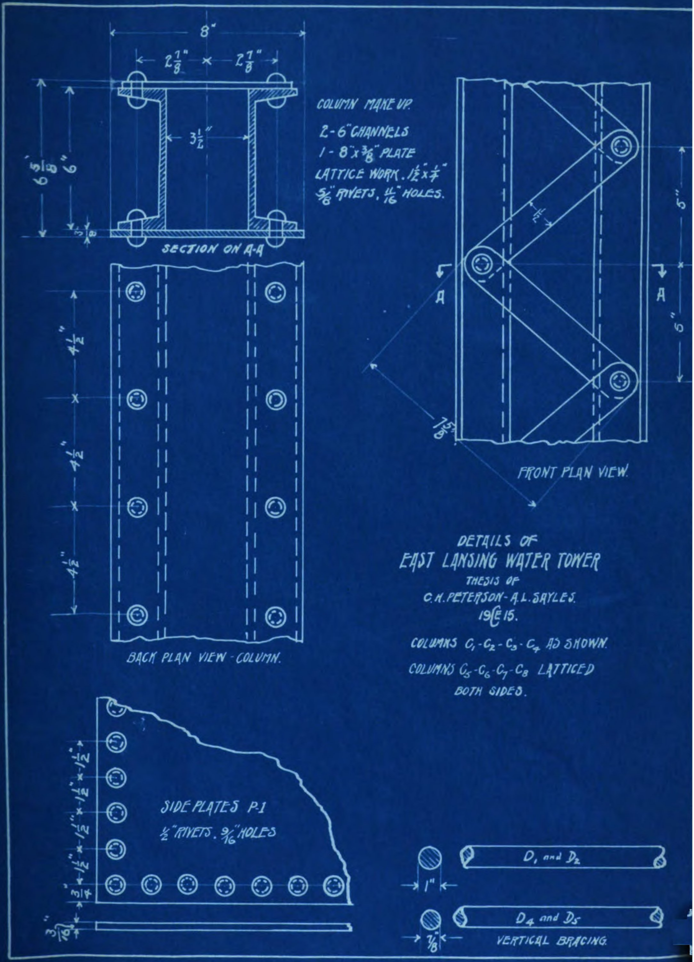
STRESSES SAME IN ALL DIRECTIONS OF SPHERE, $\therefore$

$T_2 = \frac{2.6\, hr}{t}$

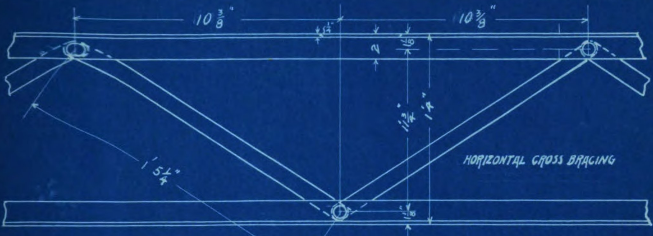
STRESSES IN SIDE PLATES

$S = \frac{2.6\, ha}{t}$

(KETCHUM'S "STRUCTURAL HANDBOOK")

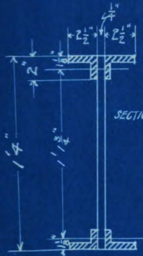


8"
2 7/8" × 2 7/8"
3 1/2"
6 5/8"
6"
3/8"
COLUMN MAKE UP.
2-6" CHANNELS
1-8"x3/8" PLATE
LATTICE WORK. 1½"x¼"
5/8" RIVETS. 11/16" HOLES.
SECTION ON A-A
A
A
5"
5"
7 5/8"
FRONT PLAN VIEW.
4½"
4½"
4½"
BACK PLAN VIEW - COLUMN.
DETAILS OF
EAST LANSING WATER TOWER
THESIS OF
C.H. PETERSON - A.L. SAYLES.
19 CE 15.
COLUMNS C1-C2-C3-C4 AS SHOWN.
COLUMNS C5-C6-C7-C8 LATTICED
BOTH SIDES.
SIDE PLATES P-1
½" RIVETS. 9/16" HOLES
3/4" - 1½" - 1½" - 1½" - 1½" - 1½"
3/16"
D1 and D2
1"
D4 and D5
7/8"
VERTICAL BRACING.



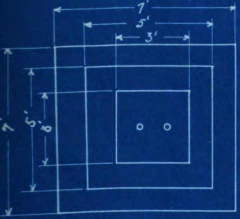
HORIZONTAL CROSS BRACING

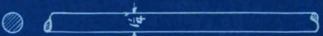
HORIZONTAL TIE RODS.



SECTIONAL VIEW

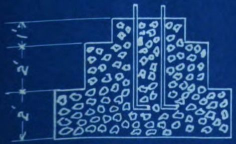
HORIZONTAL CROSS FRAME MAKE UP
4 ∟s 2 1/2" x 2" x 1/4". LATTICE WORK 1'-5 1/4" x 1 1/2" x 1/4"
RIVETS 5/8". HOLES 11/16" 2 - 3/4" RODS.





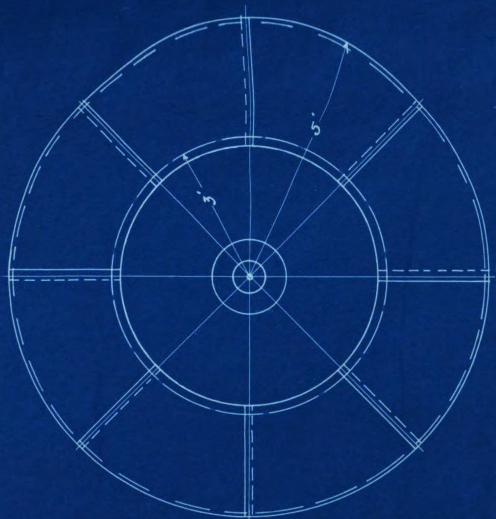
ANCHOR BOLT, 1 1/4" DIAM.

DETAILS OF
EAST LANSING WATER TOWER.
THESIS OF
C.H. PETERSON - A.L. SAYLES.
19 CE 15

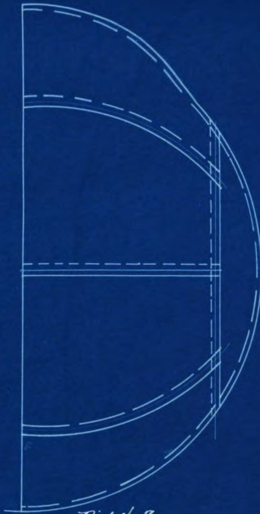


ABUTMENT MASONRY

(S)



MAKE UP OF BELL.
ALL PLATES 3/16" THICK AND 3/4" LAP
RIVET SPACING 1 1/2"
ALL RIVETS 1/2" HOLES 9/16"



Print No 7.
DETAILS OF
EAST LANSING WATER TOWER.
THESIS OF
C.H. PETERSON - A.L. SAYLES.
19E15.

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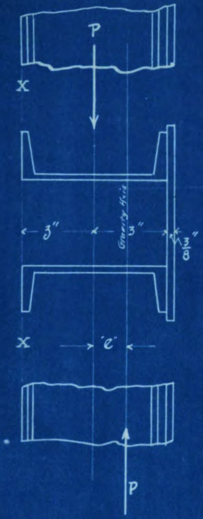
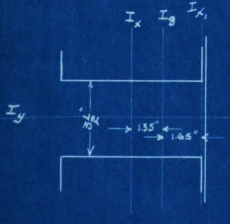
PRINT No. 8.



ECCENTRIC LOADING
DUE TO COVER PLATE.



$P = 72000^{\#}$
$A = 7.76\,\square''$
$e = 1.35''$
$c = 4.35''$
$I = 41.9\,in^4$ and $43.04\,in^4$

FORMULA FOR MAX UNIT STRESS IN COLUMN.

$$S = \frac{P}{A} + \frac{Pec}{I}$$

WHERE S = UNIT STRESS.
P = LOAD
A = AREA OF COLUMN SECTION
e = ECCENTRICITY.
C = DISTANCE TO MOST REMOTE FIBRE.
I = MOMENT OF INERTIA.

CENTRE OF GRAVITY OF COLUMN.

$$\bar{x} = \frac{\Sigma Wr}{\Sigma W}$$

WHERE W = AREA OF EACH PIECE AND r = DISTANCE FROM NEUTRAL AXIS.

USING GRAVITY AXIS AS REFERENCE LINE

$$\bar{x} = \frac{(4.76 \times 3) + 3\,(6 \times 3/16)}{7.76} = 4.35''$$

$e = 1.35''$
$4.76\,\square''$ = AREA OF 2 [
$3\,\square''$. " " PLATE.

MOMENT OF INERTIA

$I_x = I_g + Ad^2$ A = AREA, d = DISTANCE FROM GRAVITY AXIS

I_x OF 2[= $26\,in^4$ (KETCHUM)

$I_g\ 26 + 4.76 \times \overline{1.35}^2 = 34.7\,in^4$

I_{x_1} OF PLATE $= \frac{1}{3} bd^3 = \frac{1}{3} \times 8 \times \frac{27}{512} = 14\,in^4$

$I_g = 14 + 3 \times \overline{1.65}^2 = 8.34\,in^4$

TOTAL $I_g = 34.7 + 8.34 = 43.04\,in^4$

$I_y = 25.9$ FOR [

$I_y = 16.$ FOR PLATE

TOTAL $I_y = 25.9 + 16 = 41.9\,in^4$

EAST LANSING WATER TOWER.
THESIS OF
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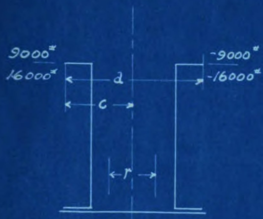
1915

PRINT NO. 9.
EAST LANSING WATER TOWER.
THESIS OF
C.H. PETERSON - A.L. SAYLES
19 CE 15



CROSS SECTION
COLUMN

STRESSES IN LACING

FORMULA $\frac{M}{S}=\frac{I}{c}$, $M=\frac{SI}{c}$ ALSO FROM FORMULA FOR UNIT COMPRESSION ALLOWED, $16000-70\frac{L}{R}=7000^{\#}$

$70\frac{L}{R}=9000^{\#}$ FOR MOST EXTREME FIBRE STRESS, COMPRESSION ON ONE SIDE AND TENSION ON OTHER.

THUS $S=M\frac{c}{I}$ $\quad c=d/2 \quad I=Ar^2$

and

$$9000 = M\frac{d/2}{Ar^2}$$

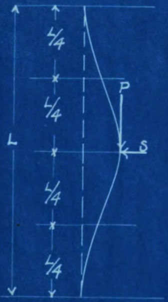
A = Area of Column Section
r = least radius of Gyration
c = distance to most remote fibre

THEN, $M = 9000\times\frac{Ar^2}{d/2}$

OR,

$9000\,Ar^2/\frac{d}{2} = S\frac{L}{4}$ where S = Shear.

AND $S=\frac{9000\times Ar^2\times 8}{L\,d}$

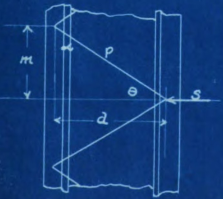


DEFLECTION
OF COLUMN

LET STRESS IN LATTICE WORK = K

THEN $K=\frac{S}{2}\times \sec\theta$

OR $K=\frac{S}{2}\times\frac{p}{d}$

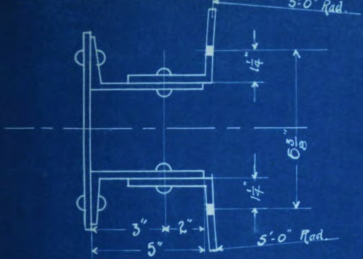


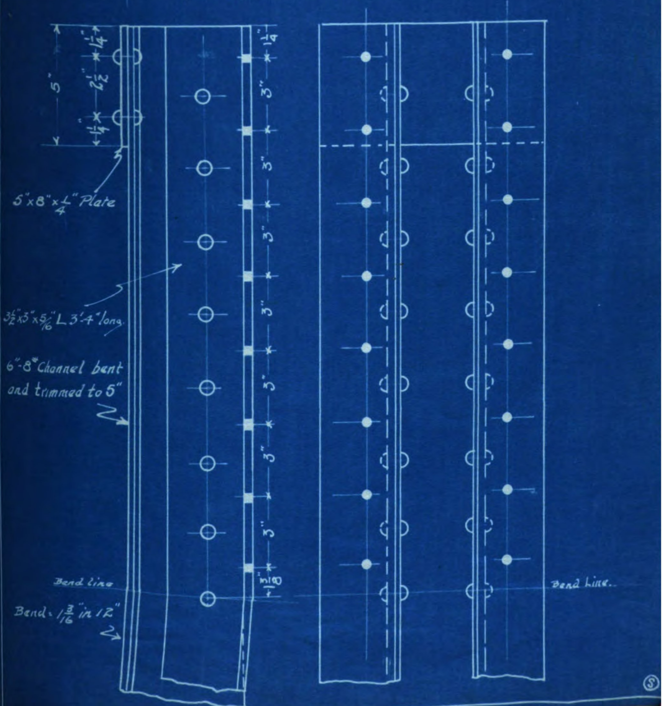
KETCHUMS FORMULA

STRESS = $280\frac{Ar}{c}\csc\alpha$

PRINT NO. 10
EAST LANSING WATER TOWER
THESIS OF
C.H. PETERSON - A. L. SAYLES
19 CE 15

RIVETED CONNECTIONS BETWEEN
TANK PLATES AND LEGS.





(S)

+ = COMPRESSION
- = TENSION

STRESSES IN
EAST LANSING WATER TOWER.
THESIS OF
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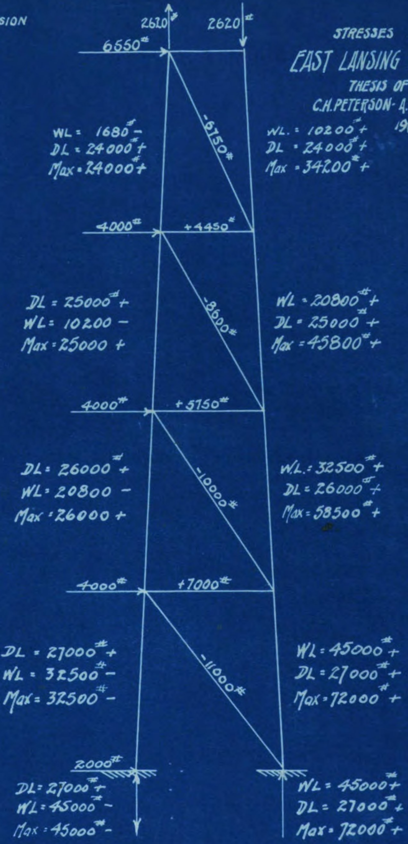
1915



PRINT NO. 11.