STRESS ANALYSIS,
STEEL FIRE TOWER

Thesis for the Degree of B. S.
MICHIGAN STATE COLLEGE
Richard W. Jones
1941

Stress Analysis, Steel Fire Tower

A Thesis Submitted to

The Faculty of

MICHIGAN STATE COLLEGE

of

AGRICULTURE AND APPLIED SCIENCE

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Bachelor of Science

June 1941

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INTRODUCTION

The need for steel observation towers, or fire towers, of the type which is analyzed in this thesis arose along with the need for the prevention and control of forest fires in the nations' timberlands. One of the most important factors in fire prevention and control is the detection of all fires while they are still in their early stages. Once a fire gets a good start, it is a difficult job to arrest its progress and keep it from spreading farther.

One man, armed with a pair of high-powered field glasses and situated in the cab of a fire tower one hundred feet above the ground, can watch over a large area of forest and can immediately report any traces of smoke he may see. If two men in different towers can see the same smoke, the exact location of the fire can be determined and men and equipment can be rushed to the spot before the fire has a chance to become very large.

A large number of these steel fire towers have been erected. The United States Forest Service has built them in the National Forests, and most of the state conservation departments have erected them to guard over their state forests.

The steel observation tower which is analyzed in this thesis is 109' high to the top of the cab, and is the most modern type in use at the present. This type has been adopted as standard by the Michigan Department of Conservation.

The tower is designed and built by the Aermotor Company, Chicago, Illinois. It consists mainly of structural steel angles, and all parts are cut to size, drilled properly, and galvanized at the factory. The members are shipped to the location of the new tower, and all the parts are numbered so that the tower is ready to assemble. It can be erected by a crew of four or five men, being assembled by means of either bolts and lock nuts, or bolts, nuts and lock washers.

The blueprint in the pocket in the back of the thesis shows an assembly view of the tower, the number of each piece, the size and number of all rolled sections, the size of bolts used and assembly details where needed. Also included in the back pocket is a checklist of all parts, giving the part number, quantity, name and description of each piece. All the information used in the analysis of the tower was taken from the assembly drawing and the checklist.

The main purpose in choosing this subject for a thesis was to enable the author to become more familiar with the methods of design and analysis of steel structures in general, and to apply these methods to a problem which required a technique different from the techniques that were used in the several design courses given in the civil engineering curriculum.

METHOD OF ANALYSIS

The method used to analyze the steel fire tower is similar to that which is commonly used in the design and analysis of a water tower. There are, however, certain features of the fire tower which make the problem of analysis somewhat different, and which require a slightly different procedure.

The presence in the structure of numerous interior bracing members and additional members in the exterior framework makes the tower a statically indeterminate structure. Therefore it can not be solved by the ordinary methods of mechanics. In order that it may be analyzed by a method which is not too highly technical, but which is practical and usable, certain assumptions are made to simplify the analysis. These assumptions are:

> The principal members which take the stresses are the columns, the diagonal braces and the horizontal struts, as shown in Fig. 1. The remaining members, with one exception, are not considered to take any stress, although their weight is included in the dead weight of the tower. The one exception consists of the horizontal girts to which the stairways are fastened. These girts are checked for stress caused by the weight of the stairways.

These assumptions form the basis for the complete stress analysis of the tower. The analysis is divided into three parts, each of which is followed through in detail on the following pages. The three parts are:

(1) The determination of the magnitude of the loads acting on the tower. These consist of the dead load and the live load.

(2) The determination of the total stresses and the unit stresses in the principal members, caused by the dead and live loads.

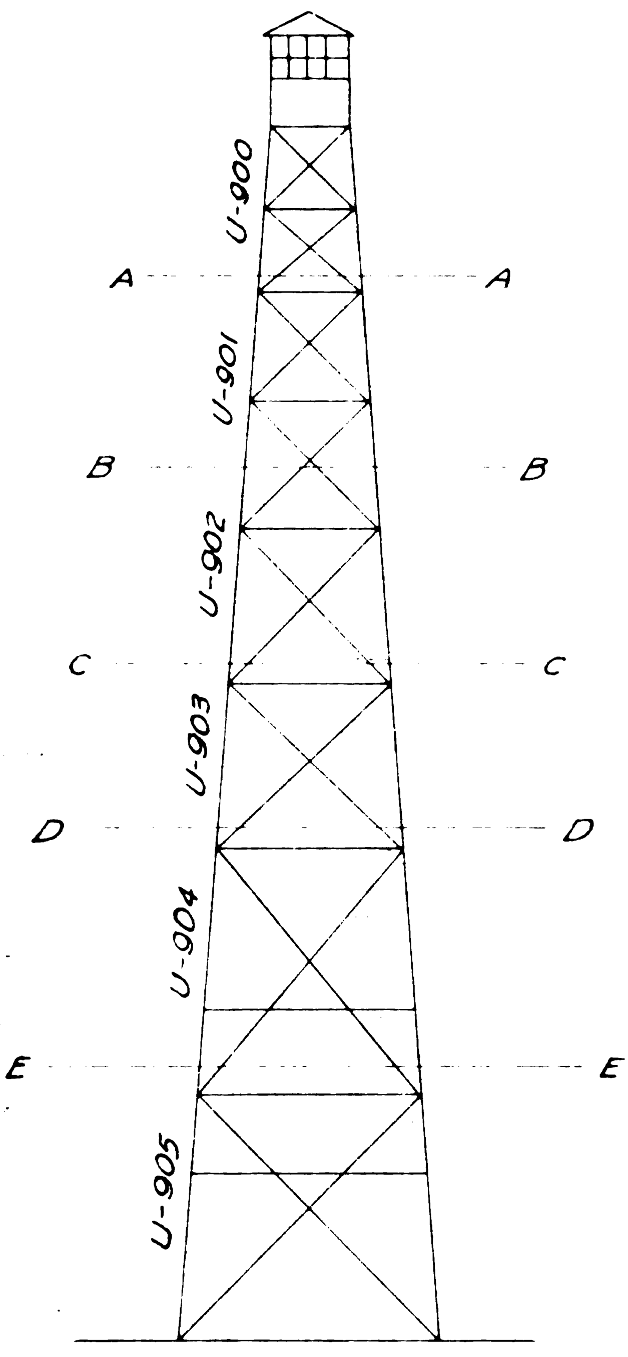
(3) The determination of the allowable unit stresses in the principal members, and a comparison between the actual unit stresses as found in part (2) and the allowable unit stresses.

DEAD AND LIVE LOADS

DEAD LOAD

The dead load to be considered in the analysis consists of the weights of the individual members, the weight of the people and equipment in the cab, and the weight due to snow on the cab roof.

In a symmetrical four-leg tower, the vertical dead load is commonly assumed to be divided equally between the four columns, and it is assumed that the struts and diagonals are not stressed by such vertical loads. However, in this tower, each column is made up of six lengths of structural steel angle, varying in size from 3"x 3"x 1/4" at the top of the tower to 5"x 5"x 3/8" at the bottom. Since the total weight on each column is not the same at different elevations, the maximum weight on each member of each column must be found. This is done by passing a section horizontally through the tower at the lower end of each member of the column, as shown in Fig. 1. Section "A-A" passes through the lower end of part U-900, section "B-B" through the lower end of part U-901, etc. The total vertical load above each section is found, and that load is divided equally between the four column members through which the section passes.



DEAD LOAD ON COLUMNS

FIG. 1

SNOW LOAD

The allowance for snow load depends on the pitch of the roof, the climate and the material of which the roof is made. Since these towers are used in so many locations, the maximum load for the given conditions is used. The computations for the snow load are as follows:

$$\text{Pitch} = \frac{\text{rise}}{\text{span}} = \frac{25''}{96''} = \frac{1}{4}$$

Type of roof = metal

Snow allowance = 25 lb. per sq. ft. of horizontal surface.

(from Structural Theory, by Sutherland and Bowman, p.61)

Horizontal projection of roof area = 7'x 7'

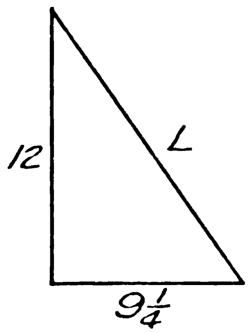
= 49 sq. ft.

Say 50 sq. ft.

Snow load = 25 x 50 = 1250 lb.

WEIGHTS OF STAIRWAYS

Before the weight of each stairway can be computed, its length must be found. The slope of all the stairways is shown in the figure:



$$L^2 = 12^2 + 9\tfrac{1}{4}^2$$
$$L^2 = 144 + 85.56$$
$$L^2 = 229.56$$
$$L = 15.15$$

L = length of stairway

= rise of stairway x $\frac{15.15}{12}$

= rise of stairway x 1.26

Rise of stairway is shown in Fig. 10.

L_2 = 6.75' x 1.26 = 8.5' = 8'-6"

L_3 = 9.0' x 1.26 = 11.35' = 11'-4"

L_4 = 10.5' x 1.26 = 13.25' = 13'-3"

L_5 = 12.75 x 1.26 = 16.08' = 16'-1"

L_6 = 13.5' x 1.26 = 17.0' = 17'-0"

L_7 = 17'-0"

L_8 = 17'-0"

L_9 = 17'-0"

The following are the computations for the weights of the stairways. The first figure is the part number as shown on the assembly drawing in the back pocket, followed by the quantity, description, weight per lineal foot and total weight of each part:

STAIRWAY NO. 1:

U-676	2 - 1½ x 1½ x 1/8 x 7'-0" @ 1.23	17.2 lb.
U-677	2 - 1½ x 1½ x 1/8 x 8'-0" @ 1.23	19.6
	16 - 2 x 2 x 1/8 x 1'-0" @ 1.65	26.4
	16 - 2 x 2 x 1/8 x 9¼" @ 1.65	20.4
	8 Treads - 2 x 10 x 2'-0" @ 4.29	68.6
U-690	1 - 1½ x 1½ x 1/8 x 2'-2 7/8" @ 1.23	2.8
U-691	1 - 1½ x 1½ x 1/8 x 4'-6 3/8" @ 1.23	5.6
U-698	1 - 2 x 2 x 1/8 x 4'-5 3/8" @ 1.65	7.4
	Total	168.0 lb.

STAIRWAY NO. 2:

U-678 U-679	4 - 1½ x 1½ x 1/8 x 8'-6" @ 1.23	41.8 lb.
	18 - 2 x 2 x 1/8 x 1'-0" @ 1.65	29.7
	18 - 2 x 2 x 1/8 x 9¼" @ 1.65	22.9
	9 Treads - 2 x 10 x 2'-0" @ 4.29	77.3
U-692	2 - 1½ x 1½ x 1/8 x 8'-5 9/16" @ 1.23	20.9
U-949; U-950 U-951; U-952	2 x 2 x 1/8 x 16'-4" @ 1.65	27.0
	Total	219.6 lb.

STAIRWAY NO. 3:

U-680 U-681	4 - $1\frac{1}{2}$ x $1\frac{1}{2}$ x 1/8 x 11'-4" @ 1.23	55.7 lb.
	24 - 2 x 2 x 1/8 x 1'-0" @ 1.65 24 - 2 x 2 x 1/8 x $9\frac{1}{4}$" @ 1.65	70.2
	12 Treads @ 8.58 lb. each	103.0
U-693	2 - $1\frac{1}{2}$ x $1\frac{1}{2}$ x 1/8 x 11'-$3\frac{1}{2}$" @ 1.23	27.7
U-949; U-950 U-951; U-952	(Same as no. 2)	27.0
U-703 U-704	2 - 2 x 2 x 1/8 x 7'-$11\frac{1}{4}$" @ 1.65	13.1
	Total	296.7 lb.
	Or	300.0 lb.

STAIRWAY NO. 4:

U-682 U-683	4 - $1\frac{1}{2}$ x $1\frac{1}{2}$ x 1/8 x 13'-3" @ 1.23	65.3 lb.
	28 - 2 x 2 x 1/8 x 1'-0" @ 1.65 28 - 2 x 2 x 1/8 x $9\frac{1}{4}$" @ 1.65	81.8
	14 Treads @ 8.58	120.2
U-694	2 - $1\frac{1}{2}$ x $1\frac{1}{2}$ x 1/8 x 13'-$2\frac{1}{2}$" @ 1.23	32.5
U-949; U-950 U-951; U-952	(Same as no. 2)	27.0
U-703 U-704	(Same as no. 3)	13.1
	Total	339.9 lb.
	Or	340.0 lb.

STAIRWAY NO. 5:

U-684 U-685	4 - 1½ x 1½ x 1/8 x 16'-1" @ 1.23	79.1 lb.
	34 - 2 x 2 x 1/8 x 1'-0" @ 1.65 34 - 2 x 2 x 1/8 x 9¼" @ 1.65	99.4
	17 Treads @ 8.58	146.0
U-695	2 - 1½ x 1½ x 1/8 x 16'-0¼" @ 1.23	39.4
U-949; U-950 U-951; U-952	(Same as no. 2)	27.0
U-703 U-704	(Same as no. 3)	13.1
	Total	404.0 lb.

STAIRWAYS NO. 6, 7, 8, 9:

U-686 U-687	4 - 1½ x 1½ x 1/8 x 17'-0" @ 1.23	83.8 lb.
	36 - 2 x 2 x 1/8 x 1'-0" @ 1.65 36 - 2 x 2 x 1/8 x 9¼" @ 1.65	105.0
	18 Treads @ 8.58	154.7
U-696	2 - 1½ x 1½ x 1/8 x 17'-0" @ 1.23	41.8
U-949; U-950 U-951; U-952	(Same as no. 2)	27.0
U-703 U-704	(Same as no. 3)	13.1
	Total	425.4 lb.
	Or	426.0 lb.

RAILINGS AT 6th, 7th & 8th LANDINGS:

U-955	2 - 2 x 2 x 1/8 x 3'-7½" @ 1.65	11.9 lb.
U-961	1 - 1½ x 1½ x 1/8 x 5'-1½" @ 1.23	6.3
U-959 U-960	2 - 1½ x 1½ x 1/8 x 2'-10" @ 1.23	7.0
	Total	25.2 lb.

WEIGHTS OF LANDINGS:

(Weights of 2" wooden planks = 7 lb. per sq. ft.)

Landing No. 1:	$(\frac{2.5+4.5}{2})$ x 2 x 7	49 lb.
Landing No. 2:	$(\frac{6 \times 3}{2})$ x 7	63 lb.
Landing No. 3:	$(\frac{6 \times 3}{2})$ x 7	63 lb.
Landing No. 4:	$(\frac{8 \times 4}{2})$ x 7	112 lb.
Landing No. 5:	$(\frac{8+3.5}{2})$ x 2.5 x 7	100 lb.
Landing No. 6:	(6 x 2.5) x 7	105 lb.
Landing No. 7:	" " "	105 lb.
Landing No. 8:	" " "	105 lb.

DEAD LOAD ABOVE SECTION A-A:

WEIGHT OF CAB-

U-956	1	Ventilator and base	10 lb.
U-670	4	Roof section- #20 ga. galv. 17 sq. ft. @ 1.5 lb./sq. ft.	102
U-947	4	Roof flashing- #20 ga. galv. 6" x 7'-0" @ 1.5	21
U-661 U-662	8	Roof angles- 2 x 2 x 1/8 x 4'-10$\frac{1}{2}$" @ 1.65	65
U-655	1	Cap plate- 12" x 12" x 3/16" with 6$\frac{1}{2}$" diam. hole	6
U-663 U-664	8	Gusset plate for roof angles- 4" x 6" x $\frac{1}{4}$"	13
U-919	4	Roof girt angles- 3 x 3 x $\frac{1}{4}$ x 6'-11$\frac{1}{2}$" @ 4.9	137
U-920	4	Roof girt clips- 3 x 3 x $\frac{1}{4}$ x 5$\frac{1}{2}$" @ 4.9	10
U-667	48	Sash clips- 1" x 1 3/4" x 3/16"	1
U-666	4	Fenestra metal sash with glass and U-668 clips-	300
U-587	4	Window sills- 3 x 3 x $\frac{1}{4}$ x 6'-11" @ 4.9	136
U-669	4	Siding- #20 ga. galv. 7' x 4' @ 1.5 lb./sq. ft.	168
U-588 U-589 U-590	2 1 1	Cab girts- 3 x 3 x $\frac{1}{4}$ x 6'-11" @ 4.9	136
U-591 U-592	1 1	Cab girts- 3 x 3 x $\frac{1}{4}$ x 6'-11" @ 4.9	69
U-593	1	Cab girt- 3 x 3 x $\frac{1}{4}$ x 2'-10$\frac{1}{2}$" @ 4.9	15
			1189 lb.

Weight forwarded-			1189 lb.
Equipment in cab-			100
Maximum of five men @ 160 lb. each-			800
Floor of cab and trapdoor- 50 sq. ft. @ 7 lb./sq. ft.			350
Snow load-			1250
Nuts, bolts, etc.-			100
WEIGHT OF STAIRWAYS-			
Weight of stairway no. 1-			168
One half weight of stairway no. 2-			110
WEIGHT OF COLUMNS-			
U-900	4	No. 1 corner post- 3 x 3 x ¼ x 19'-10" @ 4.9	388
WEIGHT BETWEEN CAB LANDING & 1st LANDING-			
U-546	8	No. 1 angle brace- 2 x 2 x 1/8 x 9'-7" @ 1.65	126
U-596	8	No. 1 girt- 2 x 2 x 1/8 x 3'-9½" @ 1.65	50
U-562	4	No. 1 tie- 2 x 2 x 1/8 x 3'-9" @ 1.65	25
U-571	8	Gusset plate, no. 2 girt- 10" x ¼" x 6½"	37
U-756x U-598 U-599	2 1 1	No. 2 girt- 2½ x 2½ x 3/16 x 7'-5¼" @ 3.07	92
U-921	1	Girt, 1st Landing- 3½ x 3½ x ¼ x 7'-1½" @ 5.8	41
U-601	1	Girt, 1st Landing- 2½ x 2½ x 3/16 x 2'-10½" @ 3.07	9
U-602	2	Girt, 1st Landing- 2 x 2 x 1/8 x 5'-1" @ 1.65	17
			4852 lb.

WEIGHT BETWEEN 1st LANDING & 2nd LANDING-

Weight forwarded-			4852 lb.
U-547	8	No. 2 angle brace- 2 x 2 x 1/8 x 9'-11½" @ 1.65	132
U-604	8	No. 3 girt- 2 x 2 x 1/8 x 4'-3½" @ 1.65	57
U-563	4	No. 2 tie- 2 x 2 x 1/8 x 3'-10" @ 1.65	25
Landing no. 1-			49

TOTAL WEIGHT ON SECTION A-A 5115 lb.

DEAD LOAD ABOVE SECTION B-B:

WEIGHT BETWEEN 2nd LANDING & 3rd LANDING-

Weight above section A-A -			5115 lb.
U-605	2	No. 4 girt- 2 x 2 x 1/8 x 8'-4½" @ 1.65	28
U-606 U-607	1 1	No. 4 girt- 2½ x 2½ x 3/16 x 8'-4½" @ 3.07	52
U-914	4	No. 1 splice angle- 3 x 3 x ¼ x 0'-10" @ 4.9	17
U-572	8	Gusset plate, no. 4 girt- 8" x ¼" x 11 3/4"	54
U-901	4	No. 2 corner post- 3½ x 3½ x ¼ x 16'-0" @ 5.8	371
U-548	8	No. 3 angle brace- 2 x 2 x 1/8 x 12'-5" @ 1.65	165
U-609	3	Girt, 2nd landing- 2 x 2 x 1/8 x 6'-2" @ 1.65	31
U-922	1	Girt, 2nd landing- 3½ x 3½ x ¼ x 6'-2¼" @ 5.8	36
U-610	8	No. 5 girt- 2 x 2 x 1/8 x 4'-10½" @ 1.65	65
U-564	4	No. 3 tie- 2 x 2 x 1/8 x 5'-0¼" @ 1.65	34

WEIGHT BETWEEN 3rd LANDING & 4th LANDING-

U-611 U-612 U-613	2 1 1	No. 6 girt- 2½ x 2½ x 3/16 x 9'-9¼" @ 3.07	120
U-923	1	Girt, 3rd landing- 4 x 4 x ¼ x 6'-5" @ 6.6	43
			6131 lb.

Weight forwarded-			6131 lb.
U-615	2	Girt, 3rd landing- $2\frac{1}{2}$ x $2\frac{1}{2}$ x 1/8 x 7'-6" @ 2.08	32
U-616	1	Girt, 3rd landing- $2\frac{1}{2}$ x $2\frac{1}{2}$ x 1/8 x 7'-$1\frac{1}{4}$" @ 2.08	15
U-617	8	No. 7 girt- 2 x 2 x 1/8 x 5'-$7\frac{1}{2}$" @ 1.65	75
U-573	8	Gusset plate, no. 6 girt- 8" x $\frac{1}{4}$" x 11 3/4"	54
U-549	8	No. 4 angle brace- 2 x 2 x 1/8 x 14'-$6\frac{1}{4}$" @ 1.65	192
U-565	4	No. 4 tie- 2 x 2 x 1/8 x 5'-10" @ 1.65	39
One half weight of stairway no. 2 -			110
Weight of stairway no. 3 -			300
One half weight of stairway no. 4 -			170
Landing no. 2 -			63
Landing no. 3 -			63
TOTAL WEIGHT ON SECTION B-B			7244 lb.

DEAD LOAD ABOVE SECTION C-C:

WEIGHT BETWEEN 4th LANDING & 5th LANDING-

Weight above section B-B -			7244 lb.
U-915	4	No. 2 splice angle- $3\frac{1}{2}$ x $3\frac{1}{2}$ x $\frac{1}{4}$ x 1'-$0\frac{1}{2}$" @ 5.8	25
U-574	8	Gusset plate, no. 8 girt- 8" x $\frac{1}{4}$" x $12\frac{1}{4}$"	56
U-618 U-619 U-620	2 1 1	No. 8 girt- 3 x 3 x $\frac{1}{4}$ x 11'-$3\frac{1}{2}$" @ 4.9	222
U-924	1	Girt, 4th landing- 5 x $3\frac{1}{2}$ x 7/16 x 7'-9" @ 12.0	93
U-622	3	Girt, 4th landing- 3 x 3 x $\frac{1}{4}$ x 8'-2" @ 4.9	120
U-902	4	No. 3 corner post- 4 x 4 x $\frac{1}{4}$ x 16'-$2\frac{1}{4}$" @ 6.6	428
U-550	8	No. 5 angle brace- 2 x 2 x 1/8 x 17'-$3\frac{1}{2}$" @ 1.65	229
U-624	8	No. 9 girt- 2 x 2 x 1/8 x 6'-6" @ 1.65	86
U-566	4	No. 5 tie- 2 x 2 x 1/8 x 7'-1" @ 1.65	47
One half weight of stairway no. 4 -			170
One half weight of stairway no. 5 -			202
Landing no. 4 -			112
		TOTAL WEIGHT ON SECTION C-C	9034 lb.

DEAD LOAD ABOVE SECTION D-D:

WEIGHT BETWEEN 5th LANDING & 6th LANDING-

Weight above section C-C -			9034 lb.
U-916	4	No. 3 splice angle- 4 x 4 x $\frac{1}{4}$ x 1'-3" @ 6.6	33
U-575	8	Gusset plate, no. 10 girt- 8" x $\frac{1}{4}$" x 12 3/16"	56
U-625 U-626 U-627	2 1 1	No. 10 girt- 3 x 3 x $\frac{1}{4}$ x 13'-2$\frac{1}{2}$" @ 4.9	259
U-925	1	Girt, 5th landing- 5 x 3$\frac{1}{2}$ x 7/16 x 7'-10" @ 12.0	94
U-629	1	Girt, 5th landing- 2$\frac{1}{2}$ x 2$\frac{1}{2}$ x 3/16 x 3'-4$\frac{1}{2}$" @ 3.07	11
U-630	2	Girt, 5th landing- 3 x 3 x $\frac{1}{4}$ x 10'-4$\frac{1}{2}$" @ 4.9	98
U-631	1	Girt, 5th landing- 3 x 3 x $\frac{1}{4}$ x 9'-6$\frac{1}{4}$" @ 4.9	47
U-903	4	No. 4 corner post- 4 x 4 x 5/16 x 13'-6$\frac{1}{4}$" @ 8.2	444
U-551	8	No. 6 angle brace- 2 x 2 x 1/8 x 19'-3" @ 1.65	255
U-632	8	No. 11 girt- 2$\frac{1}{2}$ x 2$\frac{1}{2}$ x 1/8 x 7'-6" @ 2.08	125
U-567	4	No. 6 tie- 2 x 2 x 1/8 x 7'-5" @ 1.65	49
One half weight of stairway no. 5 -			202
One half weight of stairway no. 6 -			213
Landing no. 5 -			100
		TOTAL WEIGHT ON SECTION D-D	11029 lb.

DEAD LOAD ABOVE SECTION E-E:

Weight above section D-D -			11029 lb.
U-917	4	No. 4 splice angle- 4 x 4 x 5/16 x 1'-5½" @ 8.2	48
U-576	8	Gusset plate, no. 12 girt- 8" x ¼" x 13 3/8"	62
U-633 U-634 U-635	2 1 1	No. 12 girt- 3½ x 3½ x ¼ x 15'-3" @ 5.8	354
U-927	1	Girt, 6th landing- 5 x 3½ x 7/16 x 12'-2" @ 12.0	146
U-928	1	Do. 2½ x 2½ x 3/16 x 5'-7" @ 3.07	18
U-638	2	Do. 3½ x 3½ x ¼ x 10'-4" @ 5.8	120
U-639	1	Do. 3½ x 3½ x ¼ x 10'-11¼"	64
U-673 U-674	1 1	Do. 2½ x 2½ x 3/16 x 3'-5½" @ 3.07	22
U-904	4	No. 5 corner post- 4 x 4 x 7/16 x 19'-9½" @ 11.3	895
U-552	4	No. 7 angle brace- 2½ x 2½ x 1/8 x 12'-9¼" @ 2.08	
U-553	4	Do. 2½ x 2½ x 1/8 x 11'-4"	
U-554	4	Do. 2½ x 2½ x 1/8 x 14'-9¼"	
U-555	4	Do. 2½ x 2½ x 1/8 x 13'-4"	435
U-640	4	No. 13 girt- 2½ x 2½ x 1/8 x 16'-9½"	140
U-568	4	No. 7 tie- 2½ x 2½ x 1/8 x 4'-6"	38
			13362 lb.

Weight forwarded-			13362 lb.
U-642 U-643 U-644	2 1 1	No. 14 girt- 3 x 3 x ¼ x 17'-10" @ 4.9	349
U-931	1	Girt, 7th landing- 6 x 4 x 3/8 x 13'-7½" @ 12.3	168
U-646R U-646L	1 1	Do. 2½ x 2½ x 3/16 x 4'-2¼" @ 3.07	26
U-928	1	Do. 2½ x 2½ x 3/16 x 5'-7"	18

One half weight of stairway no. 6 - 213

Weight of stairway no. 7 - 426

One half weight of stairway no. 8 - 213

Landing no. 6 - 105

Landing no. 7 - 105

Railing at Landing no. 6 & no. 7 - 50

TOTAL WEIGHT ON SECTION E-E 15035 lb.

DEAD LOAD AT BASE:

Weight above section E-E -			15035 lb.
U-918	4	No. 5 splice angle- 4 x 4 x 7/16 x 2'-1" @ 11.3	94
U-579	8	Gusset plate, no. 15 girt- 11" x ¼" x 18"	112
U-651	4	No. 15 girt- 4 x 4 x ¼ x 18'-1½" @ 6.6	478
U-556	4	No. 8 angle brace- 2½ x 2½ x 1/8 x 12'-5" @ 2.08	
U-557	4	Do. 2½ x 2½ x 1/8 x 13'-8"	
U-558	4	Do. 2½ x 2½ x 1/8 x 14'-9"	
U-559	4	Do. 2½ x 2½ x 1/8 x 16'-0"	473
U-905	4	No. 6 corner post- 5 x 5 x 3/8 x 22'-3" @ 12.3	1100
U-569	4	No. 8 tie- 3 x 3 x ¼ x 9'-7" @ 4.9	188
U-562	4	Girt, section E-E - 4 x 4 x ¼ x 12'-11½" @ 6.6	342
U-654 U-655 U-656	2 1 1	No. 16 girt- 3 x 3 x ¼ x 19'-10¼" @ 4.9	388
U-940	1	Girt, 8th landing- 6 x 4 x 7/16 x 18'-0" @ 14.3	258
U-658L U-658R	1 1	Do. 2½ x 2½ x 3/16 x 6'-4½" @ 3.07	39
U-928	1	Do. 2½ x 2½ x 3/16 x 5'-7"	18
			18525 lb.

Weight forwarded-			18525 lb.
U-623	4	No. 17 girt- 3 x 3 x ¼ x 20'-10¼" @ 4.9	409
U-580	8	Gusset plate, base- 10" x ¼" x 9 5/8"	55
One half weight of stairway no. 8 -			213
One half weight of stairway no. 9 -			213
Landing no. 8 -			105
Railing at Landing no. 8 -			25
TOTAL WEIGHT ON BASE			19545 lb.

LIVE LOAD

The only live load which is considered to act on the tower is the wind load. Since the tower is quite likely to be located in an area where the wind attains a high velocity and in addition is a fairly high structure in itself (100'), maximum values for wind pressure are used.

The maximum value for the unit wind pressure must be found first. According to the principles of aerodynamics, the value for most structural shapes is as follows:

$p = cq$, where p = unit wind pressure,
c = a coefficient, and
q = velocity pressure.

But $q = 0.00256\ V^2$,
where V = wind velocity in M. P. H.,

and $c = 2.0$ (ave. value)

$$p = 2(0.00256\ V^2)$$

$$p = 0.00512\ V^2$$

Assume maximum $V = 75$ M. P. H.

$$p = 0.00512 \times 75^2$$

$p = 28.8$ lb./sq. ft. Use 30 lb./sq. ft.

The unit wind pressure used in the computations is 30 lb. per sq. ft. on the surface of the cab normal to the wind direction and on the projected area, normal to the wind direction, of the structural steel members.

Since the members are relatively small and spaced far apart, it is assumed that there is no shielding effect of members in the same line of wind direction.

The major compressive wind stress in a column occurs when the wind blows in a diagonal direction; that is, when the direction of the wind makes an angle of 45 degrees with the sides of the tower.

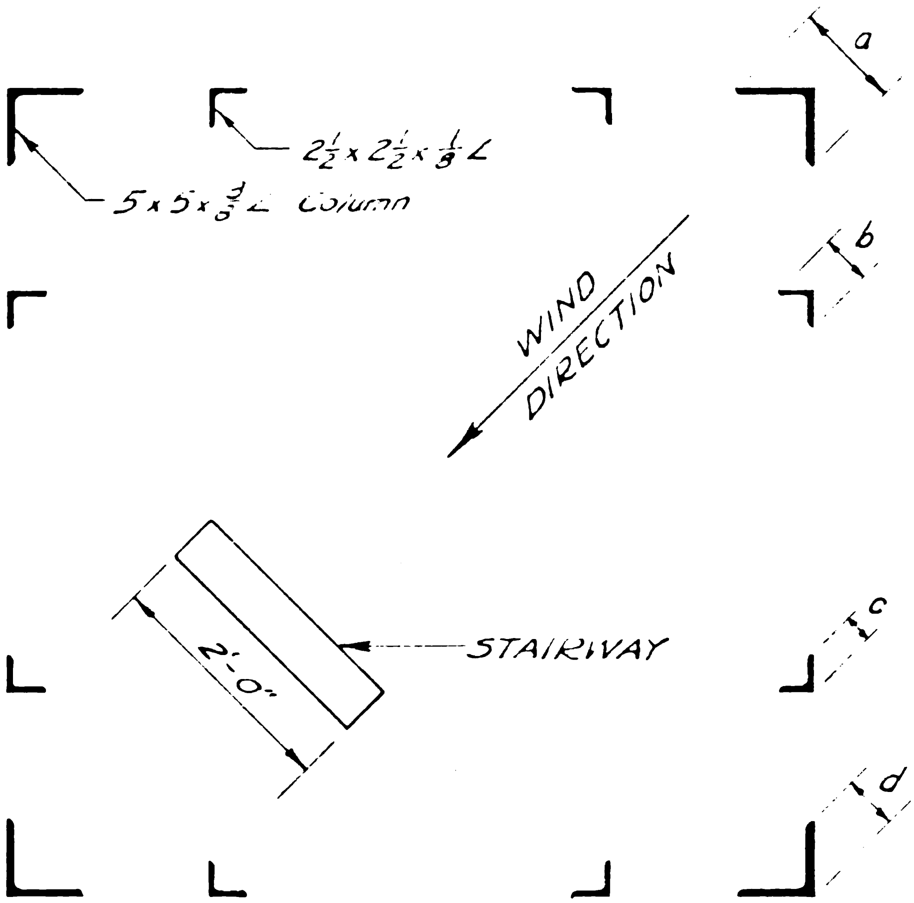
The wind load per foot of height is 170 lb. per ft. on a section near the base, as computed in Fig. 2. The value of this distributed load is assumed to be the same over the entire height of the tower.

The total wind load on the cab is computed thus:

$$P = p \times A$$

$$P = 30 \times 9.9 \times 7.5$$

$$P = 2230 \text{ lb.}$$ (See Fig. 6)



HORIZONTAL SECTION NEAR BASE

FIG. 2

$a = 5 \sec 45° = 7.07"$
$b = 2.5 \sec 45° = 3.54"$
$c = 2.5 \sin 45° = 1.77"$
$d = 5 \sin 45° = 3.54"$

AREA, NORMAL TO WIND, PER FOOT OF HEIGHT:

5x5 ∠s:	2(12 x 3.54) =	85 sq in
	2 (12 x 7.07) =	170 " "
$2\frac{1}{2}$x$2\frac{1}{2}$ ∠s:	4 (12 x 1.77) =	85 " "
	4 (12 x 3.54) =	170 " "
STAIRWAY:	12 x 24 =	288 " "

TOTAL = 798 sq. in. = 5.55 sq. ft.

WIND LOAD, PER FOOT OF HEIGHT:

$P = p \times A$
$= 30 \times 5.55$
$= 166.5$ #/ft.

The maximum wind stress in a diagonal occurs when the wind direction is parallel to one side of the tower.

The wind load in this case is 145 lb. per ft. of height, figured at a section near the base, as shown in Fig. 3. This value is assumed over the entire height of the tower. The uniformly distributed load is assumed to be concentrated at the joints, as shown in Fig. 4. The values for the concentrated loads are:

$$P_0 = 30 \times 7 \times 7.5 = 1575, \text{ say } 1600 \text{ lb.}$$

$$P_1 = \frac{6.75}{2} \times 145 = 490 \text{ lb.}$$

$$P_2 = \left(\frac{6.75}{2} + \frac{6.75}{2}\right) 145 = 980 \text{ lb.}$$

$$P_3 = \left(\frac{6.75}{2} + \frac{9}{2}\right) 145 = 1140 \text{ lb.}$$

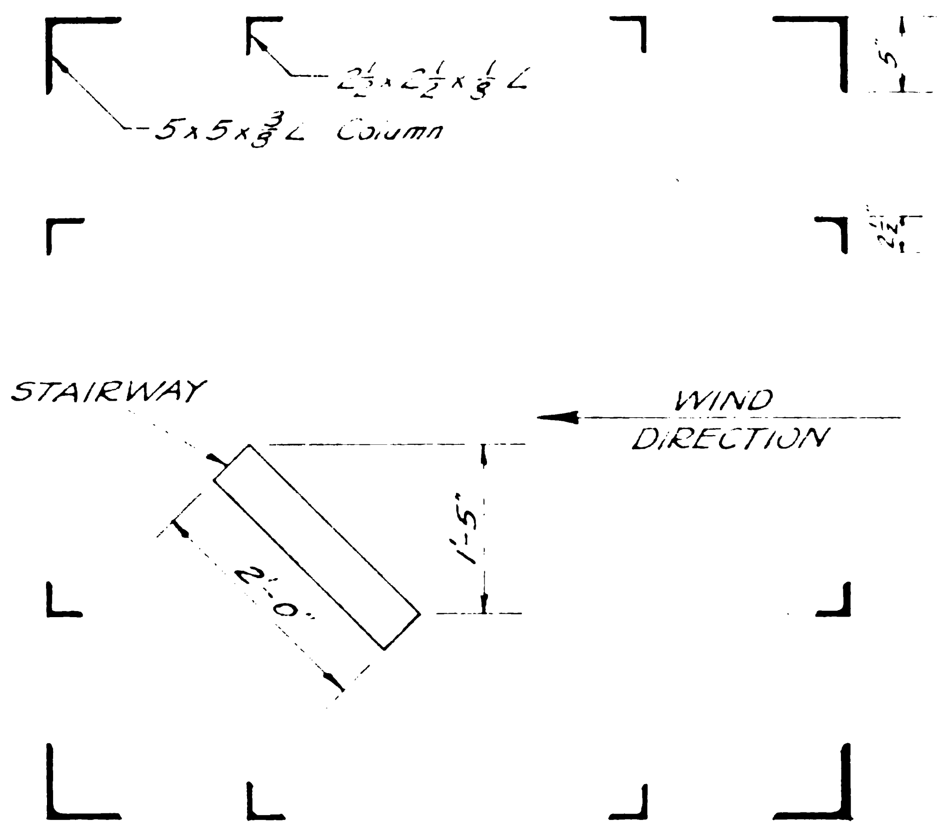
$$P_4 = \left(\frac{9}{2} + \frac{10.5}{2}\right) 145 = 1420 \text{ lb.}$$

$$P_5 = \left(\frac{10.5}{2} + \frac{12.75}{2}\right) 145 = 1690 \text{ lb.}$$

$$P_6 = \left(\frac{12.75}{2} + \frac{13.5}{2}\right) 145 = 1910 \text{ lb.}$$

$$P_7 = \left(\frac{13.5}{2} + \frac{20.25}{2}\right) 145 = 2450 \text{ lb.}$$

$$P_8 = \left(\frac{20.25}{2} + \frac{20.25}{2}\right) 145 = 2940 \text{ lb.}$$



HORIZONTAL SECTION NEAR BASE

FIG. 3.

TOTAL AREA, NORMAL TO WIND, PER FOOT OF HEIGHT:

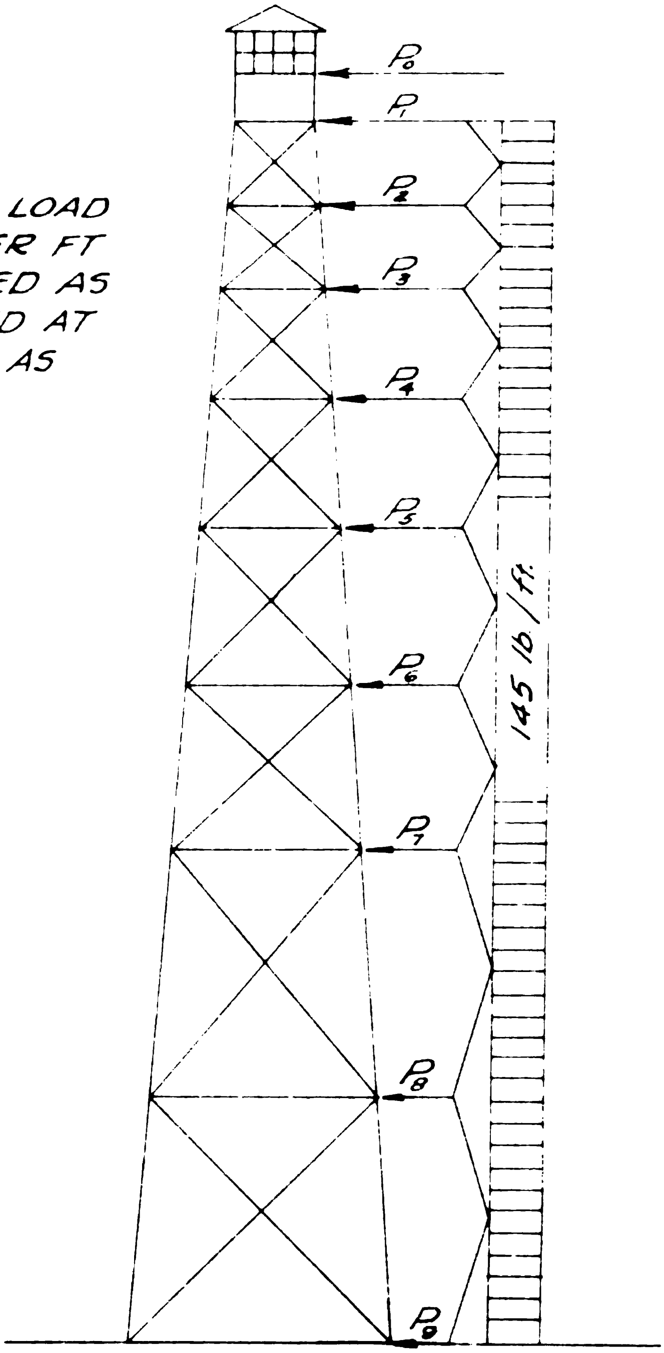
5 x 5 ∠s : 4(12 x 5) = 240 sq. in.
2½ x 2½ ∠s : 4(12 x 2.5) = 120 " "
STAIRWAY: 12 x 17 = 204 " "

TOTAL 684 sq. in. = 4.75 sq. ft.

WIND LOAD, PER FOOT OF HEIGHT:

$$P = p \times A$$
$$= 30 \times 4.75$$
$$= 142.5 \ \#/ft.$$

DISTRIBUTED LOAD OF 145 LB. PER FT IS CONSIDERED AS CONCENTRATED AT THE JOINTS, AS SHOWN.



WIND LOAD FOR MAXIMUM DIAGONAL STRESS

FIG. 4.

DETERMINATION OF STRESSES

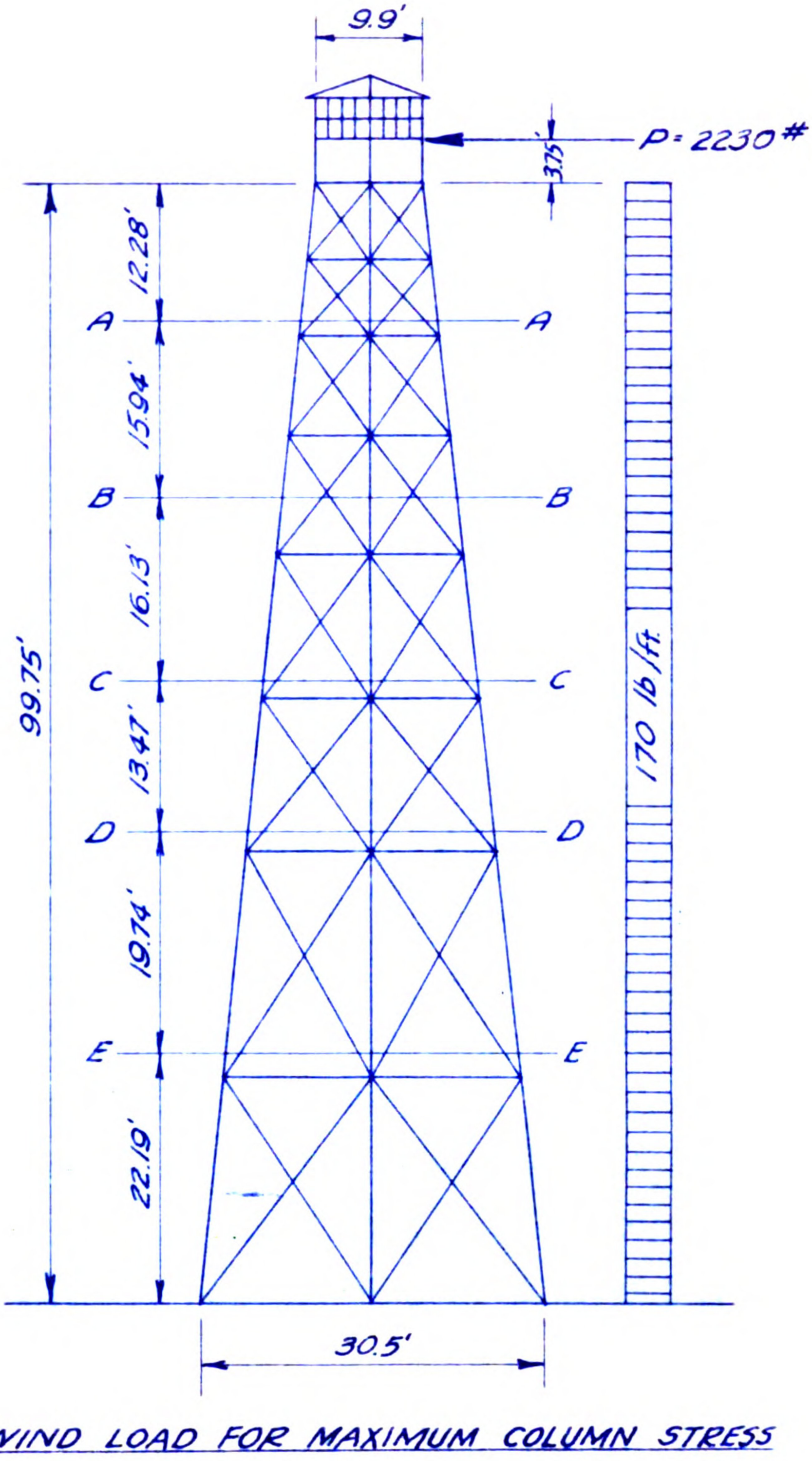
COLUMN STRESSES

The stresses in the members making up the columns are compressive stresses, due to the dead load (weight) and the live load (wind).

The compressive stress due to dead load in any member is found by dividing the total weight above the section through that member by four, since it is a four-post tower. The results are shown in Table 1 below. The section numbers and column numbers refer to Fig. 1.

TABLE 1

SECTION	COLUMN NO.	WEIGHT ABOVE SECTION	V-COMPONENT COLUMN STRESS
A-A	U-900	5115 lb.	1279 lb.
B-B	U-901	7244	1811
C-C	U-902	9034	2259
D-D	U-903	11020	2755
E-E	U-904	15035	3759
Base	U-905	19545	4886



WIND LOAD FOR MAXIMUM COLUMN STRESS

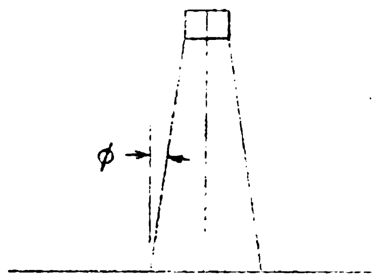
FIG. 6.

TABLE 2

SECTION	y	$(99.75 - y)$	$.2065 \times (99.75 - y)$	x	y^2
A-A	12.28	87.47	18.06	12.44	150.80
B-B	28.22	71.53	14.77	15.73	796.37
C-C	44.35	55.40	11.44	19.06	1966.92
D-D	57.82	41.93	8.66	21.84	3343.15
E-E	77.56	22.19	4.58	25.92	6015.55
Base	99.75	0	0	30.50	9950.06

SECTION	(A) $85y^2$	$(y + 3.75)$	(B) $2230 \times (y + 3.75)$	$(A) + (B)$	V_c
A-A	12,818.00	16.03	35,746.90	48,564.90	3904
B-B	67,691.45	31.97	71,293.10	138,984.60	8836
C-C	167,188.20	48.10	107,263.00	274,451.20	14400
D-D	284,167.75	61.57	137,301.10	421,468.90	19298
E-E	511,321.75	81.31	181,321.30	692,643.10	26722
Base	845,755.10	103.50	230,805.00	1,076,560.10	35297

The total vertical component of the compression in the column members equals the vertical component due to the dead load plus the vertical component due to the live load. The axial compressive stress is found from the vertical component as follows:



$$\text{Tan } \phi = \frac{\frac{1}{2}(30.5 - 9.9)}{99.75}$$

$$\text{Tan } \phi = .1032$$

$$\phi = 5^\circ\text{-}54'$$

FIG. 7.

$$\text{Cos } \phi = \frac{\text{V-component}}{\text{stress}}$$

$$\text{Stress} = \frac{\text{V-component}}{\cos \phi}$$

$$\text{Stress} = \frac{\text{V-component}}{\cos 5^\circ\text{-}54'}$$

$$\text{Stress} = \frac{\text{V-component}}{.9947}$$

TABLE 3

COMPUTATIONS FOR TOTAL COMPRESSIVE STRESS AND UNIT COMPRESSIVE STRESS

SECTION	V-COMPONENT DEAD LOAD	V-COMPONENT LIVE LOAD	V-COMPONENT TOTAL	COMPRESSION IN MEMBER
A-A	1,279	3,904	5,183	5,211
B-B	1,811	8,836	10,647	10,704
C-C	2,259	14,400	16,659	16,748
D-D	2,755	19,298	22,053	22,170
E-E	3,759	26,722	30,481	30,643
Base	4,886	35,297	40,183	40,397

SECTION	COLUMN NO.	SIZE OF COLUMN	AREA (SQ. IN.)	UNIT STRESS (COMPRESSION)
A-A	U-900	3 x 3 x 1/4	1.44	3,620 lb/sq in
B-B	U-901	3½ x 3½ x 1/4	1.69	6,335 "
C-C	U-902	4 x 4 x 1/4	1.94	8,633 "
D-D	U-903	4 x 4 x 5/16	2.40	9,238 "
E-E	U-904	4 x 4 x 7/16	3.31	9,258 "
Base	U-905	5 x 5 x 3/8	3.61	11,190 "

DIAGONAL STRESSES

The wind load which causes the maximum stress in the diagonals is shown in Figure 4. If the tower is considered as being made up of four bents, then the wind force will be resisted by the two bents whose planes are parallel to the wind direction. Therefore each bent will take one half of the concentrated wind loads. The loading on one bent is shown in Figure 10.

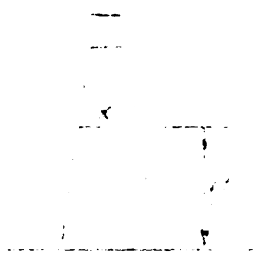
Before the stresses in the diagonals can be computed, the lengths of the horizontal and diagonal struts must be determined. This is done on the following pages in Tables 4 and 5.

COMPUTATIONS FOR LENGTH OF HORIZONTAL STRUTS-

Decrease in length in 99.75' = 21.56' - 6.72'

= 14.84'

Decrease in length in 1.0' = $\frac{14.84}{99.75}$ = .1488'



x = 21.56 - .1488y

FIG. 8.

TABLE 4

STRUT	y	.1488y	x
pr	20.25	3.01	18.55
no	40.50	6.03	15.53
km	54.00	8.04	13.52
ij	66.75	9.93	11.63
gh	77.25	11.49	10.07
ef	86.25	12.83	8.73
cd	93.00	13.84	7.72
ab	99.75	14.84	6.72

COMPUTATIONS FOR LENGTH OF DIAGONAL STRUTS-

The equations which are used for finding the lengths of the diagonal struts are derived in Fig. 9 below, and the computations are tabulated in Table 5.

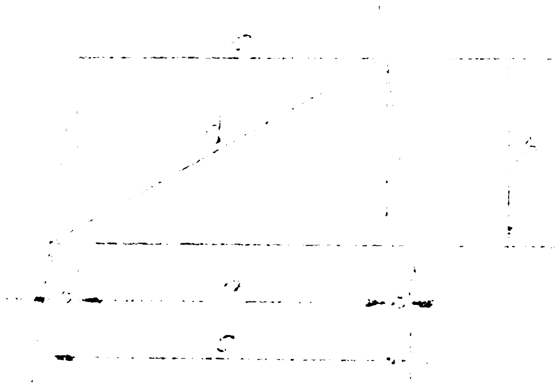


FIG. 9

Equations:

$$a + 2b = c$$

$$2b = c - a$$

$$b = \frac{c - a}{2} \qquad (1)$$

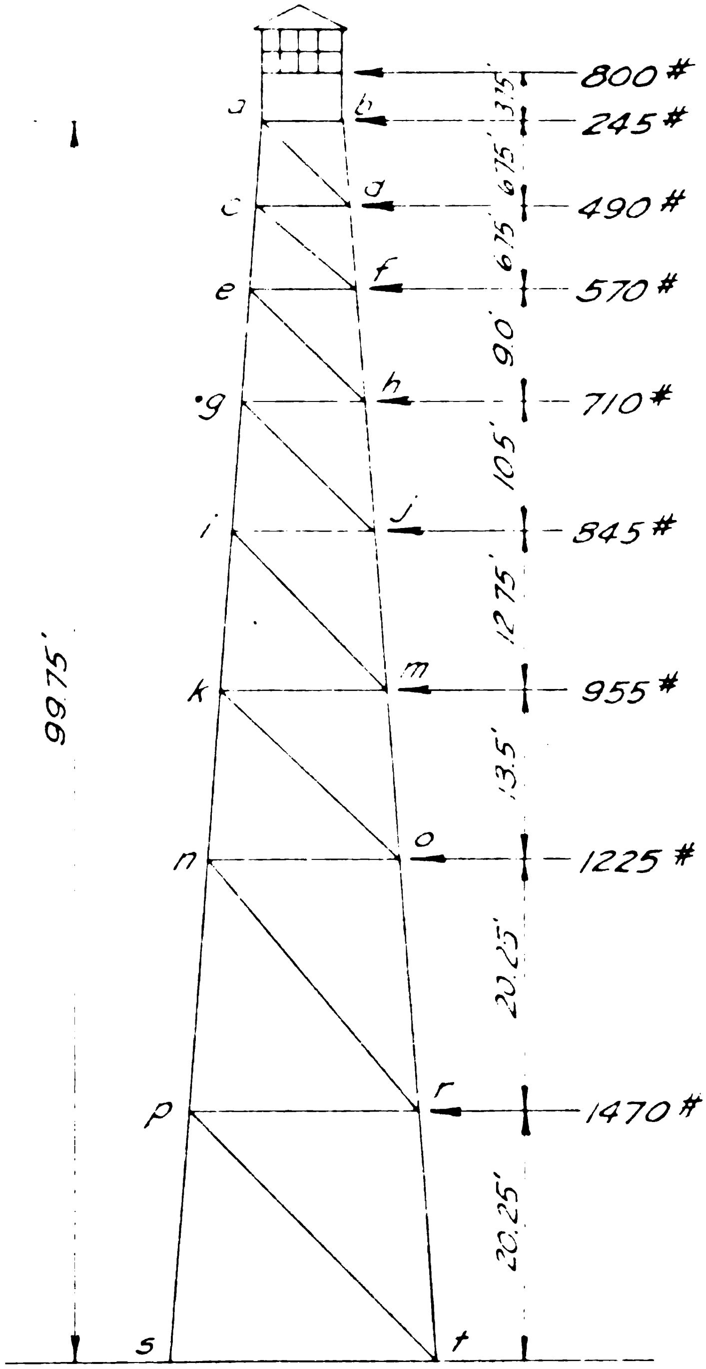
$$d^2 = h^2 + (a + b)^2$$

$$d = \sqrt{h^2 + (a + b)^2} \qquad (2)$$

TABLE 5

STRUT	"c"	"a"	"c - a"	"b"	"h"
ad	7.72	6.72	1.00	0.50	6.75
cf	8.73	7.72	1.01	0.51	6.75
eh	10.07	8.73	1.34	0.67	9.00
gj	11.63	10.07	1.56	0.78	10.50
im	13.52	11.63	1.89	0.95	12.75
ko	15.53	13.52	2.01	1.01	13.50
nr	18.55	15.53	3.02	1.51	20.25
pt	21.56	18.55	3.01	1.51	20.25

Strut	"h^2"	"a + b"	$(a + b)^2$	$h^2 + (a + b)^2$	"d"
ad	45.56	7.22	52.13	97.69	9.88
cf	45.56	8.23	67.73	113.29	10.64
eh	81.00	9.40	88.36	169.36	13.01
gj	110.25	10.85	117.72	227.97	15.10
im	162.56	12.58	158.26	320.82	17.91
ko	182.25	14.53	211.12	393.37	19.83
nr	410.06	17.04	290.36	700.42	26.47
pt	410.06	20.06	402.40	812.46	28.50



WIND LOAD ON ONE BENT

ONLY TENSION DIAGONALS SHOWN

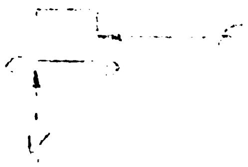
FIG 10

COMPUTATIONS FOR STRESSES IN THE DIAGONAL STRUTS-

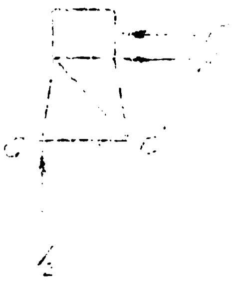
The method used for computing the diagonal stresses is as follows: First the method of sections is used and horizontal sections are passed through the tower at each horizontal strut. Moments are taken about the joints in the right-hand column (joints b-d-f, etc.) to determine the upward vertical thrust (V) in the corresponding joints in the left-hand column. Then, by using the method of joints, the vertical component of the stress in each diagonal can be found. Since the slope of each strut is known, the axial tensile stress in each diagonal can be determined.

The following sample computations show the procedure used in determining the diagonal stresses. The complete computations are tabulated in Tables 6 and 7.

$$\Sigma M_b = 0; \quad V_1 \times ab = M_b$$
$$V_1 \times 6.72 = 3.75 \times 800$$
$$V_1 \times 6.72 = 3000$$
$$V_1 = 446.4$$



$$\Sigma M_d = 0; \quad V_2 \times cd = M_d$$
$$V_2 \times cd = M_b + \Sigma F_x \times \Delta y$$
$$V_2 \times 7.72 = 3000 + 1045 \times 6.75$$
$$V_2 \times 7.72 = 10{,}053.75$$
$$V_2 = 1302.3$$



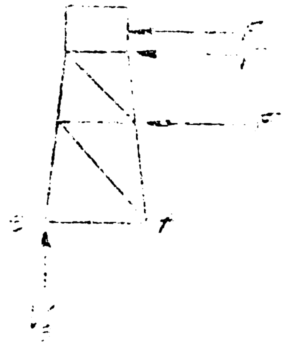
$\Sigma M_f = 0;\quad V_3 \times ef = M_f$

$V_3 \times ef = M_d + \Sigma F_x \times \Delta y$

$V_3 \times 8.73 = 10{,}053.75 + 1535 \times 6.75$

$V_3 \times 8.73 = 20{,}415.0$

$V_3 = 2338.5$

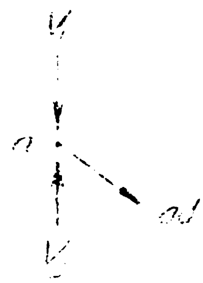


<u>At joint "a"</u>:

$\Sigma V = 0;\quad ad_v = V_2 - V_1$

$ad_v = 1302.3 - 446.4$

$ad_v = 855.9$



$ad = 855.9 \times \frac{\text{length}}{\text{V-proj.}}$

$ad = 855.9 \times \frac{9.88}{6.75}$

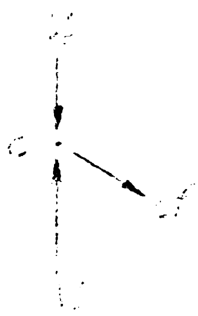
$ad = 1253 \text{ lb.}$

<u>At joint "c"</u>:

$\Sigma V = 0;\quad cf_v = V_3 - V_2$

$cf_v = 2338.5 - 1302.3$

$cf_v = 1036.2$



$cf = 1036.2 \times \frac{\text{length}}{\text{V-proj.}}$

$cf = 1036.2 \times \frac{10.64}{6.75}$

$cf = 1634 \text{ lb.}$

TABLE 6

ABOVE SECTION	ΣF_x	Δy	x	MOMENT M	V
ab	800	3.75	6.72	3,000.0	446.4
cd	1045	6.75	7.72	10,053.75	1302.3
ef	1535	6.75	8.73	20,415.0	2338.5
gh	2105	9.00	10.07	39,360.0	3908.6
ij	2815	10.50	11.63	68,917.5	5925.8
km	3660	12.75	13.52	115,582.5	8549.0
no	4615	13.50	15.53	177,885.0	11454.3
pr	5840	20.25	18.55	296,145.0	15964.7
st	7310	20.25	21.56	444,172.5	20601.7

TABLE 7

JOINT	DIAGONAL	V-COMP.	LENGTH	V-PROJ.	TENSION IN MEMBER
a	ad	855.9	9.88	6.75	1253
c	cf	1036.2	10.64	6.75	1633
e	eh	1570.1	13.01	9.00	2270
g	gj	2017.2	15.10	10.50	2901
i	im	2633.2	17.91	12.75	3685
k	ko	2905.3	19.83	13.50	4268
n	nr	4510.4	26.47	20.25	5896
p	pt	4637.0	28.50	20.25	6526

COMPUTATIONS FOR UNIT STRESS IN DIAGONAL STRUTS

TABLE 8

DIAGONAL	TENSION	BOLT DIAMETER	EFFECTIVE NET AREA	UNIT STRESS
ad	1253	5/8"	0.29	4320 lb/sq in
cf	1633	5/8"	0.29	5640 "
eh	2270	5/8"	0.29	7830 "
gj	2901	5/8"	0.29	10000 "
im	3685	5/8"	0.29	12700 "
ko	4268	5/8"	0.29	14700 "
nr	5896	3/4"	0.39	15100 "
pt	6526	3/4"	0.39	16730 "

EFFECTIVE NET AREA AT SECTION Y-Y: (SEE FIG. 11)

Net area = Area of angle − two holes

Net area = Area of angle − (d + 1/8) x 2t

For 2 x 2 x 1/8 angle and 5/8" bolt;

Net area = 0.48 − (5/8 + 1/8) x 2 x 1/8 = 0.29 sq in

For $2\frac{1}{2}$ x $2\frac{1}{2}$ x 1/8 angle and 3/4" bolt;

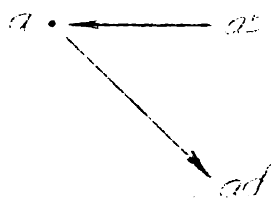
Net area = 0.61 − (3/4 + 1/8) x 2 x 1/8 = 0.39 sq in

COMPUTATIONS FOR STRESSES IN THE HORIZONTAL STRUTS-

The stresses in the horizontal struts are determined by the method of joints. The joints in the left-hand column are used, as before. The following sample computations show the procedure used to determine the stresses. The complete computations are tabulated in Table 9.

At joint "a":

$\Sigma H = 0; \quad ab = ad_h$



$$ab = ad \times \frac{\text{H-proj.}}{\text{length}}$$

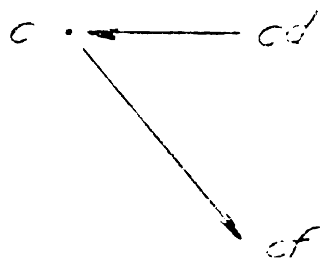
But, H-proj. = $a + b$ (Fig. 9)

$$ab = ad \times \frac{a + b}{\text{length}}$$

$$ab = 1253 \times \frac{7.22}{9.88} = 916 \text{ lb}$$

At joint "c":

$\Sigma H = 0; \quad cd = cf_h$



$$cd = cf \times \frac{\text{H-proj.}}{\text{length}}$$

$$cd = cf \times \frac{a + b}{\text{length}}$$

$$cd = 1633 \times \frac{8.23}{10.64} = 1263 \text{ lb}$$

TABLE 9

STRUT	DIAGONAL STRESS	H-PROJECTION (a + b)	LENGTH	COMPRESSION IN STRUT
ab	1253	7.22	9.88	916
cd	1633	8.23	10.64	1263
ef	2270	9.40	13.01	1640
gh	2901	10.85	15.10	2084
ij	3685	12.58	17.91	2588
km	4268	14.53	19.83	3127
no	5896	17.04	26.47	3796
pr	6526	20.06	28.50	4593

STRUT	SIZE OF STRUT	AREA	UNIT STRESS
ab	3 x 3 x 1/4	1.44	636 lb/sq in
cd	2½ x 2½ x 3/16	0.90	1403 "
ef	2 x 2 x 1/8	0.48	3417 "
gh	2½ x 2½ x 1/8	0.61	3416 "
ij	3 x 3 x 1/4	1.44	1797 "
km	3 x 3 x 1/4	1.44	2172 "
no	3½ x 3½ x 1/4	1.69	2246 "
pr	4 x 4 x 1/4	1.94	2368 "

STRESSES IN HORIZONTAL GIRTS WHICH SUPPORT STAIRWAYS-

Although these members are not considered to take any of the live load stresses, they do support the dead weight of the stairways. Because of the fact that they are quite long and have the concentrated load of the stairways near the center of the girt, they are analyzed for both shear and bending moment.

The method used for the analysis is as follows: The girt is treated as a simple beam, supported at both ends, and acted upon by two loadings. The first is a uniformly distributed load equal to the weight per unit length of the member. The second loading consists of two concentrated loads, each one of which is equal to one half the weight of the stairway which it represents.

The total shear and bending moment for each member are found by drawing their shear and bending moment diagrams. These are shown in Figures 12 to 19 inclusive. The unit shearing and bending stresses are then computed and the results are tabulated in Table 10.

U-921

7½ x 3½ x ½ x 7 – [illegible]

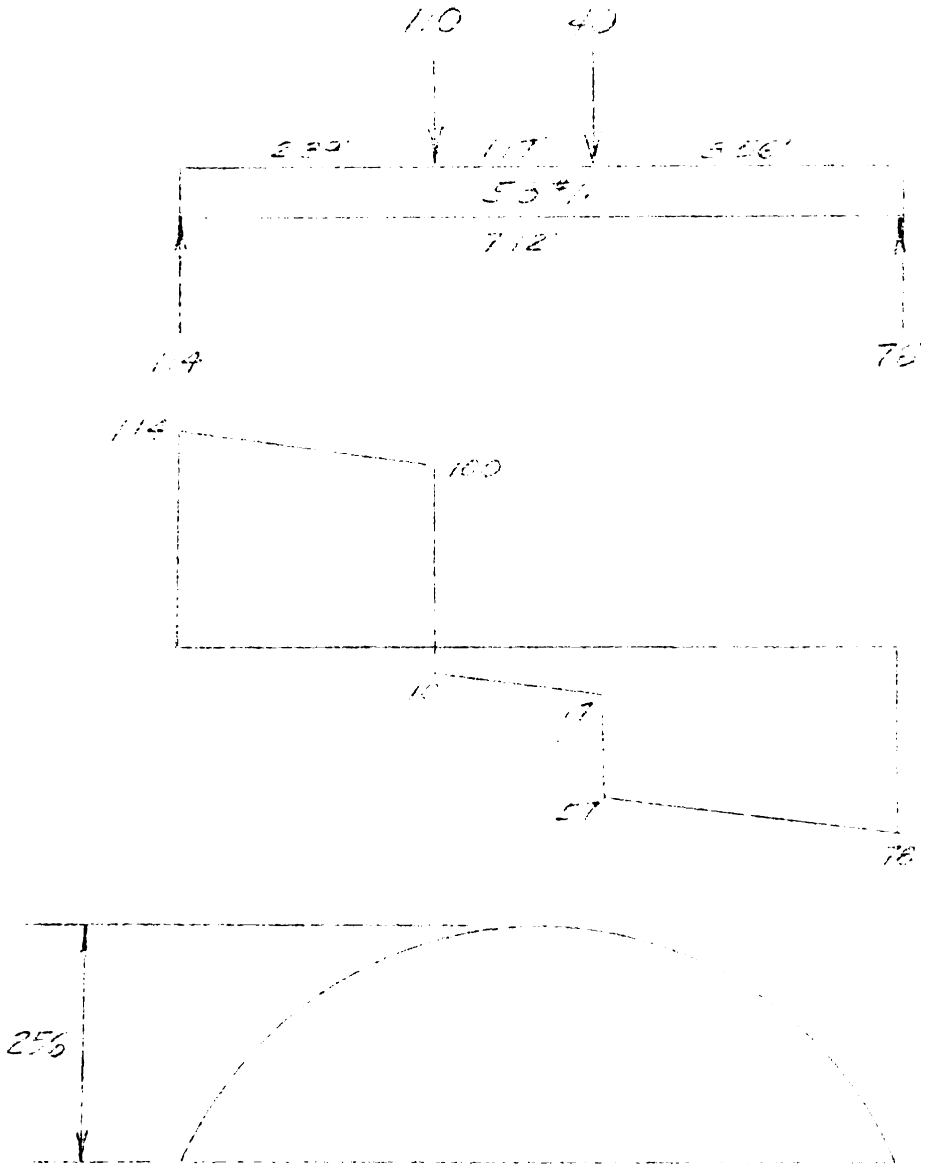


FIG 12

11-322

3½ x 3½ x [illegible] x 6'-2[illegible]"

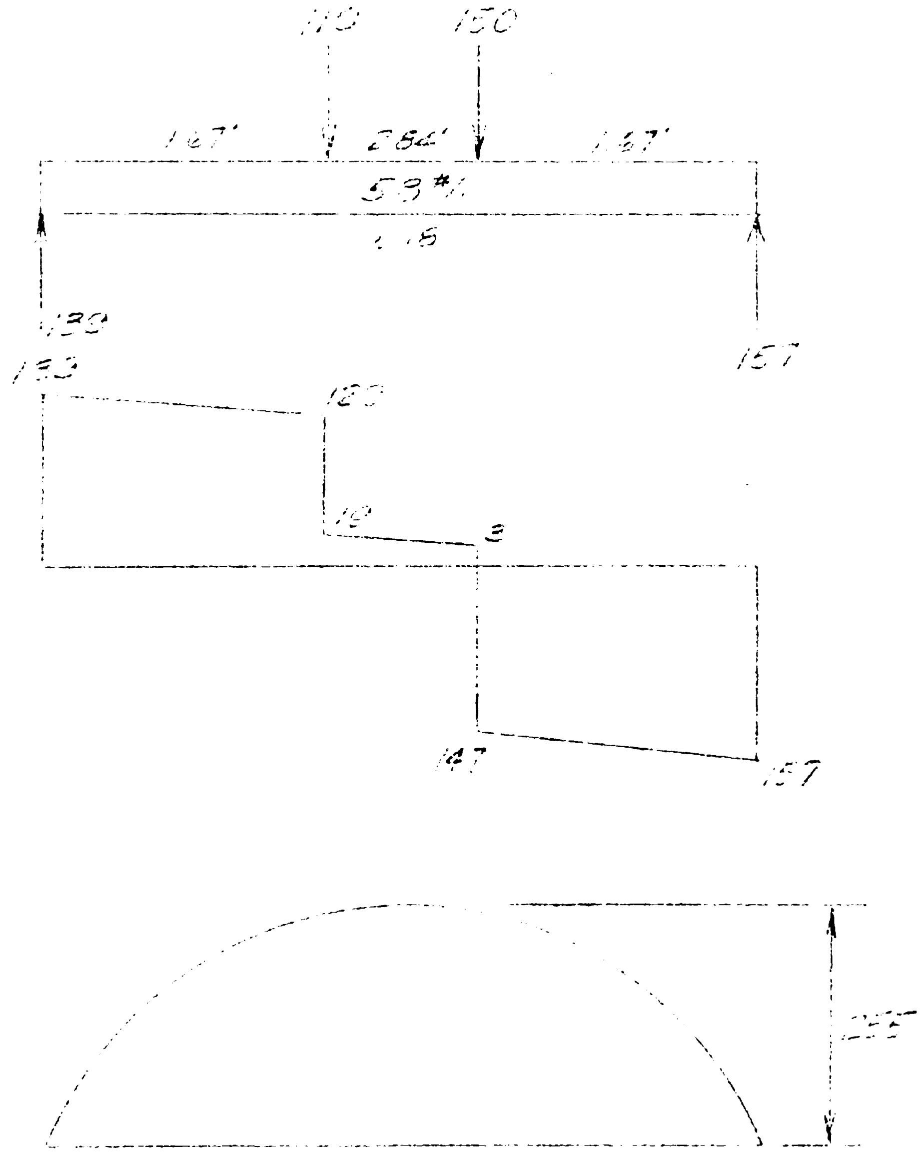


Fig 13

U-923

[illegible]

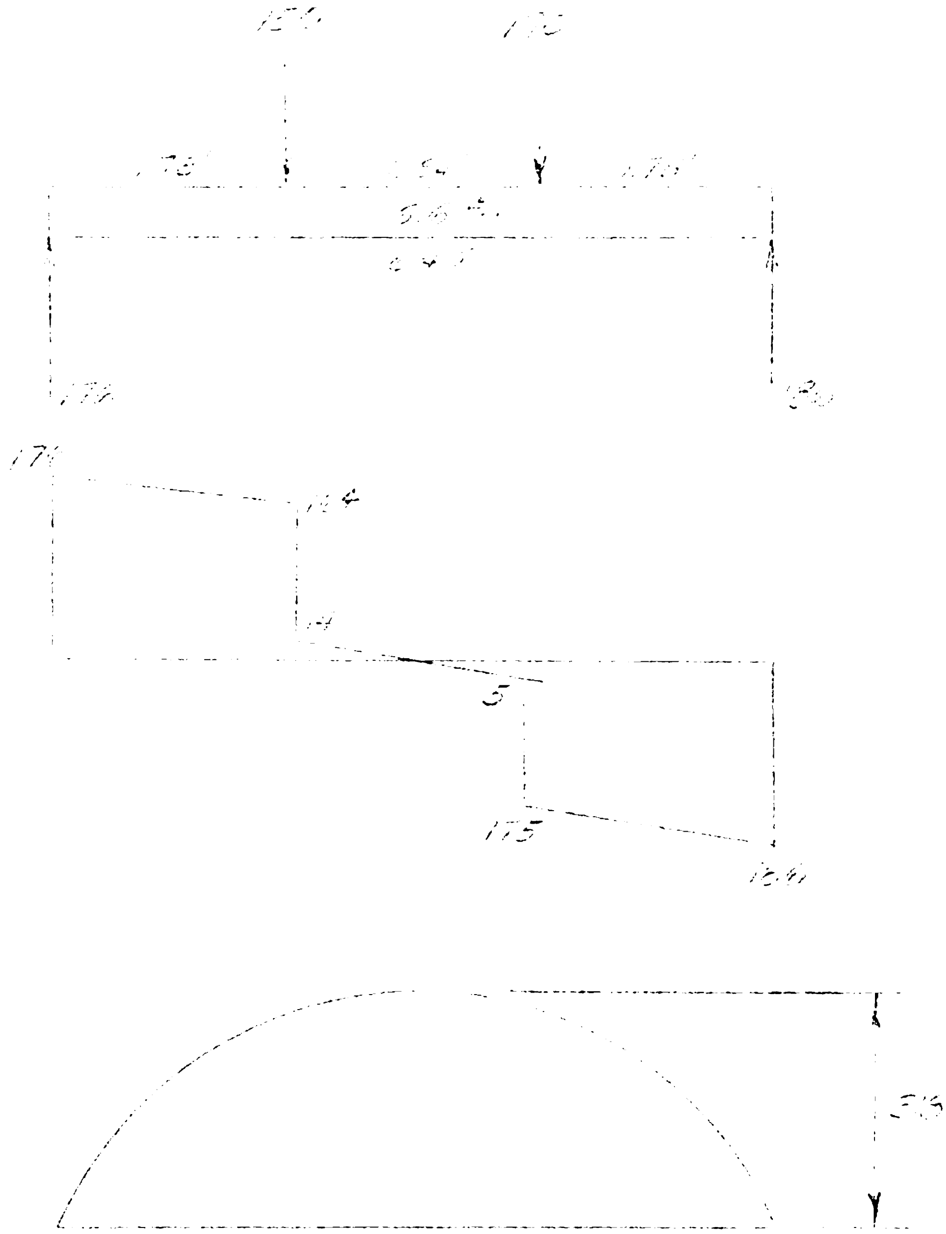


FIG. 14

U-324

5 x 3½ x 7/16 x 7'-0 5/8"

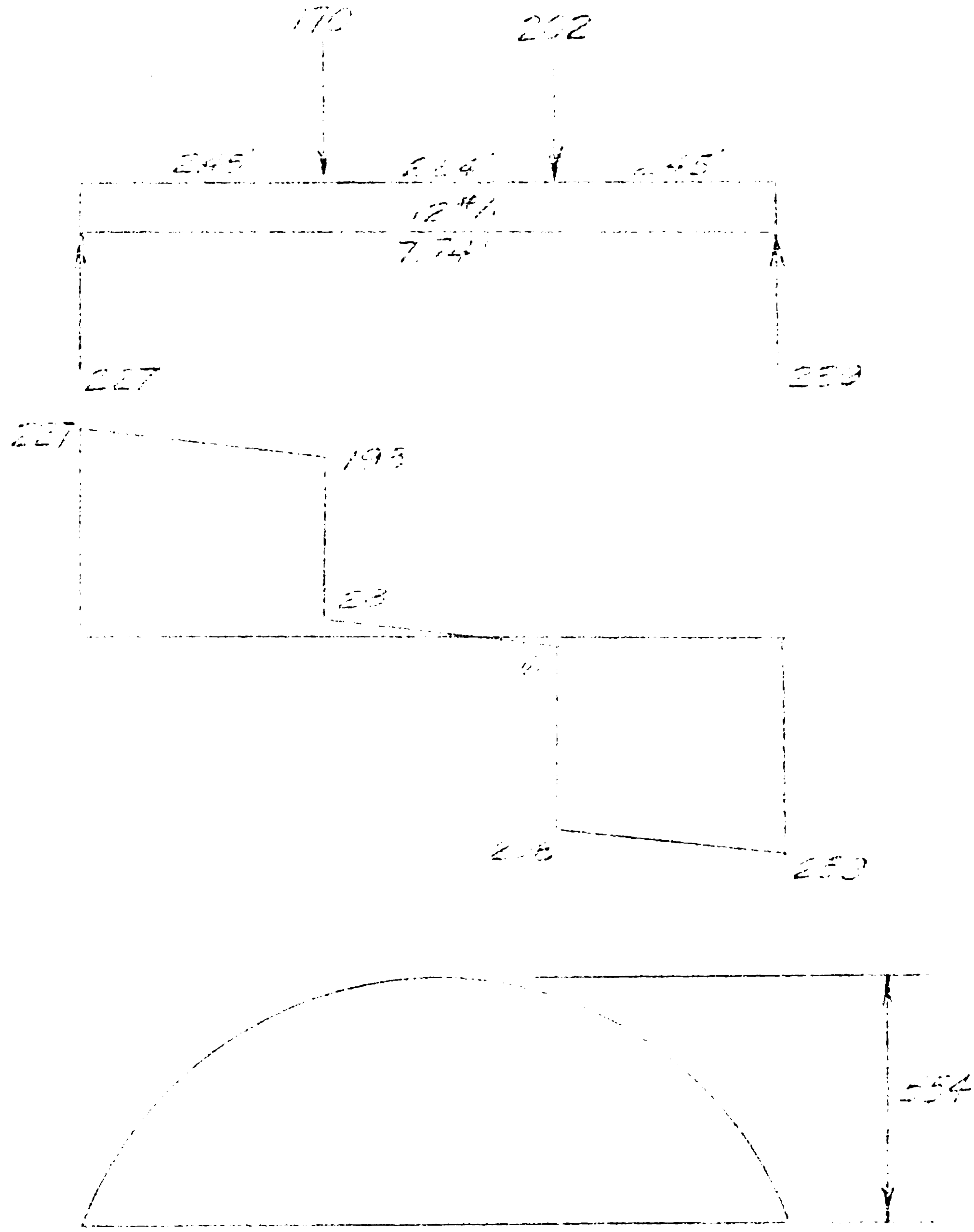


FIG 15

U-[illegible]

5 × 3[illegible] [illegible]

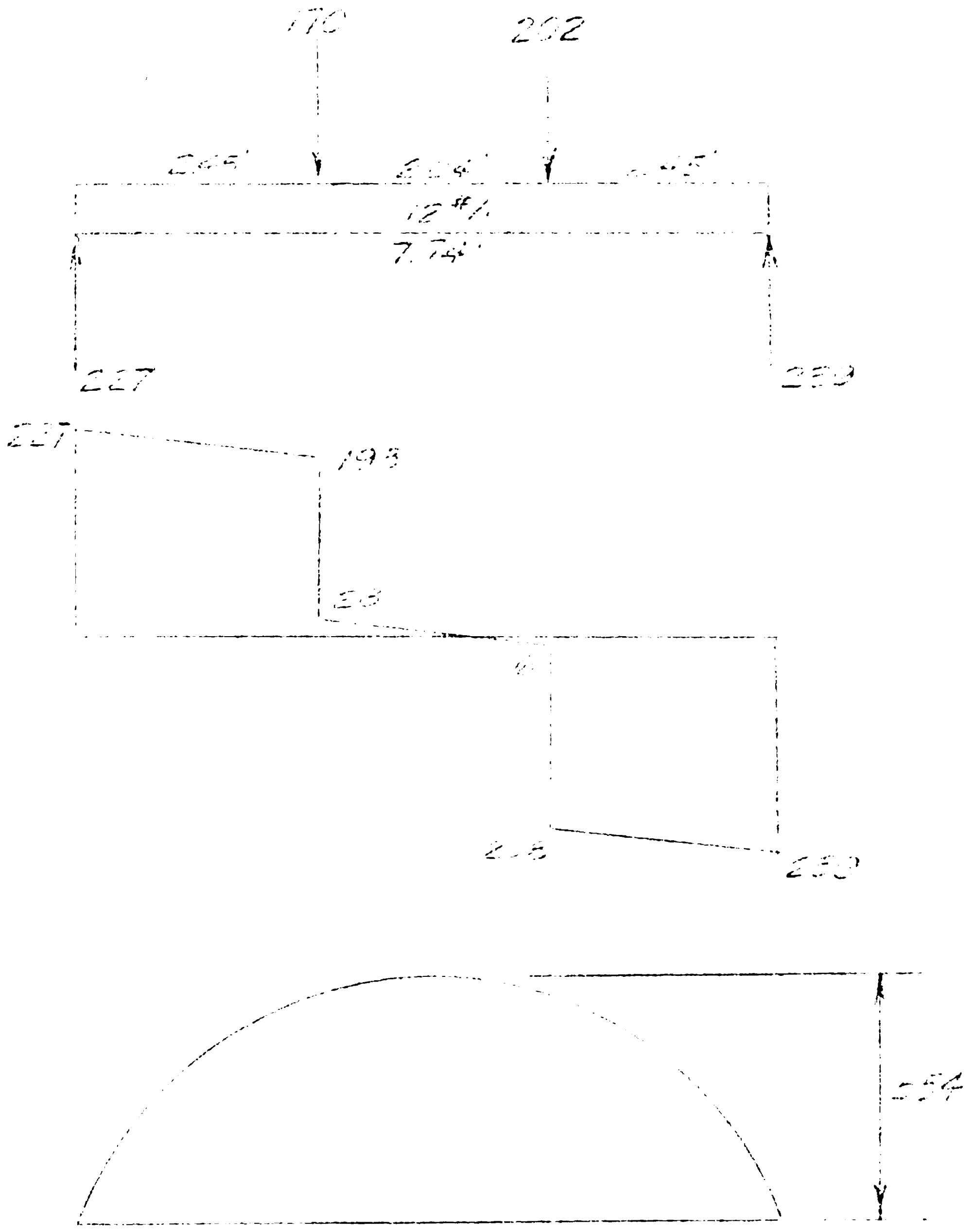


Fig 15

U-925

5 × 3½ × 7/16 × 7'-9¾"

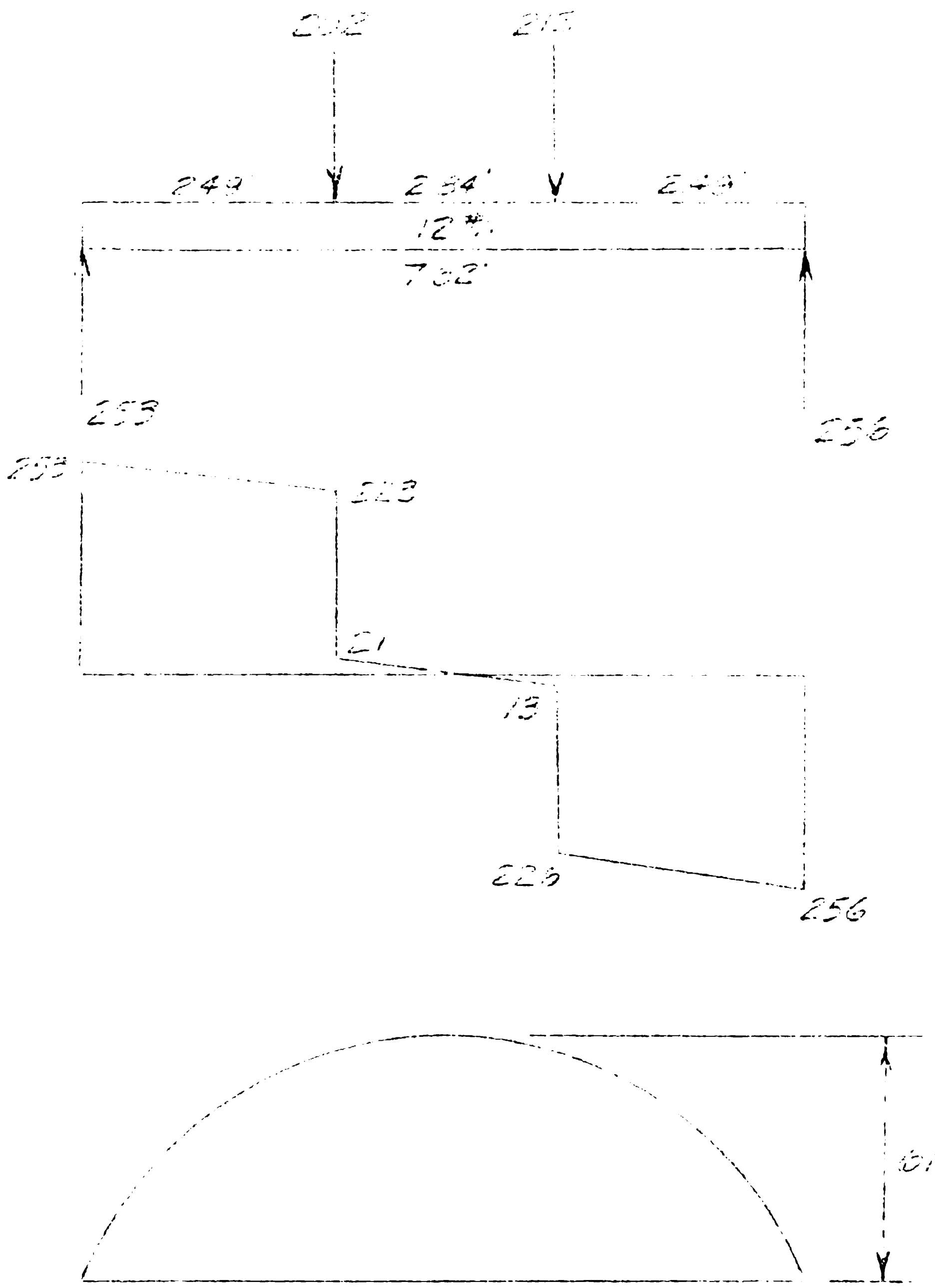


Fig. 16

U-927

5 x 3½ x $\frac{7}{16}$ x 12'-1⅞"

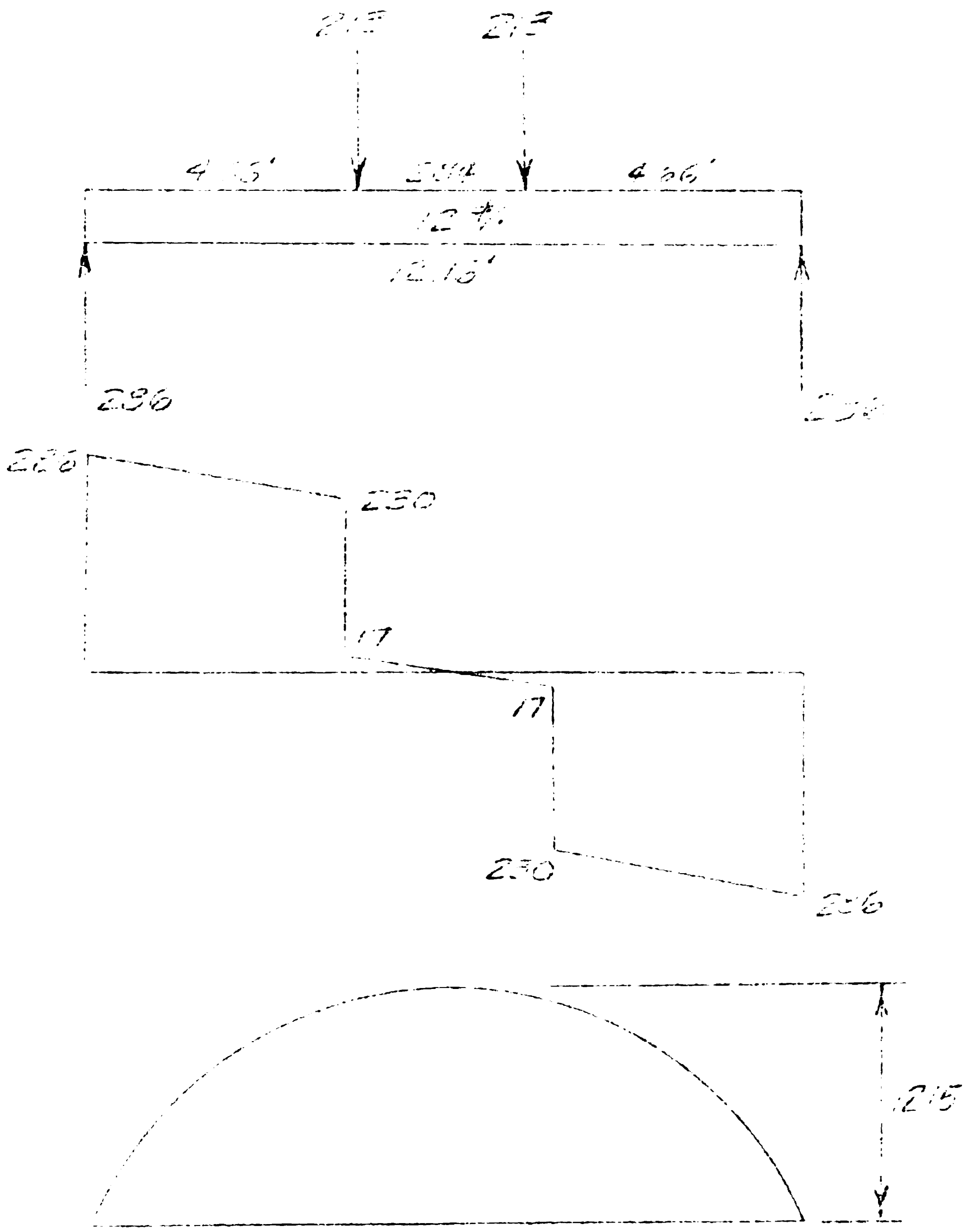


FIG 17

U-931

6 x 4 x $\frac{5}{8}$ x 12'-7$\frac{5}{8}$"

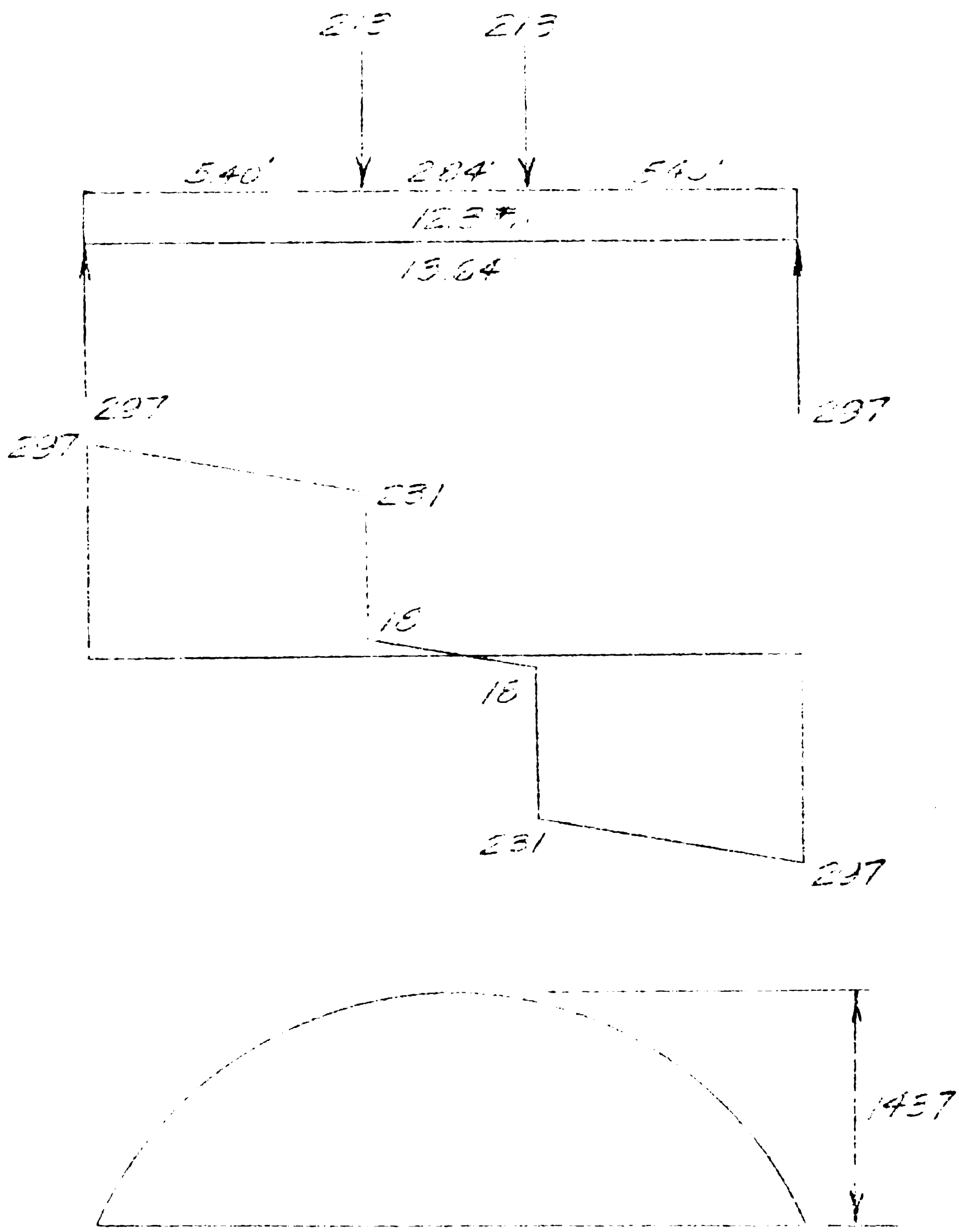


Fig. 18.

11-940

6 x 4 x 7/16 x 17'-11 1/2"

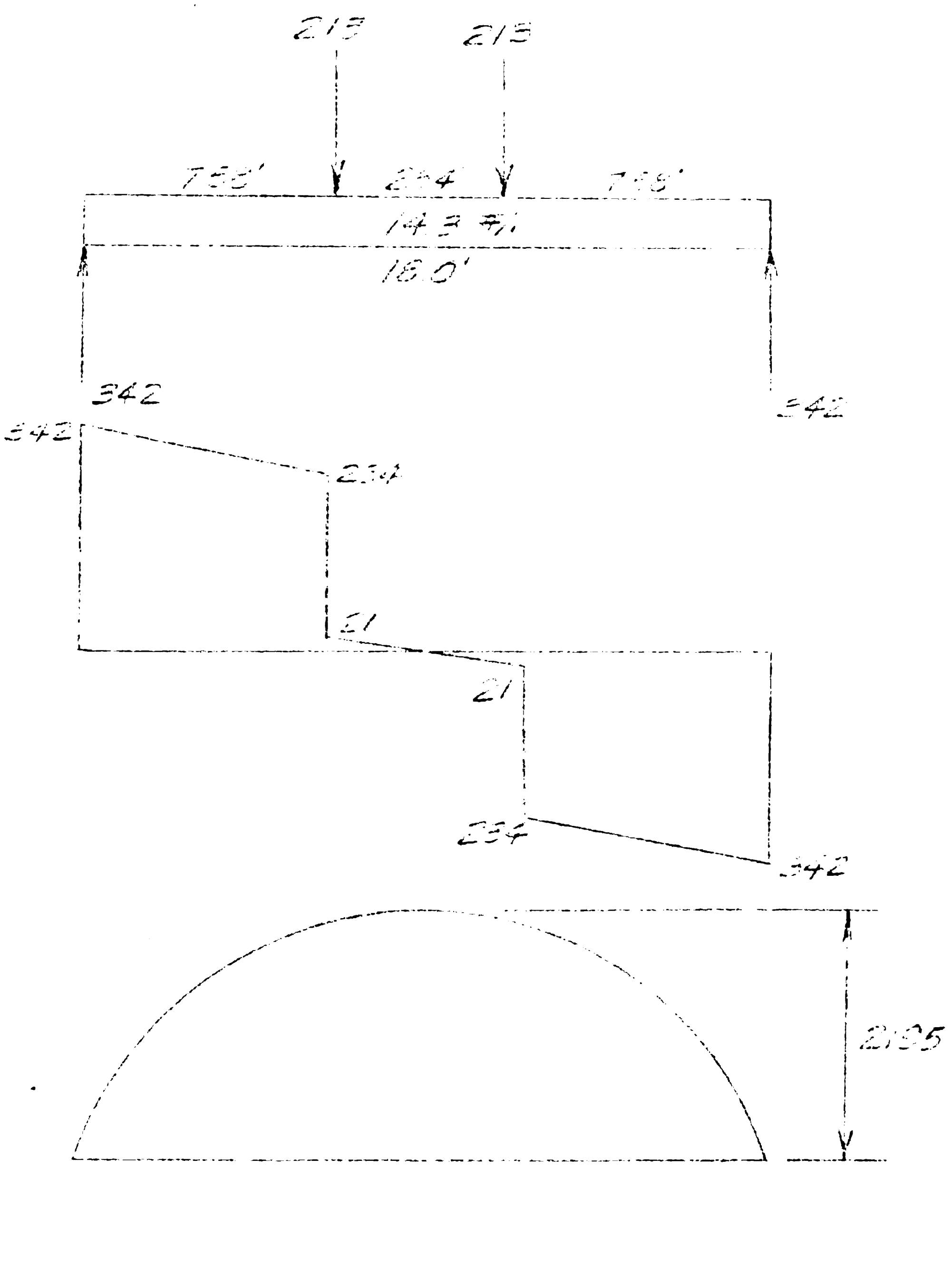


FIG 19

COMPUTATIONS FOR SHEAR AND BENDING MOMENT-

Maximum bending stress:

$f = \frac{M}{S}$, where f = maximum bending stress,

M = bending moment (in-lbs),

S = section modulus about axis parallel to short leg.

Maximum shearing stress:

$v = \frac{V}{A}$, where v = maximum shearing stress,

V = total shear,

A = cross-sectional area of member.

TABLE 10

MEMBER	BENDING	SHEAR
U-921;	$f = \frac{256 \times 12}{.79} = 3890;$	$v = \frac{114}{1.69} = 67.5$
U-922;	$f = \frac{255 \times 12}{.79} = 3870;$	$v = \frac{139}{1.69} = 82.3$
U-923;	$f = \frac{318 \times 12}{1.1} = 3470;$	$v = \frac{176}{1.94} = 90.8$
U-924;	$f = \frac{554 \times 12}{2.6} = 2560;$	$v = \frac{227}{3.53} = 64.4$
U-925;	$f = \frac{612 \times 12}{2.6} = 2820;$	$v = \frac{253}{3.53} = 71.7$
U-927;	$f = \frac{1215 \times 12}{2.6} = 5610;$	$v = \frac{286}{3.53} = 81.0$
U-931;	$f = \frac{1437 \times 12}{3.3} = 5225;$	$v = \frac{297}{3.61} = 82.3$
U-940;	$f = \frac{2195 \times 12}{3.8} = 6940;$	$v = \frac{342}{4.18} = 81.9$

ALLOWABLE STRESSES

The final step in the analysis of the fire tower is the determination of the allowable unit stresses in each member, and a comparison between the allowable stresses and the actual stresses as computed in the preceding pages, to make sure that none of the computed stresses exceed the allowable value.

COLUMN STRESSES

The column members are in compression. The allowable unit compressive stress is found by the formula,

$$s_c = 17{,}000 - 0.485 \times \frac{l^2}{r^2}, \text{ where}$$

s = allowable compressive stress,

l = greatest unsupported length,

r = least radius of gyration.

The computations for the allowable stresses in the column members, along with the computed actual stresses, are tabulated in Table 11.

TABLE 11

COLUMN NO.	l/r	ALLOWABLE s_c	ACTUAL s_c
U-900	72	14,540 lb/sq in	3,620 lb/sq in
U-901	93	12,830 "	6,335 "
U-902	96	12,150 "	8,633 "
U-903	104	11,775 "	9,238 "
U-904	105	11,640 "	9,258 "
U-905	83	13,670 "	11,190 "

DIAGONAL STRESSES

The diagonal struts are in tension. Table 12 gives the comparison between the actual and allowable stresses.

TABLE 12

STRUT	UNIT STRESS ACTUAL	UNIT STRESS ALLOWABLE
ad	4,320	20,000
cf	5,640	"
eh	7,830	"
gj	10,000	"
im	12,700	"
ko	14,700	"
nr	15,100	"
pt	16,730	"

It is also necessary to check the bolts against failure by single shear or bearing. The computations for this are tabulated in Table 13. The allowable loads in single shear and bearing are based on the following allowable unit stresses:

Shear: $s = 10,000$ lb/sq in

Bearing: $s = 20,000$ lb/sq in

TABLE 13

STRUT	NO. & DIAM. OF BOLTS	ALLOWABLE S.S.	TENSION BEARING	ACTUAL TENSION
ad	1 - 5/8"	3070*	3130	1253
cf	1 - 5/8"	3070*	3130	1633
eh	2 - 5/8"	6140*	6260	2270
gj	2 - 5/8"	6140*	6260	2901
im	2 - 5/8"	6140*	6260	3685
ko	2 - 5/8"	6140*	6260	4268
nr	2 - 3/4"	8840	7500*	5896
pt	2 - 3/4"	8840	7500*	6526

* Governing values

STRESSES IN HORIZONTAL STRUTS

The horizontal struts are in compression. The allowable unit compressive stress is found by the formula,

$$s = 17,000 - 0.485 \times \frac{l^2}{r^2}$$

But, maximum l/r ratio = 87

$$s = 17,000 - 0.485 \times 87^2$$

$$s = 17,000 - 3,670$$

$$s = 13,330 \text{ lb/sq in}$$

Table 14 gives the comparison between the actual and allowable unit stresses in the horizontal struts.

TABLE 14

STRUT	UNIT STRESS ACTUAL	UNIT STRESS ALLOWABLE
ab	636	13,330
cd	1,403	"
ef	3,417	"
gh	3,416	"
ij	1,797	"
km	2,172	"
no	2,246	"
pr	2,368	"

As before, it is necessary to check the bolts against failure by single shear or bearing. The same allowable unit stresses are used that were used for the diagonals, and the computations are tabulated in Table 15.

TABLE 15

STRUT	NO. & DIAM. OF BOLTS	ALLOWABLE LOAD S.S.	ALLOWABLE LOAD BEARING	ACTUAL LOAD
ab				916
cd	1 - 5/8"	3070*	3130	1263
ef	1 - 5/8"	3070*	3130	1640
gh	2 - 3/4"	8840	7500*	2084
ij	2 - 3/4"	8840	7500*	2588
km	2 - 3/4"	8840	7500*	3127
no	2 - 3/4"	8840	7500*	3796
pr	2 - 3/4"	8840	7500*	4593

* Governing values

STRESSES IN HORIZONTAL GIRTS

The unit stresses in the horizontal girts which support the stairways are given in Table 10. They are well below the allowable unit stresses, which are:

Bending; s 20,000 lb/sq in

Shear; s 13,000 lb/sq in

CONCLUSION

From the standpoint of safety, this type of fire tower seems to be well designed. In most of the members which were checked, the unit stresses are far below the allowable. In only a few cases do they even approach the allowable. In addition, there are a great many small bracing members which were not taken into account in the checking. These members increase the strength and rigidity of the tower. Apparently a generous factor of safety was used in the original design.

From the standpoint of economy, it seems possible that the design could be better. However, it may be that the tower was purposely over-designed to take care of stresses which might possibly be introduced either in the erection of the tower or by forces or loads which were not taken into account in the design.

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3. Ketchum, M. S., *Structural Engineers' Handbook*, 2nd Edition, 1918.

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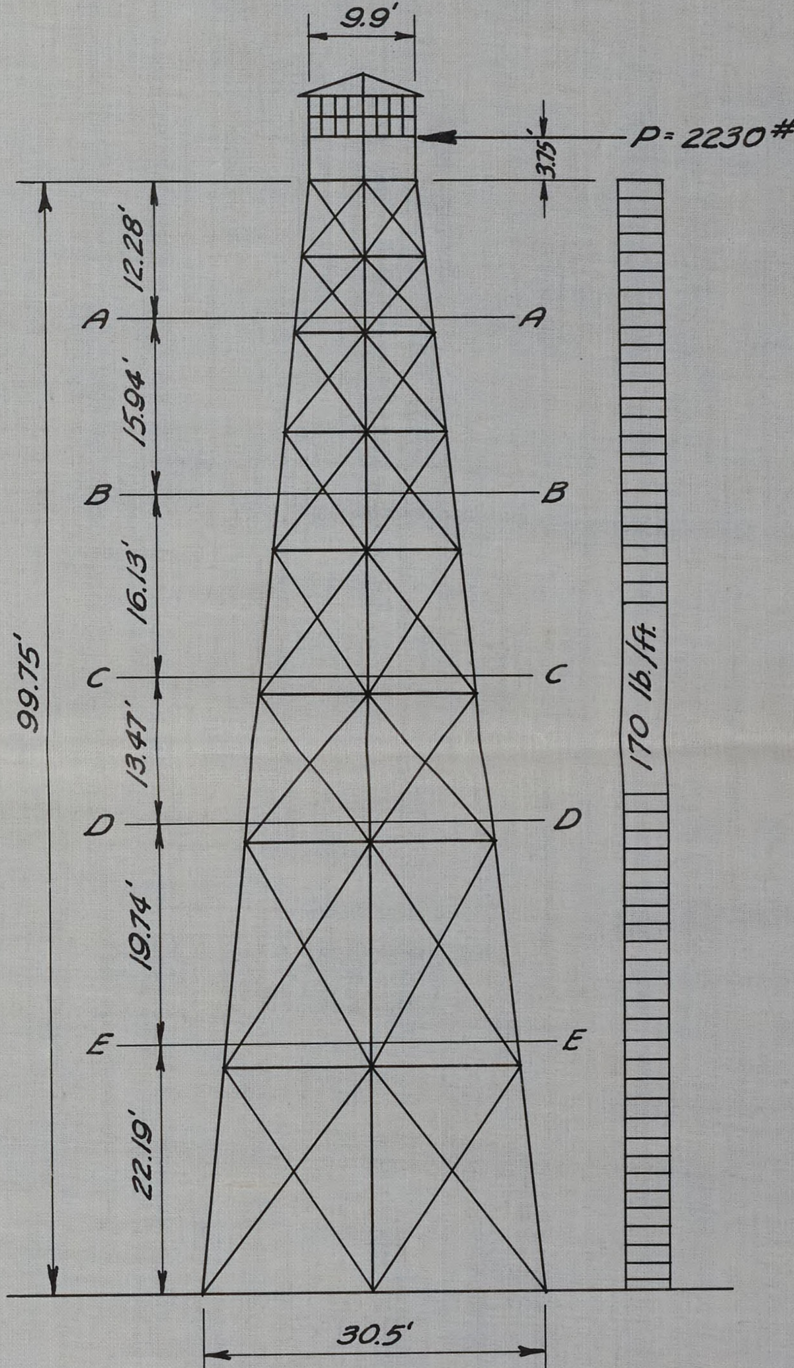

WIND LOAD FOR MAXIMUM COLUMN STRESS

FIG.

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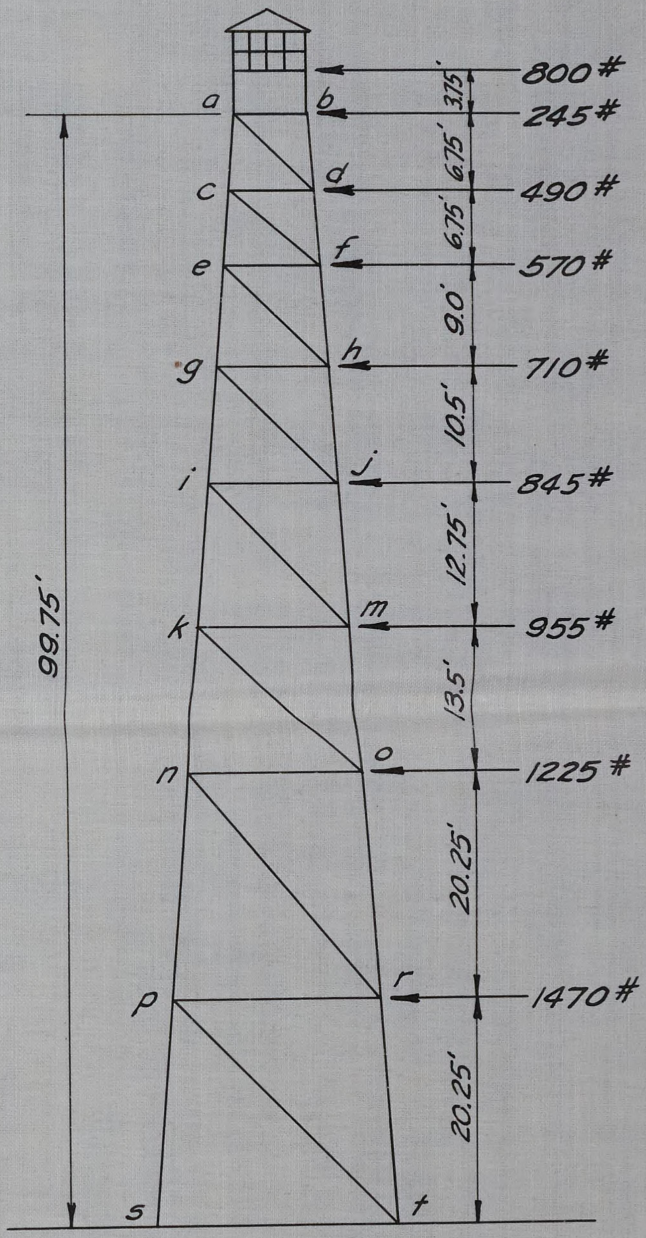
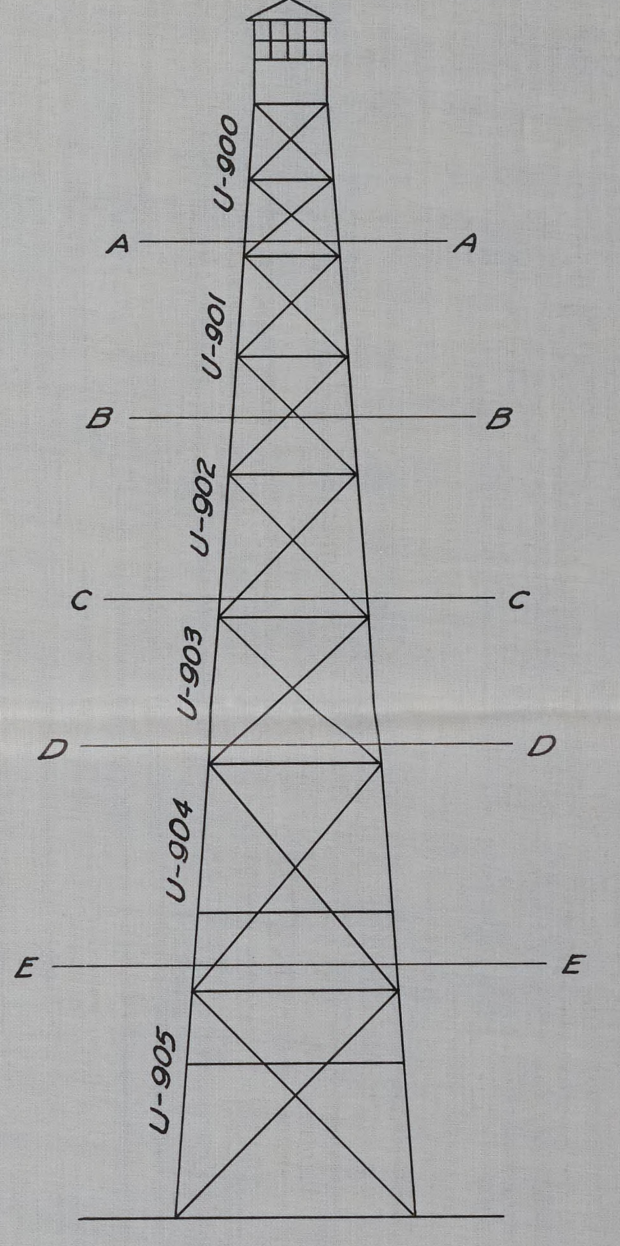
'41



WIND LOAD ON ONE BENT

ONLY TENSION DIAGONALS SHOWN

FIG. .



DEAD LOAD ON COLUMNS

FIG. 1

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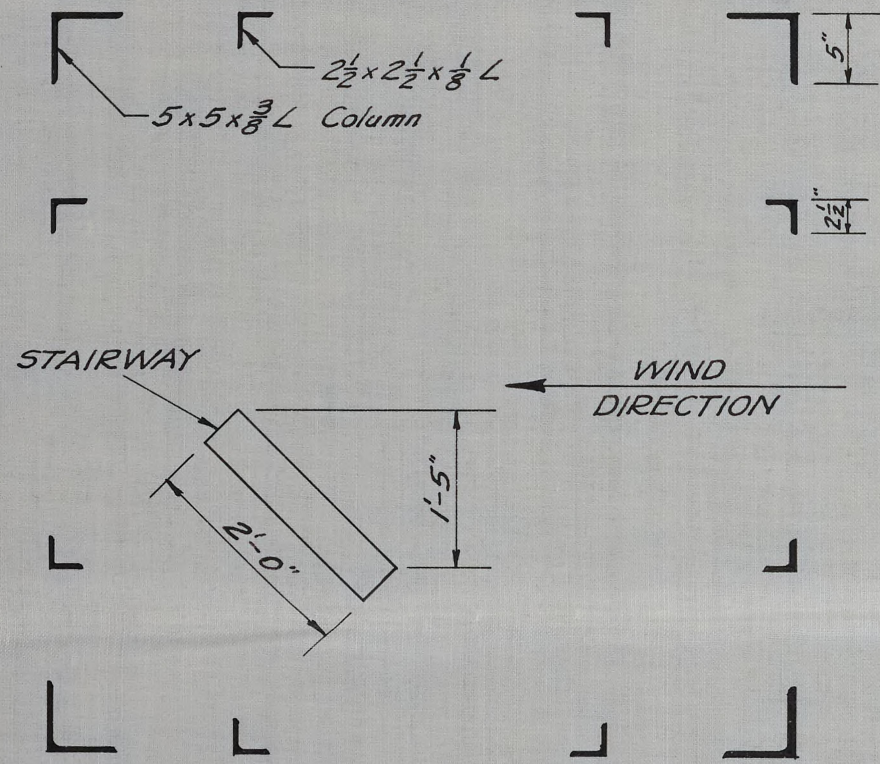
'41



HORIZONTAL SECTION NEAR BASE

FIG.

TOTAL AREA, NORMAL TO WIND,
PER FOOT OF HEIGHT:

5 x 5 ∠s:	4 (12 x 5) =	240	sq. in.
2½ x 2½ ∠s:	4 (12 x 2.5) =	120	" "
STAIRWAY:	12 x 17 =	204	" "
TOTAL		684	sq. in. = 4.75 sq. ft.

WIND LOAD, PER FOOT OF HEIGHT:

$$P = p \times A$$
$$= 30 \times 4.75$$
$$= 142.5 \ \#/ft.$$

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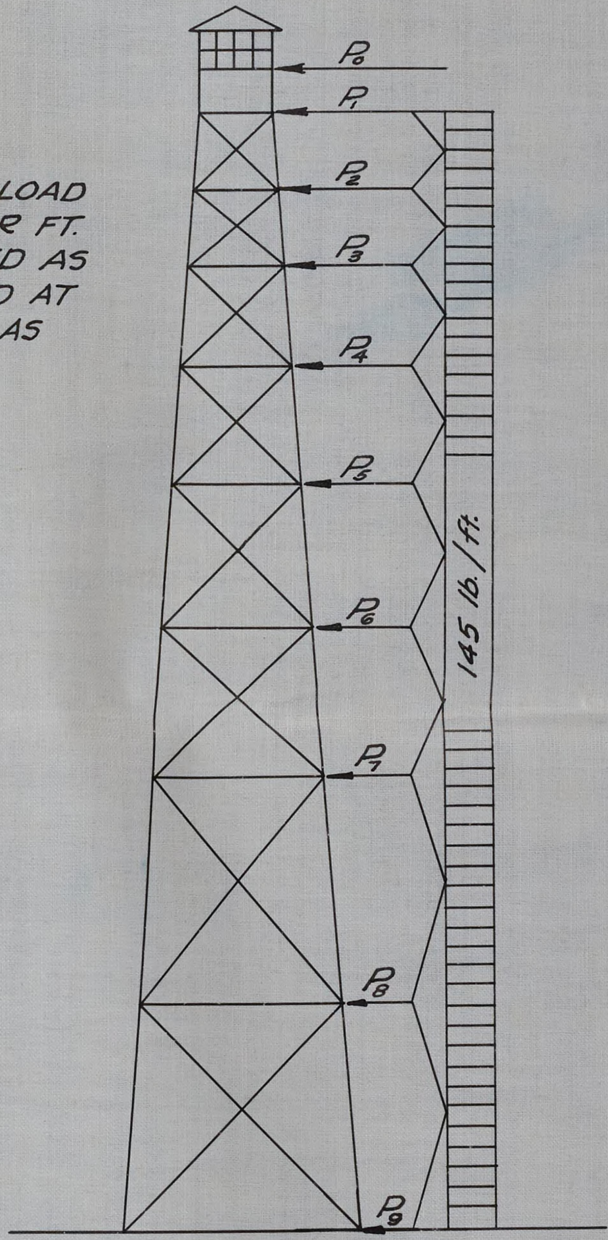
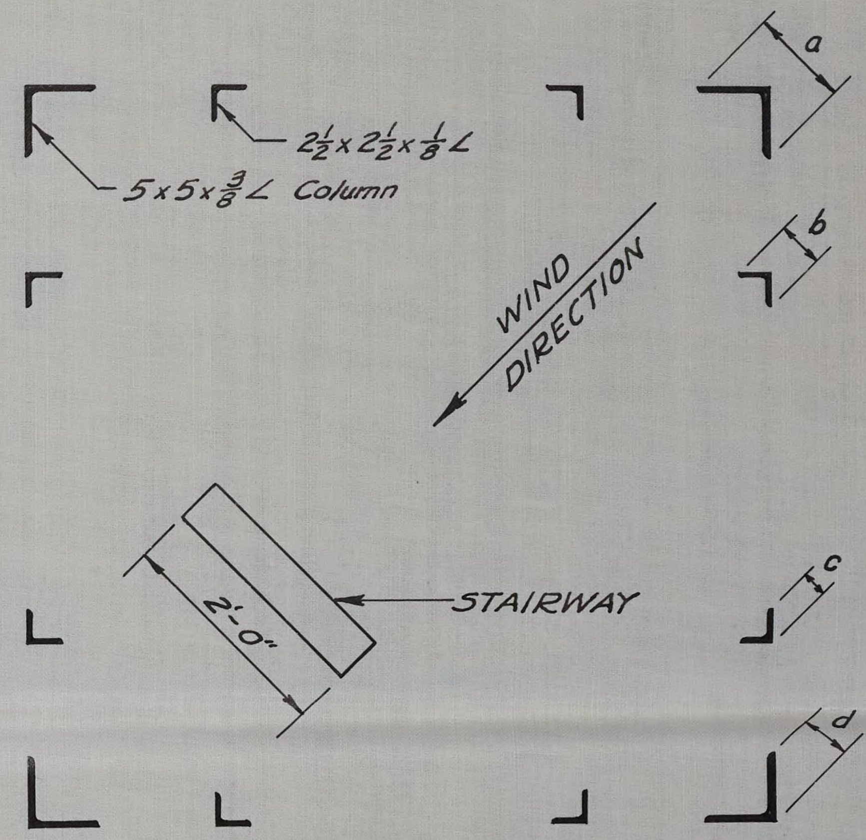
DISTRIBUTED LOAD OF 145 LB. PER FT. IS CONSIDERED AS CONCENTRATED AT THE JOINTS, AS SHOWN.



WIND LOAD FOR MAXIMUM DIAGONAL STRESS

FIG.



HORIZONTAL SECTION NEAR BASE

FIG. 2

$$a = 5 \sec 45° = 7.07"$$
$$b = 2.5 \sec 45° = 3.54"$$
$$c = 2.5 \sin 45° = 1.77"$$
$$d = 5 \sin 45° = 3.54"$$

AREA, NORMAL TO WIND,
PER FOOT OF HEIGHT:

$5 \times 5\ \angle s$:	$2(12 \times 3.54)$	$= 85$	sq. in.
	$2(12 \times 7.07)$	$= 170$	" "
$2\frac{1}{2} \times 2\frac{1}{2}\ \angle s$:	$4(12 \times 1.77)$	$= 85$	" "
	$4(12 \times 3.54)$	$= 170$	" "
STAIRWAY:	12×24	$= 288$	" "
TOTAL		$= 798$	sq. in. = 5.55 sq. ft.

WIND LOAD,
PER FOOT OF
HEIGHT:

$$P = p \times A$$
$$= 30 \times 5.55$$
$$= 166.5\ \#/\text{ft.}$$

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'41

BUNDLING AND LOADING CHECKLIST FOR ONE 99'-9" STAIRWAY TOWER, WITH ANCHOR FIXTURES-
DRAWINGS MC-39 & MD-70

ORDER NO.______________ CAR NO.________________________ DESTINATION________________________

TALLIED IN BY________________________________ DATE LOADED________________________________

TALLIED OUT BY________________________________ DATE UNLOADED________________________________

TALLY IN	NO. BDLS.	MARK	NO. PCS. IN BDL.	DESCRIPTION			TALLY OUT
	4	U-900	1	#1 Corner Post-	3 x 3 x 1/4	x 19' 9 3/4"	
	4	U-901	1	#2 " " -	3½ x 3½ x 1/4	x 16' 0"	
	4	U-902	1	#3 " " -	4 x 4 x 1/4	x 16' 2 3/16"	
	4	U-903	1	#4 " " -	4 x 4 x 5/16	x 13' 6 1/8"	
	4	U-904	1	#5 " " -	4 x 4 x 7/16	x 19' 9 9/16"	
	3	U-905	1	#6 " " -	5 x 5 x 3/8	x 22' 3"	
	1	U-905X	1	#6 " " - with U-45 Pl.-	5x5x3/8	x "	
	1	U-914	4	#1 Splice Angle-	3 x 3 x 1/4	x 0' 10"	
	1	U-915	4	#2 " " -	3½ x 3½ x 1/4	x 1' 0 1/2"	
	1	U-916	4	#3 " " -	4 x 4 x 1/4	x 1' 3"	
	1	U-917	4	#4 " " -	4 x 4 x 5/16	x 1' 5 1/2"	
	1	U-918	4	#5 " " -	4 x 4 x 7/16	x 2' 1"	
	1	U-546	8	#1 Angle Brace-	2 x 2 x 1/8	x 9' 6 3/4"	
	1	U-547	8	#2 " " -	"	x 9' 11 7/16"	
	2	U-548	4	#3 " " -	"	x 12' 5 1/8"	
	2	U-549	4	#4 " " -	"	x 14' 6 1/4"	
	2	U-550	4	#5 " " -	"	x 17' 3 5/8"	
	2	U-551	4	#6 " " -	"	x 19' 3 1/16"	
	1	U-552	4	#7 " " - Upper Sec.-	2½x2½x1/8	x 12' 9 1/4"	
	1	U-553	4	#7 " " - " " -	"	x 11' 3 3/4"	
	1	U-554	4	#7 " " - Lower " -	"	x 14' 9 1/4"	
	1	U-555	4	#7 " " - " " -	"	x 13' 3 3/4"	
	1	U-556	4	#8 " " - Upper " -	"	x 12' 5 1/16"	
	1	U-557	4	#8 " " - " " -	"	x 13' 8 1/16"	
	1	U-558	4	#8 " " - Lower " -	"	x 14' 9 1/16"	
	1	U-559	4	#8 " " - " " -	"	x 16' 0 1/16"	

______	1	U-562	4	#1 Tie-	2 x 2 x 1/8	x 3' 8 3/4"	______
______	1	U-563	4	#2 " -	"	x 3' 9 3/8"	______
______	1	U-564	4	#3 " -	"	x 5' 0 5/16"	______
______	1	U-565	4	#4 " -	"	x 5' 9 7/8"	______
______	1	U-566	4	#5 " -	"	x 7' 0 13/16"	______
______	1	U-567	4	#6 " -	"	x 7' 5 1/8"	______
______	1	U-568	4	#7 " -	$2\frac{1}{2}$ x $2\frac{1}{2}$ x 1/8	x 4' 6"	______
______	2	U-569	2	#8 " -	3 x 3 x 1/4	x 9' 7 1/16"	______
______	2	U-575	4	Gusset Plate- #10 Girt-	8 x 1/4 x 12-3/16" Plate		______
______	2	U-576	4	" " - #12 " -	8 x 1/4 x 13-3/8" "		______
______	2	U-579	4	" " - #15 " -	11 x 1/4 x 17-15/16" Plate		______
______	2	U-580	4	" " - Base-	10 x 1/4 x 9-5/8" "		______
______	2	U-919	2	Roof Girts-	3 x 3 x 1/4	x 6' 11 5/8"	______
______	1	U-587	4	Window Sills-	"	x 6' 10 3/4"	______
______	1	U-588	2	Cab Girt-	"	x "	______
		U-589	1	" " - R.-	"	x "	
		U-590	1	" " - L.-	"	x "	
______	1	U-591	1	" " -	"	x 6' 11"	______
		U-592	1	" " -	"	x "	
______	1	U-593	1	" " -	"	x 2' 10 1/2"	______
______	1	U-596	8	#1 Girt-	2 x 2 x 1/8	x 3' 9 9/16"	______
______	1	U-756X	2	#2 " -	$2\frac{1}{2}$ x $2\frac{1}{2}$ x 3/16	x 7' 5 1/4"	______
______	1	U-598	1	#2 " -	"	x "	______
		U-599	1	#2 " -	"	x "	
______	1	U-921	1	Girt- 1st Landing-	$3\frac{1}{2}$ x $3\frac{1}{2}$ x 1/4	x 7' 1 3/8"	______
______	1	U-601	1	" - 1st " -	$2\frac{1}{2}$ x $2\frac{1}{2}$ x 3/16	x 2' 10 3/8"	______
______	1	U-602	2	" - 1st " -	2 x 2 x 1/8	x 5' 1 1/16"	______
______	1	U-604	8	#3 Girt-	"	x 4' 3 5/8"	______
______	1	U-605	2	#4 " -	"	x 8' 4 7/16"	______
______	1	U-606	1	#4 " - R.-	$2\frac{1}{2}$ x $2\frac{1}{2}$ x 3/16	x "	______
		U-607	1	#4 " - L.-	"	x "	
______	1	U-922	1	Girt- 2nd Landing-	$3\frac{1}{2}$ x $3\frac{1}{2}$ x 1/4	x 6' 2 3/16"	______

.1- 99'-9" Stairway Tower-
Drwgs. MC-39 & MD-70

______	1	U-609	3	Girt- 2nd Landing-	2 x 2 x 1/8	x 6' 1 15/16"	______
______	1	U-610	8	#5 Girt-	"	x 4' 10 5/8"	______
______	1	U-611	2	#6 " -	2½ x 2½ x 1/8	x 9' 9 3/16"	______
______	1	U-612	1	#6 " - R.-	2½ x 2½ x 3/16	x "	______
		U-613	1	#6 " - L.-	"	x "	
______	1	U-923	1	Girt- 3rd Landing-	4 x 4 x 1/4	x 6' 4 3/4"	______
______	1	U-615	2	" - 3rd " -	2½ x 2½ x 1/8	x 7' 5 11/16"	______
		U-616	1	" - 3rd " -	"	x 7' 1 5/16"	
______	1	U-617	8	#7 Girt-	2 x 2 x 1/8	x 5' 7 1/2"	______
______	1	U-618	2	#8 " -	3 x 3 x 1/4	x 11' 3 9/16"	______
______	1	U-619	1	#8 " - R.-	"	x "	______
		U-620	1	#8 " - L.-	"	x "	
______	1	U-924	1	Girt at 4th Landing-	5 x 3½ x 7/16	x 7' 8 15/16"	______
______	1	U-622	3	" " 4th " -	3 x 3 x 1/4	x 8' 1 13/16"	______
______	1	U-624	8	#9 Girt-	2 x 2 x 1/8	x 6' 5 11/16"	______
______	1	U-625	2	#10 Girt-	3 x 3 x 1/4	x 13' 2 3/8"	______
______	1	U-626	1	#10 " - R.-	"	x "	______
		U-627	1	#10 " - L.-	"	x "	
______	1	U-925	1	Girt at 5th Landing-	5 x 3½ x 7/16	x 7' 9 7/8"	______
______	1	U-629	1	" " 5th " -	2½ x 2½ x 3/16	x 3' 4 3/8"	______
______	1	U-630	2	" " 5th " -	3 x 3 x 1/4	x 10' 4 5/8"	______
______	1	U-631	1	" " 5th " -	"	x 9' 6 1/4"	______
______	2	U-632	4	#11 Girt-	2½ x 2½ x 1/8	x 7' 5 13/16"	______
______	2	U-633	1	#12 " -	3½ x 3½ x 1/4	x 15' 2 3/4"	______
______	1	U-634	1	#12 " - R.-	"	x 15' 2 3/4"	______
______	1	U-635	1	#12 " - L.-	"	x "	______
______	1	U-927	1	Girt- 6th Landing-	5 x 3½ x 7/16	x 12' 1 7/8"	______
______	1	U-928	3	" - 6th, 7th & 8th Landing-	2½x2½x3/16	x 5' 7"	______
______	2	U-638	1	" - 6th Landing-	3½ x 3½ x 1/4	x 10' 3 3/4"	______
______	1	U-639	1	" - 6th " -	"	x 10' 11 3/16"	______
______	1	U-673	1	" - 6th " - R.-	2½ x 2½ x 3/16	x 3' 5 7/16"	______
		U-674	1	" - 6th " - L.-	"	x "	

Drwgs. MC-39 & MD-70

______1	U-640	4	#13 Girt-	2½ x 2½ x 1/8	x 16' 9 1/2"	______
______2	U-642	1	#14 " -	3 x 3 x 1/4	x 17' 9 11/16"	______
______1	U-643	1	#14 " - R.-	"	x "	______
______1	U-644	1	#14 " - L.-	"	x "	______
______1	U-931	1	Girt at 7th Landing-	6 x 4 x 3/8	x 13' 7 5/8"	______
______1	U-646R	1	" " 7th " -	2½ x 2½ x 3/16	x 4' 2 5/16"	______
	U-646L	1	" " 7th " -	"	x "	
______4	U-651	1	#15 Girt-	4 x 4 x 1/4	x 18' 1 3/8"	______
______4	U-652	1	Girt- Section E-E-	"	x 12' 11 5/8"	______
______2	U-654	1	#16 Girt-	3 x 3 x 1/4	x 19' 10 1/8"	______
______1	U-655	1	#16 " - R.-	"	x "	______
______1	U-656	1	#16 " - L.-	"	x "	______
______1	U-940	1	Girt- 8th Landing-	6 x 4 x 7/16	x 17' 11 7/8"	______
______1	U-658R	1	" - 8th " -	2½ x 2½ x 3/16	x 6' 4 7/16"	______
	U-658L	1	" - 8th " -	"	x "	
______4	U-623	1	#17 Girt-	3 x 3 x 1/4	x 20' 10 5/16"	______
______1	U-661	4	Roof Angles- R.-	2 x 2 x 1/8	x 4' 10 3/8"	______
______1	U-662	4	" " - L.-	"	x "	______
______2	U-666	2	Sash with Glass & U-668 Clips- Mark: "GLASS HANDLE WITH CARE"			______
______2	U-669	2	Siding-	#20 Ga. Galv. Sheet Steel		______
______1	U-670	4	Roof Section-	" " " " "		______
	U-947	4	Flashing for Roof-	" " " " "		
______1	U-676	1	#1 Stairway			______
______1	U-677	1	#1 "			______
______1	U-678	1	#2 " - R.			______
______1	U-679	1	#2 " - L.			______
______1	U-680	1	#3 " - R.			______
______1	U-681	1	#3 " - L.			______
______1	U-682	1	#4 " - R.			______
______1	U-683	1	#4 " - L.			______

1- 99'-9" Stairway Tower- Drgs. MC-39 Revised
& MD-70

1	U-684	1	#5 Stairway- R.	
1	U-685	1	#5 " - L.	
4	U-686	1	#6, 7, 8 & 9 Stairway- R.	
4	U-687	1	#6, 7, 8 & 9 " - L.	
1	U-690	1	Railing for #1 Stairway- 1½ x 1½ x 1/8 x 2' 2 7/8"	
	U-691	1	" " #1 " - " x 4' 6 3/8"	
1	U-692	2	" " #2 " - " x 8' 5 9/16"	
1	U-693	2	" " #3 " - " x 11' 3 3/8"	
1	U-694	2	" " #4 " - " x 13' 2 5/8"	
1	U-695	2	" " #5 " - " x 16' 0 1/4"	
2	U-696	4	" " #6,7,8&9 Stairway- 1½x1½x1/8 x 16' 11 13/16"	
1	U-698	1	Post for Railing- 2 x 2 x 1/8 x 4' 5 3/8"	
1	U-949	8	" " " - R.- " x 4' 0"	
1	U-950	8	" " " - L.- " x "	
1	U-951	8	" " " - R.- " x 4' 2 1/8"	
1	U-952	8	" " " - L.- " x "	
1	U-703	7	" " " - 2x2x1/8 x 3' 11 5/8"	
1	U-704	7	" " " - " x "	
1	U-955	6	" " " - 6th,7th,8th- " x 3' 7 3/8"	
1	U-959	3	Railing for 6th,7th,8th Land.-R.-1½x1½x1/8 x 2' 9 7/8"	
1	U-960	3	" " " " " " -L.- " x "	
1	U-961	3	" " " " " " - " x 5' 1 1/2"	
1	U-956	1	Ventilator with Base per Drawing MD-97	
2	U-715	2	Anchor Plate- R.- 5 x 1/2" Flat x 1' 9 1/16"	
2	U-716	2	" " - L.- " x " " x "	
2	U-976	4	Anchor Rods (Plain)- 1 1/8" Rd. (2 Nuts) x 7' 2 7/8"	
4	U-509	1	Bearing Plate- 1 1/4" Holes- 12" x 1/2" Pl. x 1' 0"	
4	U-983	4	Reinforcing Rods (Deformed)- 3/4" Rd. x 11' 2"	
18	U-990	8	" " " - 1/2" " x 6' 8 5/8"	
2	U-991	14	Reinforcing Hoops (Plain)- 1/4" Rd. x 4' 4 1/8"	
		8	Boxes of Bolts	
		2	Boxes of Small Parts	

CHECKLIST OF BOLTS WITH LOCK NUTS FOR ONE 99'-9" STAIRWAY TOWER, WITH ANCHOR FIXTURES-
DRGS. MC-39 REVISED 3/20/36, MD-97 & MD-70
(Box 5)

	Unthrd. Length	Location
205 - 3/4 x 1 3/4" Galv. Bolts with Hex. Nut	1/2"	E & J

Note: 3/4" Bolts shall have Square Heads and shall be Galvanized after Threading.
3/4" Nuts shall be Tapped after Galvanizing.

Packed by------------------

Date------------------

If you find any errors or shortages, return this checklist with your complaint.

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CHECKLIST OF BOLTS WITH LOCK NUTS FOR ONE 99'-9" STAIRWAY TOWER, WITH ANCHOR FIXTURES
DRGS. MC-39 REVISED 3/20/36, MD-97 & MD-70
(Box 6)

	Unthrd. Length	Location
204 - 3/4 x 2" Galv. Bolts with Hex. Nut	3/4"	F & K

Note: 3/4" Bolts shall have Square Heads and shall be Galvanized after Threading.
3/4" Nuts shall be Tapped after Galvanizing.

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CHECKLIST OF BOLTS AND LOCK NUTS FOR ONE 99'-9" STAIRWAY TOWER, WITH ANCHOR FIXTURES-
DRGS. MC-39 REVISED 3/20/36, MD-97 & MD-70
(Box 7)

- -

		Location
809 -	3/8 x 2 1/2" Galv. Carriage Bolts with Hex. Nut	Wood
405 -	~~11/16"~~ Galvanized Lock Nuts - 5/8"	
919 -	~~13/16"~~ " " " - 3/4"	
39 -	~~9/16"~~ " " " - 1/2"	
284 -	~~7/16"~~ " " " - 3/8"	

Note: 3/8" Carriage Bolts shall be Galvanized after Threading.
3/8" Nuts shall be Tapped after Galvanizing.
All lock nuts of the same size to be separately packed.
Washers not to be used with 1/4" Brass Bolts or 3/8" Carriage Bolts.
Lock nuts not to be used on 3/8" Carriage Bolts.

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CHECKLIST OF WASHERS FOR ONE 99'-9" STAIRWAY TOWER, WITH ANCHOR FIXTURES-
DRGS. MC-39 REVISED 3/20/36, MD-97 & MD-70
(Box 8)

- -

		Location
405 -	11/16 x 1-1/4 x 3/16" Galv. Washers	
919 -	13/16 x 1-7/16 x 3/16" " "	
39 -	9/16 x 1-1/16 x 3/16" " "	
284 -	7/16 x 3/4 x 1/8" " "	
50 -	11/16 x 1-1/4 x 1/4" Galv. Filler Washers	Z

Note: Washers not to be used with 1/4" Brass Bolts or
3/8" Carriage Bolts.
All washers of the same size to be separately packed.

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CHECKLIST OF SMALL PARTS FOR ONE 99'-9" STAIRWAY TOWER, WITH ANCHOR FIXTURES-
DRGS. MC-39, MD-97 & MD-70
(Box 1)

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8 - U-571- Gusset Plate, No. 2 Girt- 10 x 1/4 x 6 1/2" Plate
8 - U-572- " " , " 4 " - 8 x 1/4 x 11 3/4" "
8 - U-573- " " , " 6 " - 8 x 1/4 x 11 3/4" "
8 - U-574- " " , " 8 " - 8 x 1/4 x 12 1/4" "

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CHECKLIST OF SMALL PARTS FOR ONE 99'-9" STAIRWAY TOWER, WITH ANCHOR FIXTURES-
DRGS. MC-39, MD-97 & MD-70
(Box 2)

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4 - U-920- Roof Girt Clip- 3 x 3 x 1/4 x 0'-5 5/8" Angle
4 - U-663- Gusset Plate for Roof Angles- 4 x 1/4" Flat x 0'-5 3/4"
4 - U-664- " " " " " - " x " " x "
1 - U-665- Cap Plate- 12 x 3/16 x 12" Plate
8 - U-672- Filler Washer- #20 Ga. Galv. Sheet Steel
2 - U-675- Flange for Flag Pole, Cast Iron
8 - U-721- Washer for Anchor- 5 x 1 x 5" Flat
48 - U-667- Clips for Sash- 7/16" hole- 1 x 3/16" Flat x 0'-1 3/4"

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