18HT SELF-SUPPORTING TOWER

SPAULDING" AX Series for Cement Installation

DESCRIPTION: AX28, the 24 foot tower plus 4 foot base stubs. All steel -- heavily galvanized for long life.

All riveted construction, no wells to rust.

Hex brace design gives greater strength, braces riveted in center as well as at ends.

The AX28 tower consist of sections AX2, AX3 and AX4. Total height 24 feet.

STRESS IN THE VERTICAL MEMBERS

Section	Ht. Above Ground (FT.)	Wind Load (PSF)	Column Stress (PSI)	Allow. Stress (PSI)	Margin Safety
4	0.	25.0	21492.9	21506.3	0.00
3	8.00	25.0	11688.0	21150.9	0.81
2	15.67	25.0	4214.1	21024.7	3.99

Overturning Moment at base of tower = 396.110 + 02 (IN-LBS)
Total Shear at the base of tower = 27.755 + 01 (LBS)

STRESS IN THE VERTICAL CONNECTIONS

Section	Bolt Dia. (IN.)	Applied Load (LBS)	Allow. Shear (LBS)	Load Bearing (LBS)	Margin Shear	Safety Bearing
4	0.500	3108.4	7860.0	4021.9	1.53	0.29
3	0.250	1620.3	1965.0	2011.0	0.21	0.24
2	0.250	559.3	1965.0	2011.0	2.51	2.60

STRESS IN THE BRACING MEMBERS

Section	Applied Load (LBS)	ALLOWABLE Load (LBS)	Margin Safety
4	202.3	1058.51	4.23
3	138.3	1096.93	6.93
2	73.7	1133.89	14.39

STRESS IN THE BRACING CONNECTIONS

Section	Rivet Dia. (IN)	Applied Load (LBS)	Allow. Shear (LBS)	Load Bearing (LBS)	Margin Shear	Safety Bearing
4	0.156	202.30	255.9	359.1	0.26	0.78
3	0.156	138.29	255.9	359.1	0.85	1.60
2	0.156	73.69	255.9	359.1	2.47	3.87

Extra stress from the top 27 foot of tubing is within the safety factor allowed.

An allowance of 20 pounds for tubing is covered under axial load stress figures.

TEST RESULTS

An initial loading was placed on the cantilever such that, in combination with the dead load, a distributed loading of 10 pounds per square foot of effective projected area (effective area equals 1.5 times the projected area of one face) was applied to each section. Subsequently, additional load was applied to the entire specimen in increments corresponding to 1.25 pounds per square foot of projected area until failure occurred. Failure resulted from a local crippling of the compression leg immediately below the lowest X-brace. The loading condition at failure is summarized in the following table.

Section	AX-2	AX-3	AX-4
Dead Load (lbs.)	17	20	27
Superimposed Load at Failure (lbs.)	80	83	84
Total Load at Failure (lbs.)	97	103	111
Shear at Base of Section (lbs.)	183	286	397
Moment at Base of Section (lb-ft.)	1377	3194	5841

This report by the Spaulding Products Company of Frankfort, Indiana was conducted by John E. Goldberg, Ph. D., Registered Professional Engineer, Indiana, Illinois, April, 1959. The information contained in this report is a summary from their test results.

STRENGTH ANALYSIS
OF
SPAULDING AX-TYPE
ANTENNA TOWERS

Prepared for

Spaulding Products Co., Inc.

Frankfort, Indiana

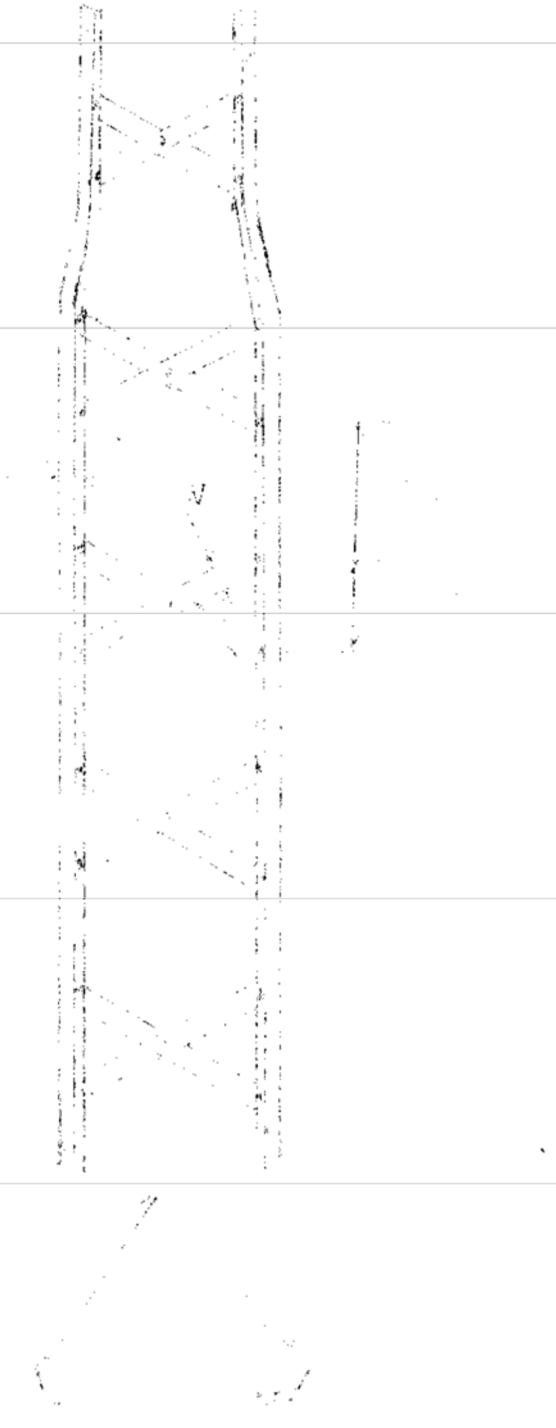
by

John E. Goldberg, Ph. D.

Registered Professional Engineer
(Illinois, Indiana)

West Lafayette, Indiana

April, 1960



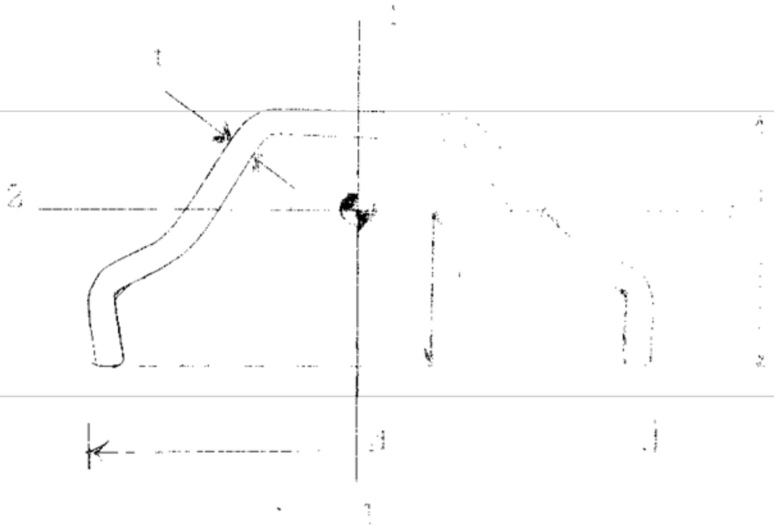
Introduction

The Spaulding AX-Type Antenna Towers are open, latticed towers of triangular section. The towers are manufactured in sections approximately eight feet long which are bolted together with lap splices to form towers up to 61' 8" (nominal 64-feet) The sections are numbered consecutively from AX-1 at the top to AX-8 at the bottom of a 64-foot tower. For shorter towers, the proper number of upper sections are used. Thus, for example, a 32-foot tower will consist of sections AX-1 to AX-4. The lateral dimensions of successive sections increase, thus providing greater depth where increasing bending moments must be resisted. Elements are cold formed from Armco Zinc Grip Galvanized Steel or equivalent.

The towers are intended to support television receiving antennas, such as for home use. In normal applications, the towers are free-standing. The critical loading condition is the wind load condition. The wind loads are taken to be proportional to the exposed or projected area on one face, which is assumed to be normal to the direction of the wind, multiplied by an appropriate factor to account for the wind load on the two remaining, oblique faces

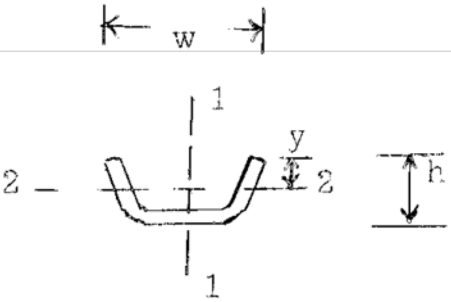
Section Properties

The pertinent section properties [illegible] listed in the tables below.



Cross Section of Typical [illegible]

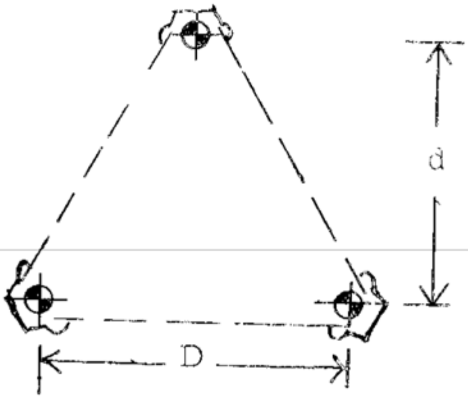
SECTION PROPERTIES OF VERTICAL ELEMENTS								
Tower Section	t in.	b in.	d in.	y in.	Area in.²	[illegible]	[illegible]	[illegible]
AX-1	.048	.813	1.875	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
AX-2	.048	.813	1.937	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
AX-3	.048	.875	1.937	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
AX-4	.075	.937	2.062	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
AX-5	.075	1.000	2.312	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
AX-6	.090	1.000	2.562	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
AX-7	.105	1.375	[illegible]	.623	[illegible]	[illegible]	[illegible]	[illegible]
AX-8	.105	1.375	3.000	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]



Cross Section of Typical Diagonal Element

	Section Properties of Diagonal Elements								
Tower Sect.	t in.	h in.	w in.	y in.	Area in^2	I_1 in^4	r_1 in	I_2 in^4	r_2 in
AX-1	.048	.35	.75	.25	.0546	.00295	.232	.000739	116
AX-2	.048	.35	.75	.25	.0546	.00295	.232	000739	.116
AX-3	.048	.35	.75	.25	.0546	.00295	.232	.000739	.116
AX-4	.060	.35	.70	.25	.0684	.00368	.232	.000924	.116
AX-5	.075	.42	1.05	.40	.1125	.01312	.341	.00454	.201
AX-6	.075	.42	1.05	.40	.1125	.01312	.341	.00454	.201
AX-7	.075	.42	1.05	.40	.1125	.01312	341	.00454	.201
AX-8	.075	.42	1.05	.40	.1125	.01312	.341	.00454	.201

The section properties at the base of the various tower sections are listed in the table below.



Typical Cross Section of Tower

Section Properties of Tower

Tower Sect.	Area in^2	d in.	Wt. of Section
AX-1	.396	9.0	18 lbs.
AX-2	.414	11.0	17
AX-3	.432	13.0	20
AX-4	.717	14.9	27
AX-5	.759	17.1	40
AX-6	.960	19.3	45
AX-7	1.389	21.6	62
AX-8	1.423	24.2	68

Strength of Elements

The width-to-thickness ratios for the flat areas of the various elements are such that local crippling is not a consideration. Moreover, since each element is essentially a channel and its cross section is symmetrical about its minor axis, the mode of possible compressive failure of each element may be taken as symmetrical. Accordingly the allowable compressive stress for the various elements is taken as

$$F'_a = 17,000 - .485\,(L/r)^2$$

The allowable stresses are increased by 33-1/3 percent for the wind load case, in accordance with standard codes:

$$F_a = 1.333\left[17,000 - .485\,(L/r)^2\right]$$

The allowable compressive stresses in the various members are computed in the following tables.

Vertical Members				
Sect.	L in.	r in.	F'a psi	Fa psi
AX-1	12	.242	15,800	21,100
AX-2	12	.251	15,800	21,100
AX-3	12	.293	16,200	21,600
AX-4	12	.303	16,200	21,600
AX-5	12	.315	16,300	21,700
AX-6	12	.313	16,300	21,700
AX-7	12	.423	16,600	22,100
AX-8	12	.414	16,600	22,100

Diagonal Members				
Sect.	L in.	r in.	F'a psi	Fa psi
AX-1	5.8	.116	15,800	21,100
AX-2	6.6	.116	15,300	20,500
AX-3	7.6	.116	14,900	19,900
AX-4	8.6	.116	14,300	19,100
AX-5	9.7	.201	15,900	21,200
AX-6	11.0	.201	15,500	20,700
AX-7	12.0	.201	15,200	20,300
AX-8	13.3	.201	14,900	19,900

Wind Loads and Axial Loads

The wind load of one face normal to the direction of the wind is taken at 15 psf acting on the projected area of the lower 60 feet of that face, and 20 psf on the portion above the 60-foot level. At the remaining two faces, the normal lies at 60° to the direction of the wind and therefore, the wind velocity component on such faces is one-half of that on the frontal face. Since the wind pressure varies as the square of the velocity, the load on each of the two oblique faces is one-fourth of that on the frontal face and the total load may be taken as 1.5 times the load on the frontal face. An antenna having a projected area of 2 square feet and assumed to be located 5 feet above the tower is also included.

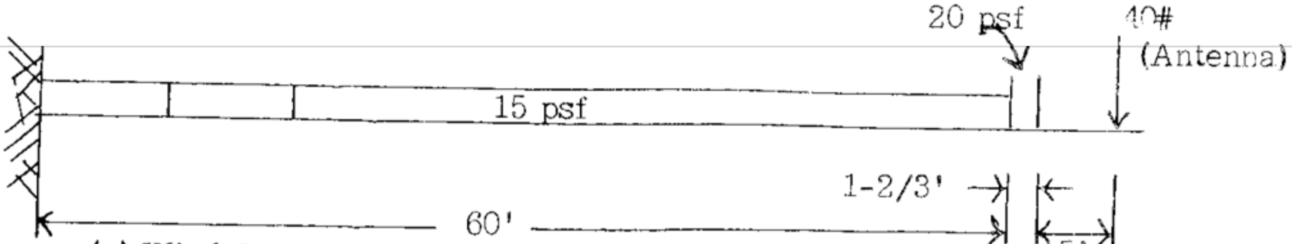
Projected areas are computed in the following table.

Projected Area Calculations

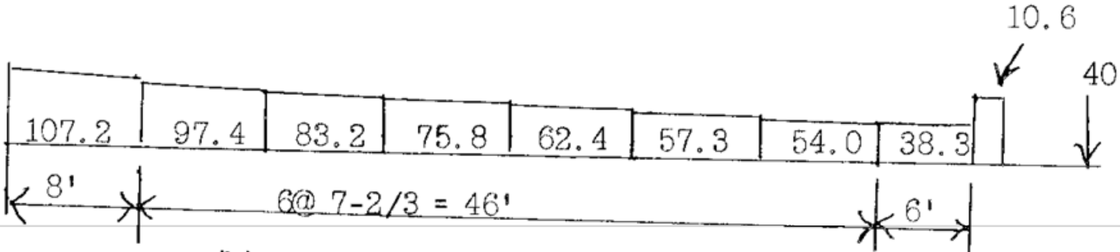
Sect.	Width of Leg in.	Diagonals		Area sq. ft.			
		Width in.	Length in.	Two Legs	Ten Diags.	One Face	Sect.
AX-1	1.29	.75	10.00	1.65	.52	2.17	3.26
AX-2	1.40	.75	11.75	1.79	.61	2.40	3.60
AX-3	1.43	.75	13.75	1.83	.72	2.55	3.82
AX-4	1.57	.70	15.75	2.01	.76	2.77	4.15
AX-5	1.60	1.05	18.00	2.05	1.31	3.36	5.04
AX-6	1.72	1.05	20.50	2.20	1.50	3.70	5.55
AX-7	2.10	1.05	22.50	2.69	1.64	4.33	6.49
AX-8	2.20	1.05	25.20	2.93	1.84	4.77	7.15

The wind loadings, shear and bending moment diagrams are shown in the following figure.

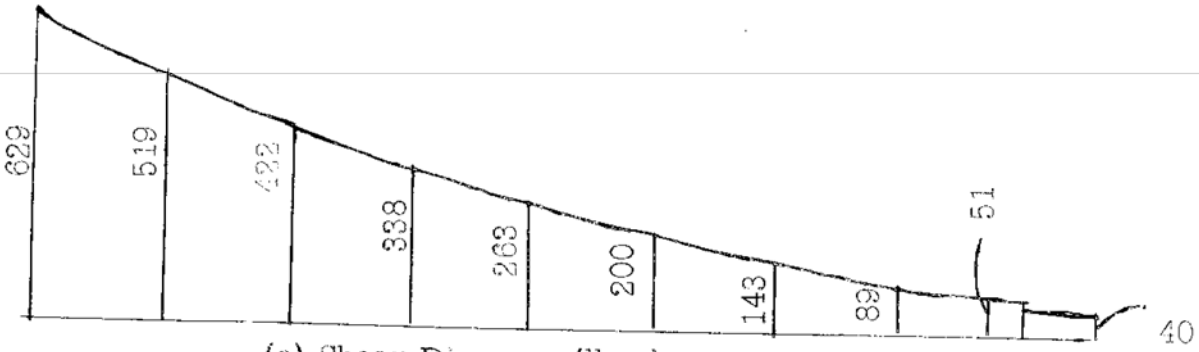
In computing the applicable axial loads subsequently in the section on Stresses, an allowance on 20 pounds is made for the weight of the antenna and [illegible]



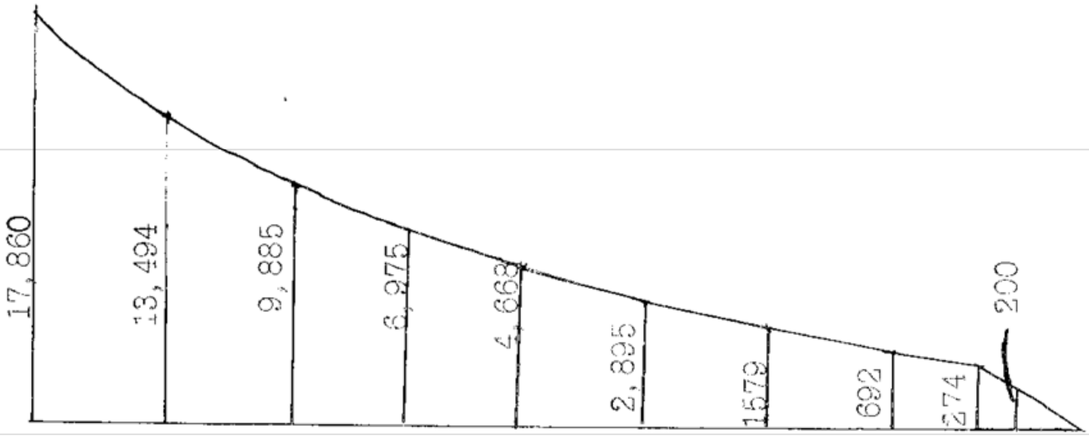
(a) Wind Load Intensities



(b) Wind Loads



(c) Shear Diagram (lbs.)



(d) Moment Diagram (ft-lbs.)

Stresses

Vertical Members

The average longitudinal stress in the vertical members attains its critical magnitudes when the wind is normal to the windward face of the tower and a single member is in the position of the compression chord. In this case the single compression vertical is the critical member.

The average longitudinal stress in the critical vertical member may be taken as

$$f = \frac{1}{A}\left(-\frac{M}{d} - \frac{P}{3}\right)$$

Where

A = cross sectional area of 1 vertical

d = normal distance between centroids

M = bending moment

P = axial load

These stresses are computed for the base of each tower section in the following table. The axial loads, P, are the weight of all sections above the critical section in question, including an allowance of 20 pounds for the weight of the antenna and accessories.

Average Streses in Verticals at Base of Section

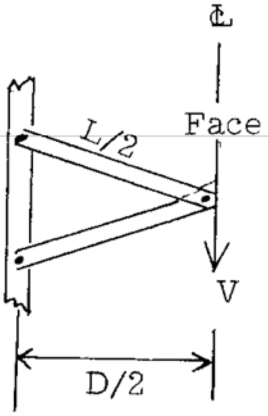
Sect.	A sq. in.	d in.	P lbs.	M ft-lbs.	$\frac{P}{3}$	$\frac{12M}{d}$	$\frac{P}{3}+\frac{12M}{d}$ lbs.	f psi	Allow F psi
AX-1	.132	9.0	38	692	13	922	935	7,100	21,100
AX-2	.138	11.0	55	1,579	18	1,722	1,740	12,600	21,100
AX-3	.144	13.0	75	2,895	25	2,670	2,695	18,750	21,200
AX-4	.239	14.9	102	4,668	34	3,770	3,804	15,950	21,300
AX-5	.253	17.1	142	6,975	47	4,820	4,867	19,250	21,700
AX-6	.320	19.3	187	9,885	62	6,150	6,212	19,400	21,700
AX-7	.445	21.6	249	13,494	83	7,500	7,583	17,000	22,100
AX-8	.471	24.2	317	17,860	106	8,850	8,956	19,050	22,100

The stresses in the diagonals are due to the shear force on tower.

The shear in each of the oblique faces of the tower may be taken as

$$S = \frac{1}{2} \quad \frac{H}{\text{Cos } 30^\circ} = .577H$$

Where H is the total shear on the tower at the section under consideration.



Since the X-braces are spaced vertically at 18.75 inches, the vertical component of the force carried by a pair of diagonals is

$$V = \frac{18.75\,S}{D} = 10.8\,\frac{H}{D}$$

and the axial load in each diagonal is

$$Q = \frac{VL}{13.5}$$

$$= .80\,H\,\frac{L}{D}$$

and the axial stress in the diagonal is given by $f = Q/A$.

The axial loads and stresses in the diagonals at the lower ends of the respective sections are computed in the following table

Stresses in Diagonals

Sect.	L in.	D in.	A sq. in.	H lbs.	Q lbs.	Q/A psi	Allow. F psi
AX-1	12.4	10.4	.0546	89	85	1560	21,100
AX-2	14.5	12.8	.0546	143	130	2380	20,500
AX-3	16.4	15.0	.0546	200	175	3210	19,900
AX-4	18.5	17.2	.0684	263	227	3320	19,100
AX-5	20.9	19.8	.1125	338	286	2540	21,200
AX-6	23.4	22.4	.1125	422	351	3120	20,700
AX-7	25.9	25.0	.1125	519	430	3820	20,300
AX-8	28.8	28.0	.1125	626	516	4590	19,900

From the foregoing calculations, it is seen that the actual average stresses in the verticals and in the web members due to gravity and the specified intensity of wind load are less than the allowable stresses.

[illegible] SPLICES

The verticals are spliced by 1035 steel bolts of the sizes and numbers [illegible]. The shear and bearing strength are based upon basic allowable stresses of 15,000 psi and 3.5 times the allowable compressive stress for the material (see AISI Code) respectively, multiplied by 1.33 for wind load conditions. The thickness of the member is denoted by t in the following table.

Loads at Vertical Splices

Sect.	Bolts	t	Allow. Load, lbs.		Appl. Load
			Shear	Bearing	
AX-1	2-1/4	.048	1960	2020	935
AX-2	2-1/4	.048	1960	2020	1740
AX-3	2-1/2	.048	7840	4040	2695
AX-4	2-1/2	.075	7840	6300	3804
AX-5	2-1/2	.075	7840	6300	4867
AX-6	2-1/2	.090	7840	7550	6212
AX-7	3-1/2	.105	11760	13200	7583
AX-8	3-1/2	.105	11760	13200	8956

The diagonals are attached to the verticals by A17ST aluminum alloy rivets, having basic allowable shear and bearing stresses of 10,000 and and 36,000 psi respectively. These allowable stresses are increased by one-third for the wind load condition. The allowable loads and applied loads on the attachments of the diagonals are computed in the following table.

The maximum or resultant load on a rivet is, as shown previously,

$$V = 10.8 \frac{H}{D}$$

These values are listed as the applied loads in the following table.

Loads at Diagonal Connections

Sect.	t	Rivet	Allow. Loads, lbs. Shear	Allow. Loads, lbs. Bearing	Applied Loads lbs.
AX-1	.048	5/32	256	270	93
AX-2	.048	5/32	256	270	120
AX-3	.048	5/32	256	270	144
AX-4	.060	3/16	368	405	165
AX-5	.075	3/16	368	505	185
AX-6	.075	3/16	368	505	203
AX-7	.075	1/4	655	675	224
AX-8	.075	1/4	655	675	242

5-67

REPORT ON
TEST OF

SPAULDING AX-TYPE
64 - FOOT
FREE-STANDING
ANTENNA TOWER

PREPARED FOR

SPAULDING PRODUCTS CO., INC.
FRANKFORT, INDIANA

by

John E. Goldberg, Ph. D.
Registered Professional Engineer
(Indiana, Illinois)

West Lafayette, Indiana

April, 1959

SUMMARY

Transverse loading tests, simulating wind loading, were made on a Spaulding AX-68, 64-foot free-standing antenna mast or tower. These tests indicate that the ultimate strength of the tower corresponds to the loading due to a wind velocity of approximately 92 miles per hour.

Date of Test: Wednesday, April 1, 1959

Location of Test: Spaulding Products Co., Inc. Plant, Frankfort, Indiana

Observers: Messrs. R. L. Beard, Sr., and B. W. Lambert of Spaulding
Products Co., Inc.
Mr. John E. Goldberg, Registered Professional Engineer,
Director of Test.

I. TEST ARTICLE

The test article consisted of a standard 64-foot open triangular mast produced by the Spaulding Products Company and designated by the manufacturer as type AX. The mast consists of eight sections, each nominally eight foot long, which are bolted together to form the 64-foot mast.

The sections are fabricated with formed galvanized steel elements. Each face of each section contains five pairs of cross-braces, each pair being in an *X*-arrangement.

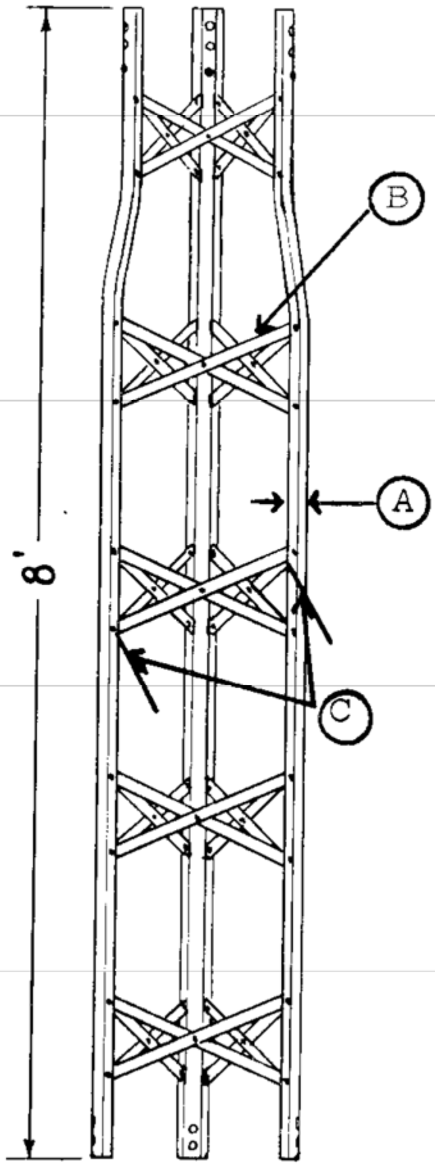
The test article was taken from stock, and the thicknesses and other dimensions of its elements correspond with those of the AX-models currently being produced by the Spaulding Products Company.

II. PROCEDURE

The [illegible] tower was mounted in a horizontal [illegible] [illegible] at the base of the tower. In this horizontal position, the dead weight of the tower contributed to the transverse loading. The tower was [illegible] windward face of the tower. Preliminary [illegible] and procedures [illegible] have [illegible].

[illegible]

[illegible]


8'
B
A
C

III. PROJECTED AREA CALCULATIONS

In accordance with the usual specifications and codes for the design of open, triangular antenna towers, the wind load is assumed to act upon an area which is equal to 1.5 times the projected area of one face. The relevant areas are calculated in the following table for each of the eight sections of the tower. Section AX-1 is the top section of the tower; Section AX-8 is the lowest section.

References to sizes of legs and cross braces are made to the drawing of one side of one section of tower on opposite page.

	A	B	C				
Sect.	Width of Leg (in.)	Cross-Brace		Area (Sq.-Ft.)			
		Width (in.)	Clear Length (in.)	Two Legs (in.)	Ten Braces	One Face	Section
AX-1	1.29	.75	10.00	1.69	0.52	2.21	3.32
AX-2	1.40	.75	11.75	1.83	0.61	2.44	3.66
AX-3	1.43	.75	13.75	1.87	0.72	2.59	3.89
AX-4	1.57	.70	15.75	2.06	0.76	2.82	4.23
AX-5	1.60	1.05	18.00	2.09	1.31	3.40	5.10
AX-6	1.72	1.05	20.50	2.26	1.50	3.76	5.64
AX-7	2.10	1.05	22.50	2.74	1.64	4.38	6.57
AX-8	2.20	1.05	25.20	2.88	1.84	4.72	7.08

IV. TEST RESULTS

An initial loading was placed on the cantilever such that, in combination with the dead load, a distributed loading of 10 pounds per square foot of effective projected area (effective area equals 1.5 times the projected area of one face) was applied to each section. Subsequently, additional load was applied to the entire specimen in increments corresponding to 1.25 pounds per square foot of projected area until failure occurred. Failure resulted from a local crippling of the compression leg immediately below the lowest X-brace. The loading condition at failure is summarized in the following table.

Section	AX-1	AX-2	AX-3	AX-4	AX-5	AX-6	AX-7	AX-8
Dead Load (lbs.)	18	17	20	27	40	45	62	58
Superimposed Load at Failure (lbs.)	68	80	83	84	94	113	111	118
Total Load at Failure (lbs.)	86	97	103	111	134	158	173	176
Shear at Base of Section (lbs.)	86	183	286	397	531	689	862	1038
Moment at Base of Section (lb.-ft.)	334	1377	3194	5641	9437	14165	20171	27534

V. DISCUSSION

Assuming a drag coefficient of 1.2, the dynamic pressure corresponding to the loading of 26.25 psf which existed at failure is

$$q = \frac{26.25}{1.2} = 21.88 \text{ psf.}$$

The relation between dynamic pressure and wind velocity, V, in miles per hour is given by the well known formula

$$q = .00256V^2$$

Thus, corresponding to a distributed loading of 26.25 psf and an assumed drag coefficient of 1.2, the wind velocity is

$$V = \sqrt{\frac{q}{.00256}}$$

$$= \sqrt{\frac{21.88}{.00256}}$$

$$= 92.4 \text{ mph.}$$

Hence, the ultimate wind velocity which the tower itself may be expected to withstand is 92.4 mph.