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of
The Institute of Radio Engineers

EDITED BY
ALFRED N. GOLDSMITH, Ph.D.

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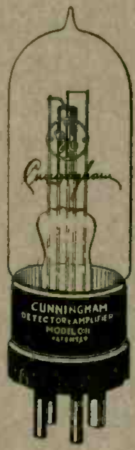

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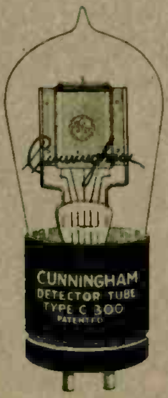

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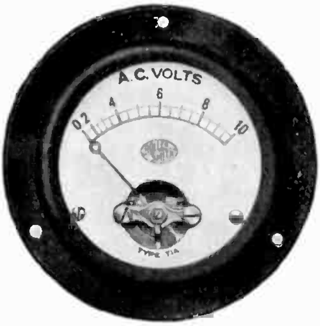

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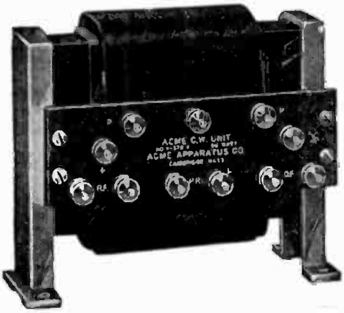

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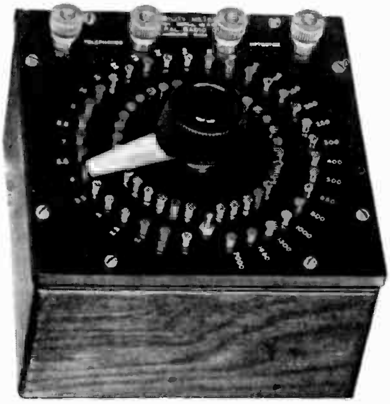

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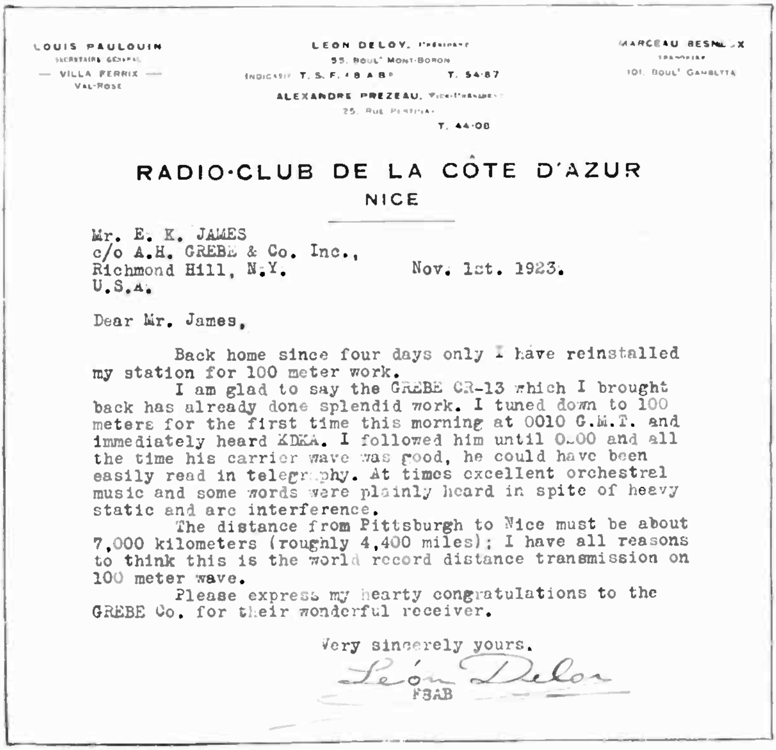

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Nov. 1st. 1923.

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The distance from Pittsburgh to Nice must be about 7,000 kilometers (roughly 4,400 miles); I have all reasons to think this is the world record distance transmission on 100 meter wave.

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Very sincerely yours,

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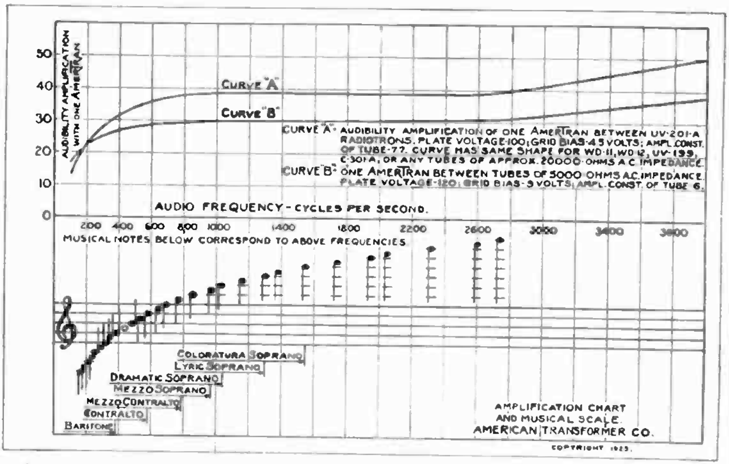
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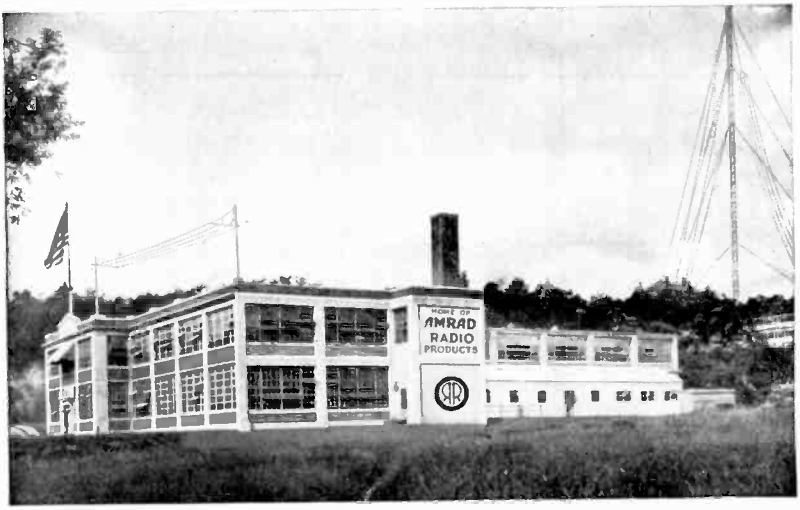

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A Radio Statement to the Public

KEEPING its pledge to the public, the Radio Corporation of America has concentrated its vast research forces upon the solution of certain fundamental problems —problems which have become more apparent as broadcasting stations and radio receivers multiply.

Briefly stated, there is today a necessity for

—*A radio receiver providing super-selectivity*—the ability to select the station you want—whether or not local stations operate. A selectivity which goes to the theoretical limits of the science.

—*Super-sensitiveness* — meaning volume from distant stations—along with selectivity

—*Improved acoustics*—more faithful reproduction of broadcasted voice and music than has ever been possible before.

—*"Non-radiating" receivers*—a new development, a type of receiver which, no matter how handled, will not interfere with your neighbor's enjoyment.

—*More simplified operation*—a super-receiver requiring no technical skill, thus making the greatest achievements of entertainment immediately available to all members of the family.

—*A receiver for the apartment house* and populated districts, requiring neither aerial nor ground connection.

—*Another type of improved receiver for the suburban districts*, equally capable to that above, for use where the erection of an aerial presents no problem.

Painstaking search in quest of these ideals has led to new discoveries, setting new standards—discoveries, which have established:

First—that improved acoustics are possible—a matter of scientific research—for truly melodious reception.

Second—that dry battery operated sets can be so designed as to give both *volume* and distance.

Third—that the regenerative receiver could be markedly improved — providing selectivity, sensitiveness and simplicity of operation hitherto deemed impossible.

Fourth—that the Super-Heterodyne—the hitherto complicated device requiring engineering skill to operate—could be vastly improved—improved in sensitiveness and selectivity—and simplified so that the very novice and the layman could enter new regions of entertainment and delight.

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PROCEEDINGS OF
The Institute of Radio Engineers

Volume 12 FEBRUARY, 1924 Number 1

CONTENTS

GENERAL INFORMATION

The **Proceedings** of the Institute are published every two months and contain the papers and the discussions thereon as presented at the meetings in New York, Washington, Boston, Seattle, San Francisco, or Philadelphia.

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RECEIVING MEASUREMENTS AND ATMOSPHERIC DISTURBANCES AT THE RADIO PHYSICAL LABORATORY, BUREAU OF STANDARDS, WASHINGTON, JULY AND AUGUST, 1923*

By

L. W. Austin

(Chief of the Radio Physical Laboratory, Bureau of Standards, Washington, D. C.)

(*Communication from the International Union of Scientific Radio Telegraphy*)

The observations for July and August afford some opportunities for a comparison of this summer's result with the corresponding values of last year.

Lafayette's change of frequency from 12.8 kilocycles per second (kc.) to 16.2 kc., mentioned in the May-June report, has been accompanied by an increase in signal strength in Washington of about 1.6 times. As far as is known, there have been no changes other than the change in frequency to explain the increase.

This, together with some observations on shorter wave stations, may indicate a distinct optimum frequency in the neighborhood of 16 kc. for northern trans-Atlantic communication, but of course it is still too early to draw definite conclusions on this point.

The signal strength of Nauen, both in the morning and during the afternoon fading, is practically the same as in the corresponding months last year. The atmospheric disturbances are considerably lighter than in 1922.

---

*Received by the Editor, November 3, 1923

Field Intensity of Nauen and of Disturbances ($f = 23.4$ kc. $\lambda = 12{,}800$ m.) in July, 1923, in Micro-volts per Meter

Date	9 A. M.		3 P. M.	
	Signal	Disturbance	Signal	Disturbance
2	34.7	30	6.5	150
3	47.0	30	2.0	210
5	30.0	40	*	135
6	23.4	30	*	125
7	16.3	42	. . . .	—
9	30.0	25	*	160
10	19.0	35	*	180
11	23.4	30	*	300
12	34.2	20	2.0	200
13	22.0	22	*	180
14	17.0	30	**	. . . .
16	13.7	100	*	380
17	55.7	48	16.1	240
18	42.0	60	18.0	60
19	36.4	48	18.4	150
20	47.0	65	12.2	100
21	**	60	. . . .	. . . .
23	55.7	48	2.0	150
24	42.7	48	*	240
25	42.0	65	*	380
26	72.5	30	27.0	100
27	. . . .	. . . .	. . . .	. . . .
28	. . . .	. . . .	. . . .	. . . .
30	**	28	*	360
31	**	15	6.3	130
Average	35.2	41.2	5.5	196.5

*Not heard.

**Not sending.

. . . . Not taken.

Field Intensity of Lafayette and of Disturbances ($f = 15.9$ *kc.* $\lambda = 18{,}900$ m.) in July, 1923, in Micro-volts per Meter

Date	9 A. M.		3 P. M	
	Signal	Disturbance	Signal	Disturbance
2	**	40	66.3	200
3	126.0	35	40.4	260
5	120.0	50	24.5	135
6	66.3	35	2.0	180
7	84.0	60	....	....
9	108.0	35	15.0	170
10	120.0	55	*	210
11	102.0	48	42.3	350
12	137.0	30	57.3	280
13	140.0	25	36.2	200
14	120.0	40	....	....
16	77.2	160	2.0	410
17	330.0	60	102.0	260
18	108.0	50	84.0	70
19	160.0	65	114.0	150
20	160.0	80	84.0	130
21	90.0	75	....	....
23	168.2	80	45.2	175
24	156.2	65	18.0	280
25	150.0	55	2.0	350
26	175.0	80	60.0	150
27	....	....	....	....
28	....	....	....	....
30	150.0	35	2.0	550
31	66.3	20	40.2	150
Average	132.4	55.5	41.9	232

*Not heard.

**Not sending.

....Not taken.

Field Intensity of Nauen and of Disturbances ($f = 23.4$ kc., $\lambda = 12{,}800$ m.) in August, 1923, in Micro-volts per Meter

Date	9 A. M.		3 P. M.	
	Signal	Disturbance	Signal	Disturbance
1	26.0	10	10.5	150
2	25.7	65	10.0	200
3	**	20	....	....
4	26.2	60	....	....
6	25.6	35	*	300
7	25.0	55	....	....
11	25.6	50	....	....
13	25.6	25	15.0	200
14	38.2	40	*	110
15	25.6	60	2.0	200
16	34.2	50	*	250
17	26.6	45	*	200
18	25.7	30	....	....
20	47.0	30	9.3	100
21	21.5	20	*	280
22	27.0	30	*	250
23	30.0	20	2.0	80
24	25.7	48	30.0	120
25	25.7	40	....	....
27	30.2	25	2.0	240
28	27.0	60	9.0	250
29	**	50	*	280
30	18.0	65	*	200
31	31.0	50	*	500
Average	27.8	40.9	5.0	217.1

*Not heard.

**Not sending.

....Not taken.

Field Intensity of Lafayette and of Disturbances ($f = 15.9$ kc., $\lambda = 18{,}900$ m.) in August, 1923, in Micro-volts per Meter

Date	9 A. M.		3 P. M.	
	Signal	Disturbance	Signal	Disturbance
1	102.0	15	60.2	180
2	84.0	85	90.0	250
3	152.0	25	. . . .	. . . .
4	84.0	65	. . . .	. . . .
6	60.0	50	72.2	320
7	78.2	75	60.0	300
11	102.0	80	. . . .	. . . .
13	78.2	35	54.0	250
14	78.2	35	42.2	110
15	120.0	60	30.4	250
16	**	65	18.0	300
17	84.0	60	2.0	250
18	145.0	45	. . . .	. . . .
20	152.0	35	60.2	110
21	126.0	25	25.4	300
22	84.0	30	30.0	300
23	96.0	25	96.0	100
24	152.0	45	120.0	150
25	126.0	50	. . . .	. . . .
27	120.0	25	48.3	240
29	**	60	30.2	300
30	120.0	80	40.0	250
31	120.0	60	2.0	630
Average	107.7	49.1	48.9	255

*Not heard.

**Not sending.

. . Not taken.

RATIO OF AVERAGES

f kilocycles	Signal P. M. / A. M.	Disturbance P. M. / A. M.	A. M. Signal / Disturbance	P. M. Signal / Disturbance
		JULY		
15.9	0.316	4.18	2.38	0.180
23.4	0.156	4.77	0.854	0.028
		AUGUST		
15.9	0.454	5.20	2.19	0.192
23.4	0.180	5.31	0.680	0.023

Radio Physical Laboratory,
Bureau of Standards,
September 25, 1923.

SUMMARY: The signal strengths of the Nauen and Lafayette Stations, and the corresponding strength of the atmospheric disturbances in Washington are given for July and August, 1923.

THE RADIO EQUIPMENT OF THE STEAM YACHT "ELETTRA"*

By

Eric A. Payne

(Marconi's Wireless Telegraph Company, Ltd.)

The steam yacht "Elettra" was designed by Messrs. Cox and King, of London, and built by Messrs. Ramage and Ferguson, at Leith, Scotland, being completed in May, 1904. She was originally the property of the Archduchess Maria Theresa of Austria, being then called "Rovenska," and was used by the British Admiralty for naval purposes during the war. In the year 1919, she was purchased by Senatore Guglielmo Marconi and renamed "Elettra."

The principal dimensions are as follows: Overall length, 220 feet (72.2 m.), length at water line, 198 feet (64.9 m.), beam, 27½ feet (9.2 m.), and the depth, 16½ feet (5.4 m.). The registered tonnage is 232, gross tonnage 633, and the Thames measurement tonnage 693. The yacht is driven by a triple expansion condensing steam engine. The high, medium and low pressure cylinders have diameters of 16, 26, and 42 inches, respectively, and the stroke is 27 inches. The nominal horsepower is 137, and the indicated horsepower is about 1000.

There are two coal-fired boilers having grate surfaces of 95 square feet area, and a total heating surface of 645 square feet.

The working pressure for the main boilers is 180 pounds per square inch, and for the donkey boiler 120 pounds per square inch. The normal cruising speed is 10 knots, with the engine running at 90 revolutions per minute. The consumption of fuel at this speed is about 12 tons per day, and a sufficient quantity may be carried for about 12 days, normal steaming.

Sails are also used when the wind is favorable, as, apart from the speed gained, they assist in steadying the yacht. Figure 1 is a view of the yacht, and Figure 1A shows the arrangement of the antennas.

The main storage battery for lighting and supplying the radio

---

*Received by the Editor, August 17, 1923.

when the dynamo is not running is situated in the propeller shaft tunnel. It consists of 36 cells and has a capacity of 500 ampere-hours. This battery is charged by a dynamo which is driven by a small steam set. A gasoline motor is also provided for use when the yacht is in port and there is no steam available.

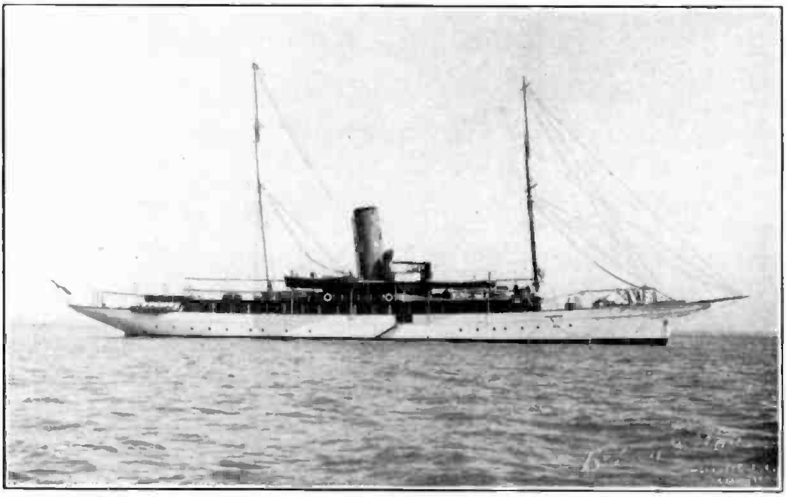

Figure 1—The Steam Yacht "Elettra"

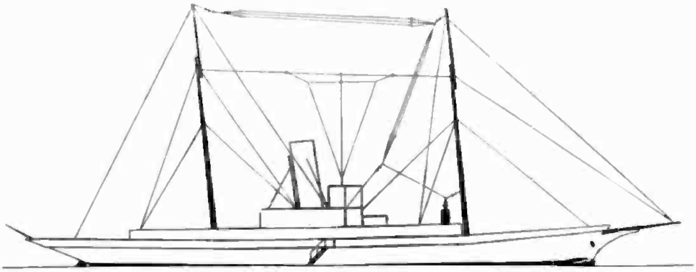

Figure 1A—Rigging Plan of Steam Yacht "Elettra"

A submarine signal receiver is fitted with which it is possible to tell from which direction the signal is coming. There are two microphones situated inside the hull, one on either side of the bow. By means of a throw-over switch, either of these may be connected to a battery and telephones located in the chart house. When in the vicinity of a signal station, the navigator listens in the telephones, and the microphone which is more directly facing the signal bell gives the louder response. The ship's log has an electric repeater, whereby the distance travelled thru the water is recorded on dials in the engine room and in the chart house. A powerful searchlight is fitted to the foremast, the light being supplied by an electric arc lamp.

The yacht is navigated by a Sperry Gyroscope compass. The master gyro compass is installed below in a fairly central position, and the charging generator and motor alternator for revolving the gyro rotor, are placed in the engine room. The switchboard for controlling the various circuits is fitted near the master compass.

One electrically operated repeater for steering purposes is located on the bridge, and another on the top deck for taking bearings of distant objects. By the use of this compass in conjunction with the radio direction finder, very exact navigation is effected. Figure 2 shows the yacht being steered by Sperry gyro compass.

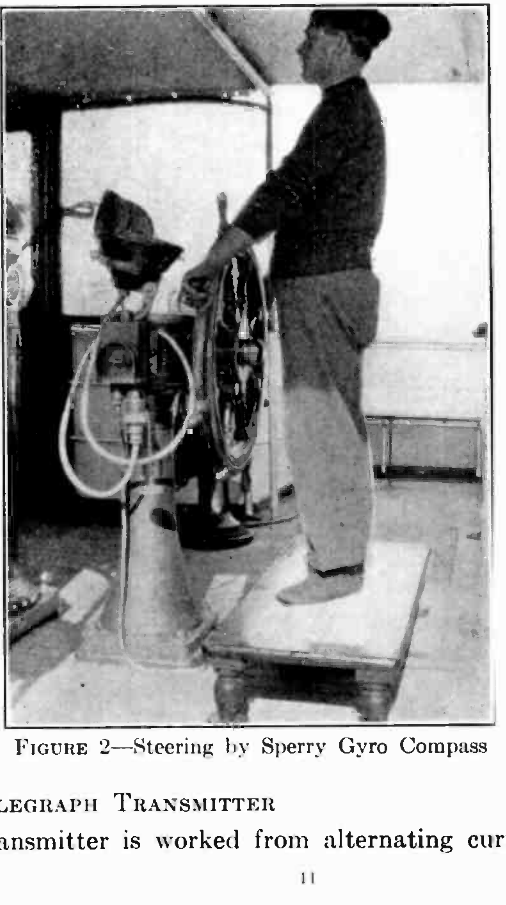

Figure 2—Steering by Sperry Gyro Compass

Valve Telegraph Transmitter

This transmitter is worked from alternating current which is supplied by a motor alternator driven from the yacht's main lighting battery. The supply is 400 volts at a frequency of 300 cycles. The filament current is supplied by small step-down transformers and is regulated by chokes with variable iron cores, operated thru gearing, by handles from the front of the transmitting panel. For the high tension plate voltage, the alternating current supply is stepped up by an oil-cooled transformer to 12500 volts, and then rectified by two 2-electrode valves. This transformer has a centre point tapping, and the valves are arranged for double rectification. A condenser of large capacity is connected across the output, and iron cored chokes are placed in series, and a fairly smooth and steady supply is obtained, of direct current at about 8000 volts. Figure 4A shows the connections of the rectifier circuits.

This direct current, high tension supply is fed to three 3-electrode valves, which have their plates connected in parallel. Each grid is connected to the reaction coil thru a separate condenser and resistance, this reaction coil providing a variable coupling between the plates and grids. The plates are connected to the aerial inductance thru a blocking condenser, composed of four glass tube condensers. In series with the direct current high tension supply to the plates is an air-cored choke and between the supply side of this and the earth connection, another glass tube condenser is connected, for by-passing any high frequency currents which may have got thru the choke.

Signaling is effected by simultaneously breaking the main transformer primary, and the grid circuit, by means of a relay, which is controlled by the hand-telegraph key, and operated by the direct current supply. Figure 4B shows the oscillator circuits.

The handle of the safety gates of the transmitter is mechanically coupled to a switch, so that the power is cut off when these gates are opened. Also, the act of opening these gates operates push rods, which discharge the smoothing condensers, so that the apparatus is safe to handle.

Ammeters are provided for reading the filament and plate currents. The power input to the transmitter is regulated by an iron-cored choke, connected in the primary circuit of the main transformer. To compensate for the drop in voltage caused when the key is pressed, a small iron-cored compensating choke in the primary circuit of the filament transformers is short-circuited by an additional contact on the signaling relay. By means of a variable iron core, the value of this choke may be adjusted so that the filament brilliancy is maintained constant during telegraphic transmission.

The amount of coupling between the grid and plate circuits, and the position of the plate connection to the aerial inductance, are adjusted to give maximum aerial current, at the same time, keeping the plate current as small as possible.

Any wave length from 200 to 3000 meters may be obtained by means of a variable inductance and series condenser; a rough adjustment being made by a tapping and the final adjustment by a variometer.

TELEPHONY

The same transmitter may be used for telephonic communication when required. Modulation is effected by two valves, which have their plates connected to the high tension, direct current supply. The grids of these valves are coupled thru an iron-cored choke and battery to the filaments, and also thru a coupling condenser, to the plate of an amplifying valve.

The plate current for this amplifying valve is also supplied from the same high tension supply, thru a large resistance, and its filament current is supplied from an accumulator, so as to ensure an absolutely steady emission.

A microphone and battery are connected to the grid of this amplifier valve thru a small iron-cored transformer.

Ammeters are connected in the plate circuits of both modulating and amplifier valves, so as to indicate the amount of modulation.

The telephone transmitter is operated by a remotely controlled relay, which changes the aerial from the receiver, lights up the modulating valves, and starts the main transmitter oscillating.

In order to carry on conversation with another station, it is necessary to operate only one small switch, which controls this relay. Figure 3 shows the front of the transmitter, Figure 4 the rear view with the control relays, Figure 4C the modulator, and Figure 5 the complete layout on the yacht.

MAIN SPARK TRANSMITTER

Power for the main spark transmitter is supplied by a motor alternator, driven from the direct current supply from the yacht's battery. Alternating current of $1\frac{1}{2}$ kilowatts is supplied at a voltage of 200, and a frequency of 500 cycles.

This voltage is stepped up by an oil-cooled transformer and

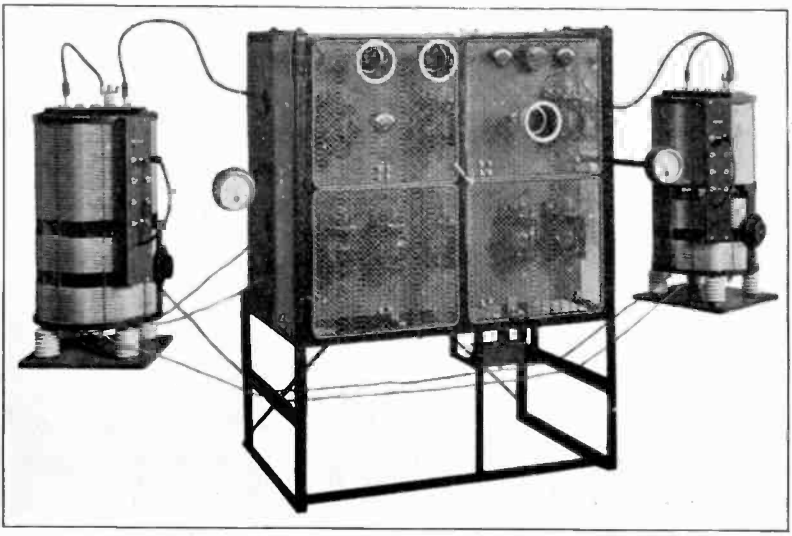

FIGURE 3—3 K.W. Valve Telegraph and Telephone Transmitter, Arranged for Inductive Coupling to Aerial

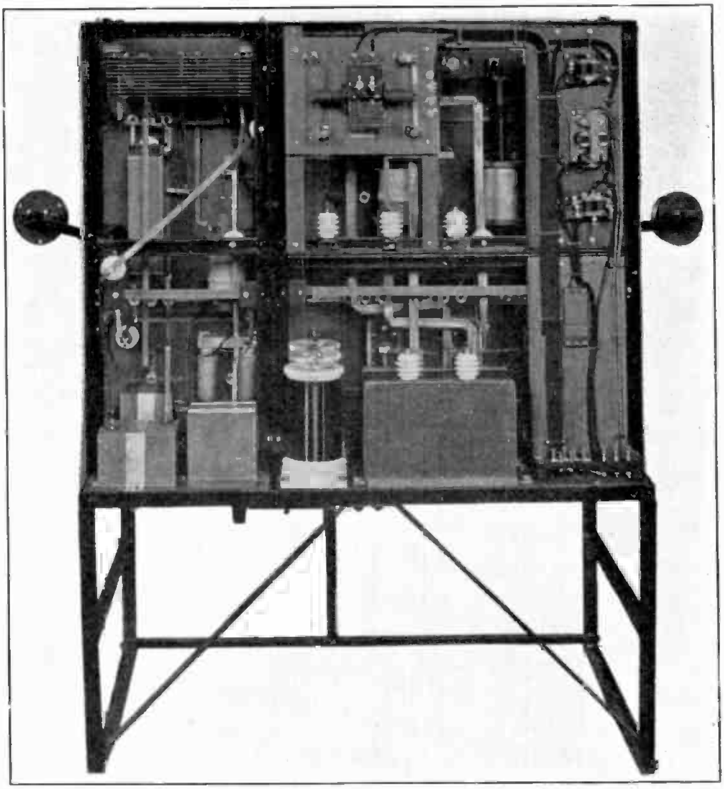

FIGURE 4—3 K.W. Valve Telegraph and Telephone Transmitter—Rear View Showing Control Relays

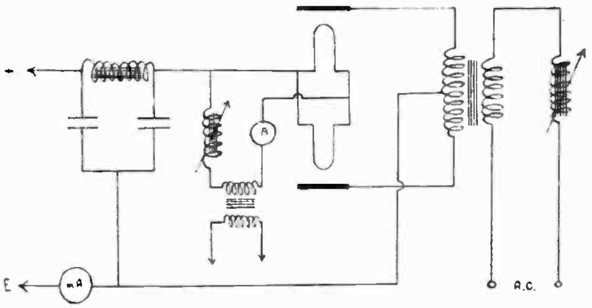

FIGURE 4A—Rectifier

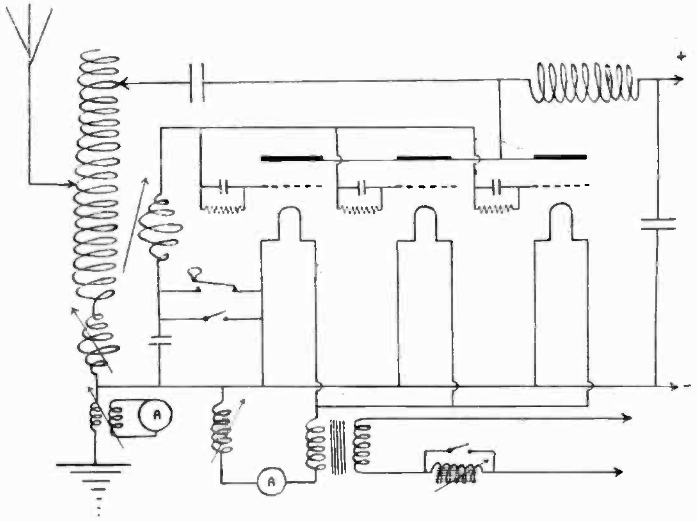

FIGURE 4B—Oscillator

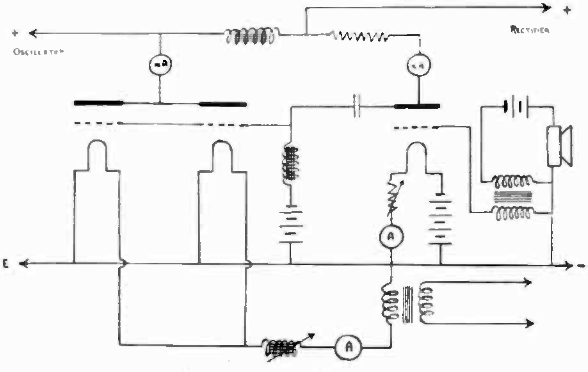

FIGURE 4C—Modulator

supplied to a quenched spark gap of eight plates, thru suitable high frequency chokes. A mica condenser and flat spiral inductance form the primary closed circuit, which is coupled to the aerial circuit by another flat inductance, made of copper strip. The coupling is varied by altering the number of secondary turns, and the aerial is tuned by altering the tappings on other flat spiral inductances. By means of a switch which changes simultaneously the primary and secondary tappings, the wave length may instantly be changed to 450, 600, or 800 meters.

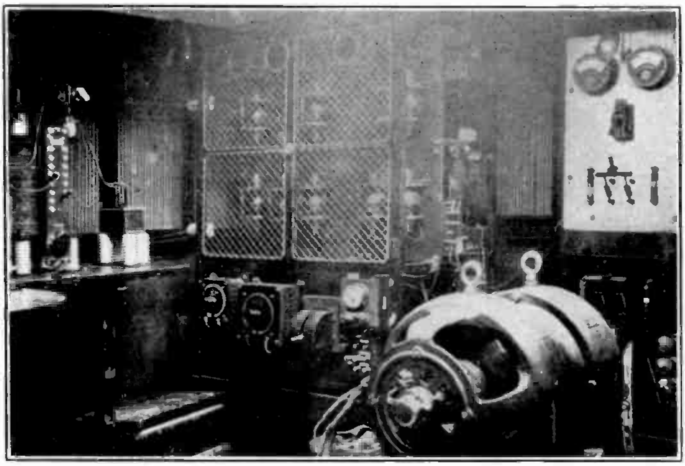

FIGURE 5—3 K.W. Valve Transmitter, Showing Motor Alternator and Aerial Inductance

The signaling key is placed in the primary circuit of the power transformer.

A hot wire ammeter is provided for measuring the aerial current, and a voltmeter for indicating the alternating current supply voltage.

Power to the transmitter is varied by altering the excitation of the alternator field, the number of plates in the spark gap being varied accordingly. Figure 6 is a view of the complete transmitter, and Figure 6A shows the connections.

EMERGENCY SPARK TRANSMITTER

For short distance working, and times when current from the yacht's supply is not available, an emergency spark transmitter is supplied. This derives its power from a storage battery of twelve cells, which supply current to a small inductor motor-alternator having an output of 0.25 kilowatt at 800 cycles frequency. This supply is stepped up to 2000 volts by a small transformer, and supplied to a quenched gap.

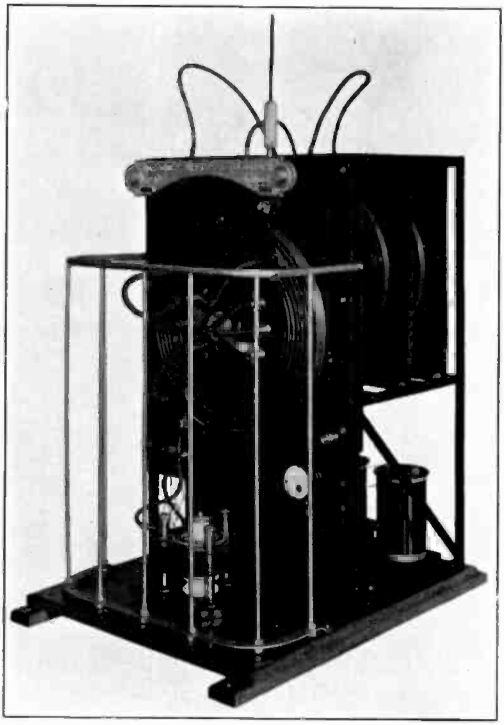

FIGURE 6—1.5 K.W. Quenched Gap Transmitter

This spark gap, a mica condenser, and a flat spiral inductance, form the closed circuit, which is directly coupled to the aerial circuit. Wave lengths of 300, 450, 600, and 800 meters may be obtained by a switch, part of which alters tappings in the closed circuit, and the other part alters tappings on the aerial inductance. Final tuning is effected by a variometer in the aerial circuit, resonance being indicated by an ammeter in series with the earth lead. The power is varied by adjustment of the generator field, and by inserting an iron-cored choke into the primary of the transformer. Signaling is carried out by means of a telegraphic key placed in the supply leads of the transformer. Figure 7 is a view of the transmitter, Figure 8 the motor alternator, and Figure 8A the connections of the set.

SHIP TUNER TYPE RECEIVER

This is a simple two circuit tuner in which the primary and

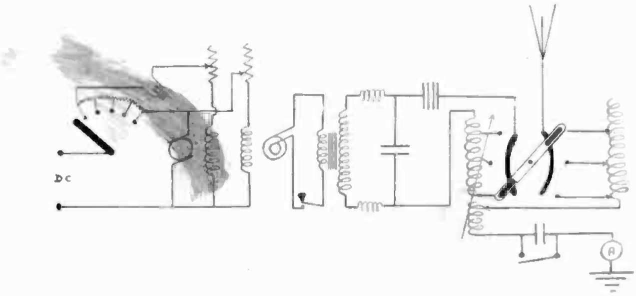

Figure 6A—1.5 K.W. Quenched Spark Transmitter

secondary windings are auto-coupled by means of a small coil provided with tappings. A wave range of from 200 to 25000 meters may be obtained by connecting various sized coils in the primary and secondary circuits by switches.

Figure 7—0.25 K.W. Quenched Spark Transmitter

A continuous adjustment is obtained by variable condensers, that in the primary circuit being connected either in series or in parallel by means of a switch. A small fixed condenser may be also connected in parallel with the secondary condenser, in order to reach the maximum wave length. A coil of high impedance is connected across the antenna and earth terminals to by-pass any static charge from the aerial. The whole tuner is enclosed in a small copper-lined box, and is extremely compact for such a wide range of wave lengths. Figure 9 shows the tuner, and Figure 9A the connections.

DETECTOR-AMPLIFIER

Radio frequency amplification, rectification, and low frequency amplification are all carried out by one four-electrode valve. The air-cored radio frequency transformer is pro-

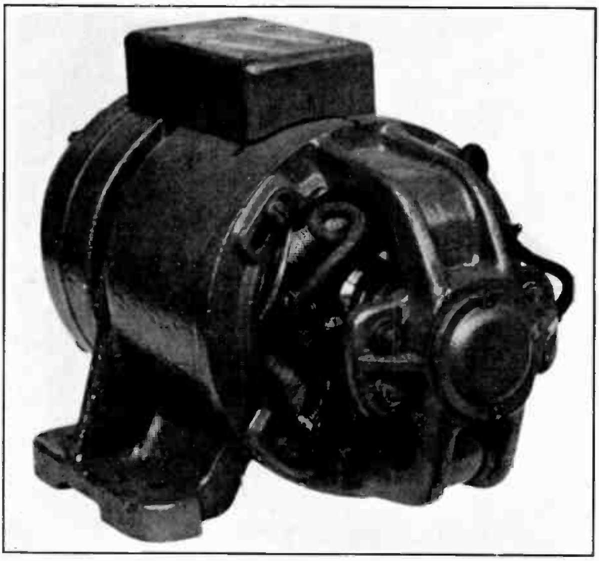

FIGURE 8—Motor Alternator for Emergency Transmitter

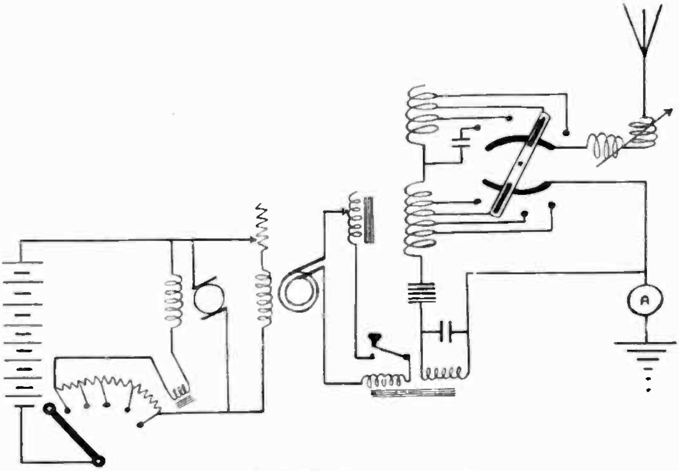

FIGURE 8A—0.25 K.W. Emergency Transmitter vided with three tappings, so that good amplification is obtained over the whole range of wave lengths. The signals from the tuner are applied to the inner grid circuit, and amplified into the outer grid circuit and primary of the air core transformer. From

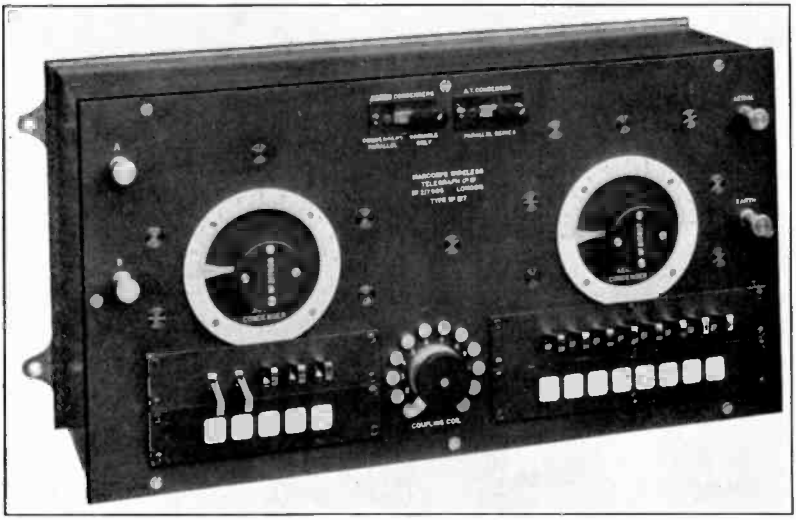

FIGURE 9—Receiving Tuner

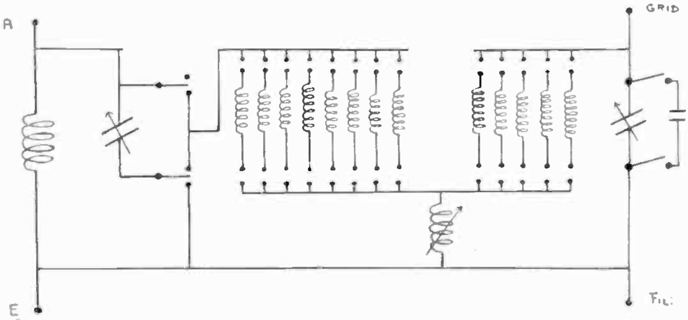

FIGURE 9A—Tuner

the secondary of this transformer they are rectified in the plate circuit, and transferred back to the inner grid circuit by way of the iron cored transformer. The amplified signals are then received by telephones in the outer grid circuit. Both the primary and secondary of the iron-cored transformer, and also the telephones, are shunted with condensers for by-passing the radio frequencies.

A grid potentiometer and filament resistance are provided for controlling the point of working on the curve and the strength of signals. Figure 10 is a view of the amplifying detector, and Figure 10A shows the connections.

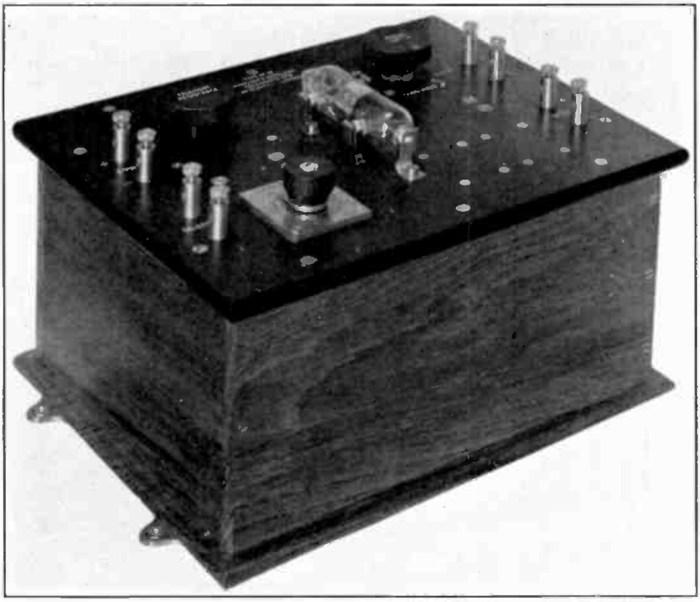

FIGURE 10—Amplifying Detector for Receiver

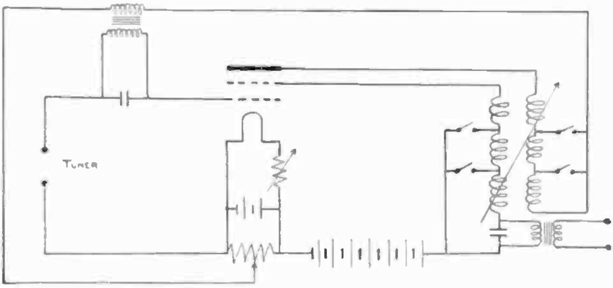

FIGURE 10A—Amplifier-Detector

LOCAL OSCILLATOR

For the reception of continuous waves, beat reception is employed. One valve is arranged to generate oscillations on all wave lengths from 200 to 25000 meters, by using flatly-wound coils tightly coupled together. Four pairs of coils cover the complete range of wave lengths, and continuous adjustment is obtained by a variable condenser, which may be connected across either the grid only, or across both coils. By this means, two wave length ranges are obtained for each pair of coils.

The coils are enclosed in an ebonite box and may be plugged in as required, each box containing two pairs and being reversed for changing the wave range. A small rotatable coupling coil is arranged in the vicinity of the coils in order to couple the oscillator to the receiver. Figure 11 is a view of the local oscillator, and Figure 11A gives the connections.

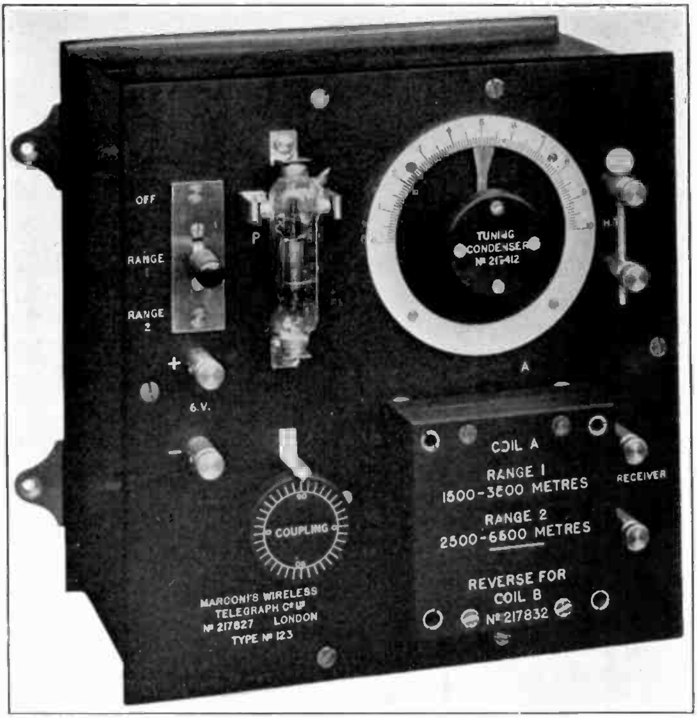

FIGURE 11—Local Oscillator for Receiver

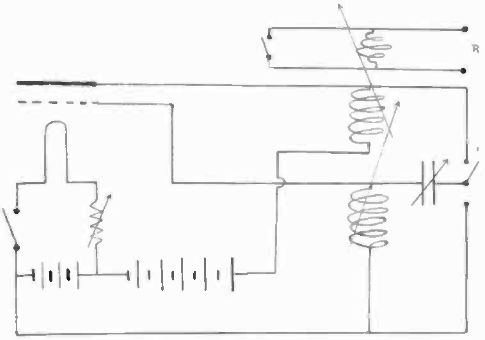

FIGURE 11A—Oscillator for Local Oscillator Reception

AERIALS

The special aerials for the direction finder are suspended over the bridge from a jumper stay running between the two masts. There are two triangular loops, one with its plane in the fore and aft line of the ship and the other athwartships. The four leads from these two loops are brought down thru lead-covered non-inductive cables into the chart room below, and led to the instrument, a view of which is shown in Figure 12. The antenna, direction finder, and tuner are shown in Figure 12A.

The width of each loop is 24 feet (7.87 m.) and the height is 34 feet (11.15 m.).

GONIOMETER

The goniometer is wound with two field coils at right angles to one another, one being connected to the fore and aft loops and

FIGURE 12—The Direction Finder

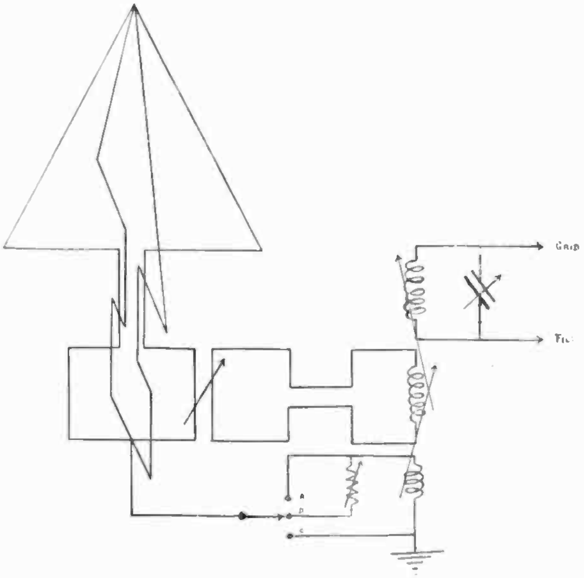

FIGURE 12A—Direction Finder Aerial and Circuits

the other to the athwartships loop; these are plainly shown in Figure 13, which is a view of the goniometer unit.

Within these two field coils a rotatable search coil is placed, the spindle of which is attached to a pointer which moves over a circular scale, graduated in degrees from 0 to 360.

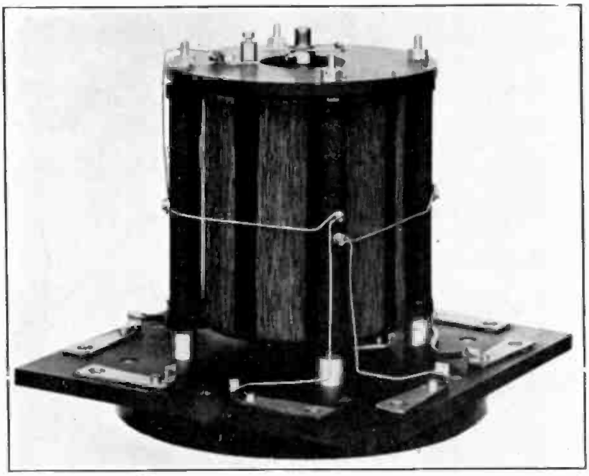

FIGURE 13—View of the Goniometer, Showing Field Coils

TUNER

The search coil is tightly coupled thru a transformer to the amplifier, the secondary of this transformer being tuned by a variable condenser. A tertiary winding on this transformer is connected from the centre points of the field coils, and thru a damping resistance to earth.

A range of from 300-4000 meters may be obtained by using three differently wound transformers, any of which may be brought into operation by means of a switch.

AMPLIFIER-DETECTOR

The radio frequency amplifier employs four valves. These are coupled together by air cored transformers, which are wound with high resistance wire so as to have a fairly flat resonance curve and give good amplification over the entire range of wave lengths used. The potential of the grids is adjusted by a potentiometer and the filament brilliancy by a variable resistance.

One valve is used as a rectifier and one as a low frequency amplifier, these being coupled by iron-cored transformers.

The low frequency amplifier may be cut out by a switch if the signals are too loud. Figure 14 is a rear view of the amplifier, and Figure 14A shows the connections.

GENERAL

A relay is fitted which connects the four aerial leads to earth when the instrument is not in use. By operating a switch, the instrument may be used as an ordinary receiver, using the whole aerial system as a vertical aerial. This gives a uniform polar diagram and is useful for standing by. For direction finding, the effect of the two loops is used, this giving a figure-of-eight polar diagram.

For finding the actual sense of the direction, the effect of the two loops is combined with that of the vertical aerial system, thus giving a cardioid polar diagram.

Either of these methods of reception may be employed by the operation of the single switch shown in the diagram, Figure 12A. The switch at position *A* gives a uniform polar curve; at *B* a cardioid, and at *C* a figure-of-eight diagram.

OPERATION

To take bearings with the instrument, the station, the bearing of which it is desired to find, is first picked up, using the stand-by position, and tuning on the variable condenser. As

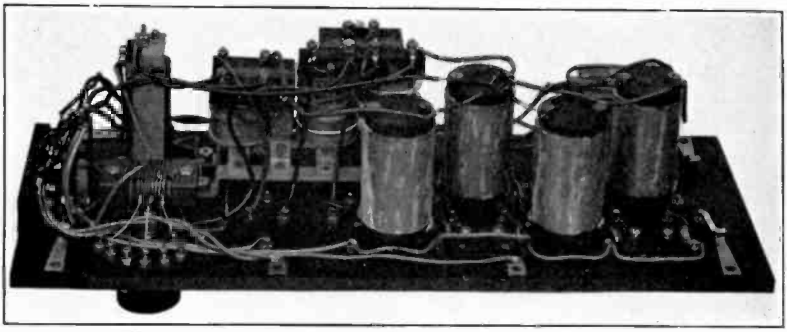

Figure 14—Amplifier for Direction Finder, Rear View

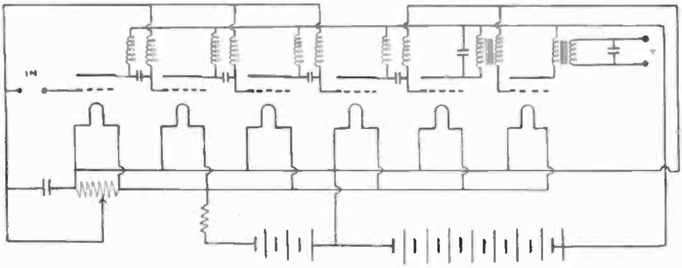

Figure 14A—Amplifier-Detector

soon as the signals are heard, they are rapidly tuned in and then the switch is put over to the position for using the two loops. The strength of the signals is adjusted to a suitable value by altering the filament brilliancy or by cutting out the low frequency amplifier, and the pointer of the goniometer is swung around the position where signals are a minimum strength, and two points at which they are of a similar strength are noted; the mean of these two points is taken as the bearing required.

If possible, several sets of readings are obtained, and an average taken. Altho the sense of the direction is usually obvious, this may always be checked by switching on the cardioid polar diagram, the sense then being indicated by a small pointer attached at right angles to the other pointer. From this description it sounds as if the taking of a bearing were a lengthy process, but actually, it is a matter of seconds.

Any known error of the instrument is, of course, allowed for before the reading is given to the navigating officer. Figure 15 is a view of the direction finder situated in the chart room of the yacht.

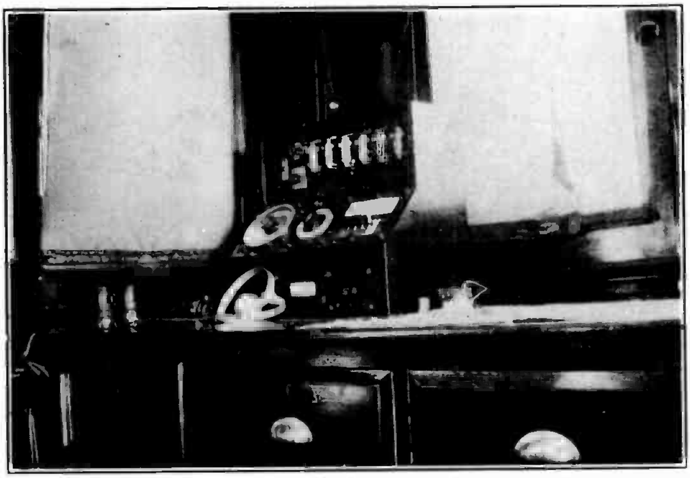

Figure 15—Direction Finder Located in Chart Room

ACKNOWLEDGMENTS

The author is indebted to Senatore Marconi for permission to publish these particulars of his yacht and its radio equipment, and to Marconi's Wireless Telegraph Company, Ltd., for supplying photographs of some of the apparatus.

SUMMARY: A description is given of the continuous wave telegraph, telephone, and main and emergency spark transmitters, and of the receivers and radio goniometer of the steam yacht "Elettra."

THE DEVELOPMENT OF THE STANDARD DESIGN FOR SELF-SUPPORTING RADIO TOWERS FOR THE UNITED FRUIT AND TROPICAL RADIO TELEGRAPH COMPANIES*

By

Albert W. Buel

(Consulting Engineer, United Fruit Company, Radio Department, New York)

This paper is largely collated from records of designs, construction, maintenance, reports on failures, reconstruction and reinforcement of some 20 or 30 radio towers, built by the United Fruit Company and the Tropical Radio Telegraph Company, between 1906 and 1923, and some other designs for towers from 100 ft (30.5 m.) to 1,000 ft. (305 m.) high. It has been prepared at the request of Mr. George S. Davis, General Manager of the Radio Department of the United Fruit Company and of the Tropical Radio Telegraph Company, to whom the author is indebted for much assistance, advice, and consultation, and for the photographs used in illustrations. All of this work since 1911 has been under the personal direction of Mr. Davis, except that the original design of the 200 ft. (61 m.) towers made in 1906 and the 50 ft. (15 m.) extension added in 1910 came under his predecessor, Mr. M. Musgrave. To Mr. Davis is due the credit for the adoption of the three-legged or triangular tower and for a number of important improvements in details.

THE PROBLEM AND SUGGESTIVE PRECEDENTS

In June, 1906, Mr. Mack Musgrave, then Superintendent of the Fruit Company's telegraph service, brought his radio tower problem to the author, who had designed bridges and other structures for that Company. He wanted 200 ft. (61 m.) towers

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*Received by the Editor, May 3, 1923.

For the information of our readers, the following articles on towers and masts for radio antenna supports have appeared in the Proceedings of The Institute of Radio Engineers:

R. A. Weagant, "Design and Construction of Guy-Supported Towers for Radio Telegraphy," volume 3, number 2, June, 1915, page 135.

C. F. Elwell, "Wooden Lattice Masts," volume 3, number 2, June, 1915, page 161.

C. F. Elwell, "The Rome Radio Station of the Italian Navy," volume 8, number 3, June, 1920, pages 193-196.

In conjunction with Mr. Buel's paper, these should be of material assistance to radio station designer.—Editor.

to carry 20 antenna wires equivalent to number 10 copper wire[1] in size, with a span of 300 ft. (91.5 m.) between 42 ft. (12.6 m.) yard arms. He had a fabricator's design and estimate for 200 ft. (61 m.) towers, 14 ft. (4.6 m.) square at base and at top—rectangular in elevation—but the weights and cost were much higher than they were then willing to accept.

There were not then many precedents for steel towers, outside of viaduct towers (of which the author had recently designed some 230 ft. (70 m.) high), and of the Eiffel Tower in Paris. It was obvious that the curved outline of the legs of the latter tends to reduce the weight of the bracing—(horizontal struts and diagonals)—and also of the surface area exposed to wind.

In his discussion of a paper on the Kinsua Viaduct on the Erie Railroad, the towers of which were designed without diagonals, Mr. Gustave Lindenthal suggested the use of rod diagonals to reduce the bending stresses in the legs and struts without sacrificing the advantages of the design under discussion. ("Transactions of the American Society of Civil Engineers," volume XLVI.) This suggestion had been adopted by the author for the 230 ft. (70 m.) towers of the Las Vacas Viaduct in Guatemala with considerable success, demonstrating the advantages of adjustable rod bracing in special cases, notwithstanding its practical abandonment by most structural steel designers for important structures for many years past.

With these points in mind, it will be readily seen how the outline of the original design for the 200 ft. (61 m.) tower quickly took form, with its curved legs and rod diagonals. Figure 1 shows the completed design from which ten or more towers were built, some of them with the 50 ft. (15 m.) extension, also shown in the figure. This was added in 1910 without increasing any of the sections below and without consulting the designer, who did not know of the increase in height to 250 ft. (76 m.) until after one of the towers failed in the hurricane of 1914. Some of these towers, extended to 250 ft. (76 m.) were used in a four-tower station, 300 by 600 ft. (91.5 by 183 m.) center to center of towers, with messenger cables in the 300 ft. (91.5 m.) spans and the antenna wires on the 600 ft. (183 m.) span. This increased the wire pull from the design load of 2,000 lbs. (920 kg.) to 7,000 lbs. (3,220 kg.), and the resulting moment at the base from 400,000 ft. lbs. (56,000 kg. m.) to 1,750,000 ft. lbs. (240,000 kg. m.), or 437.5 percent. Still these towers stood up until a really violent hurricane came along in 1914. Some of the first 200 ft. (61 m.)

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[1] Diameter of number 10 wire = 0.102 inch = 0.259 cm.

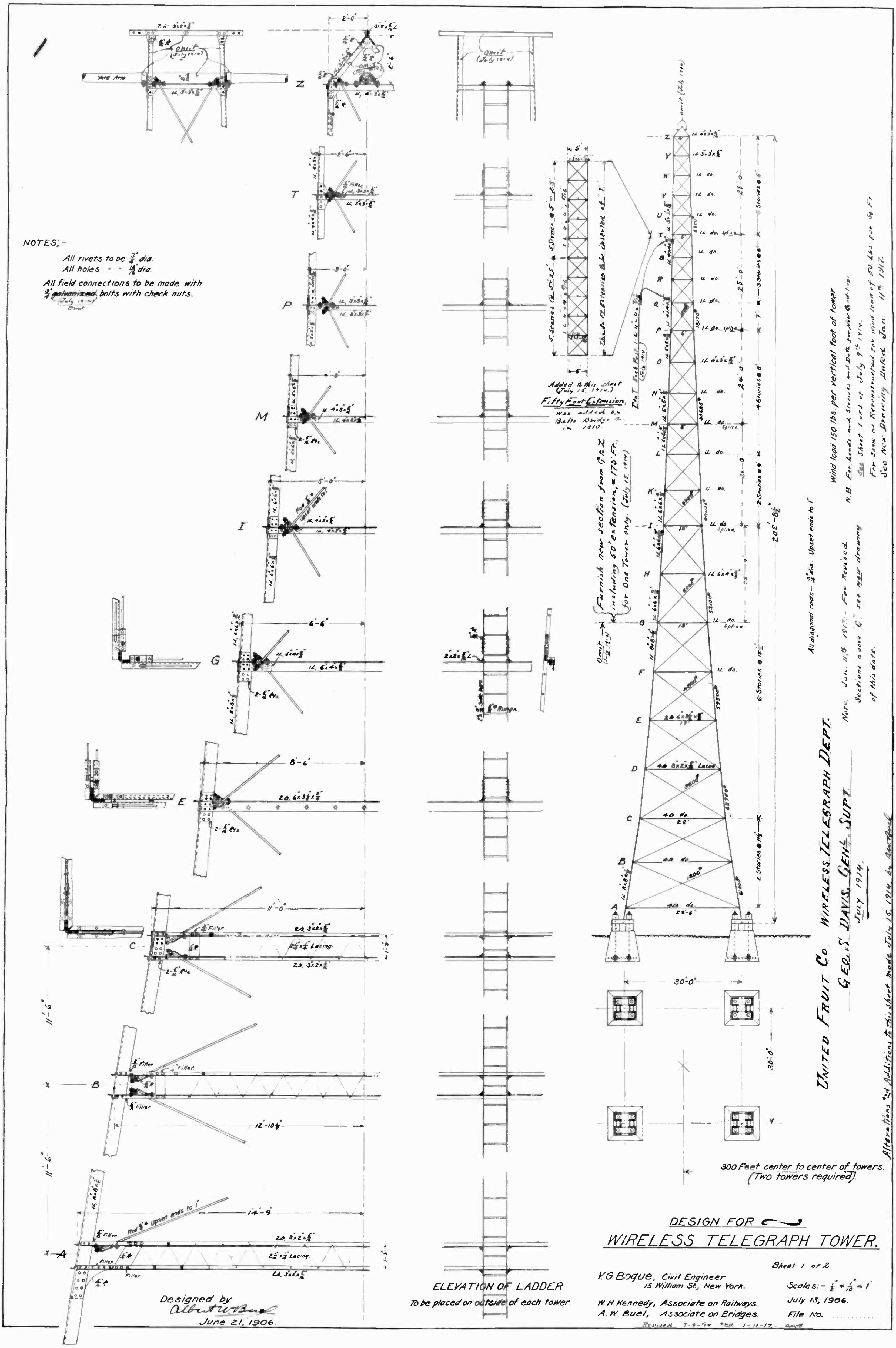


FIGURE 1—DESIGN FOR RADIO TOWER

towers are still in service, and it was their excellent behavior in high winds that was, no doubt, responsible for the increase in height and wire pull without increase in sections. Figure 2 shows two of these towers at Puerto Limon, Costa Rica, and Figure 3 the tower at Bocas del Toro, Panama.

As might be expected from an examination of the design, the towers are very flexible. We have come to recognize this as a desirable feature, but it was not appreciated at the time. The effects of flexibility will be referred to in another place.

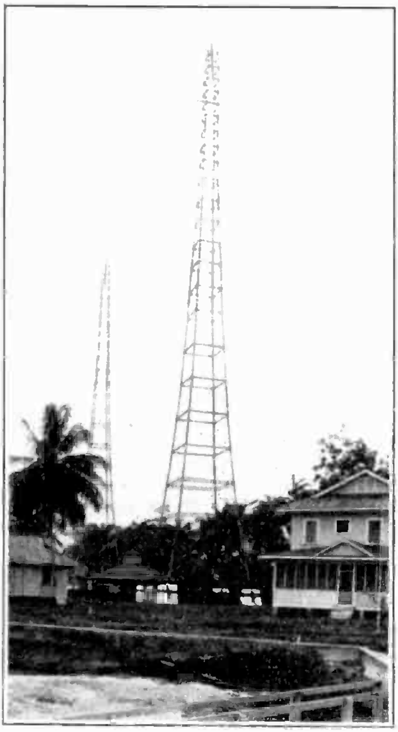


FIGURE 2—General View of the United Fruit Company Station, Limon, Costa Rica, 1923

A story has been told about one of the original 200 ft. (61 m.) stations, that the flexure of the towers was so considerable as to cause alarm, to the extent that steel guys were put on. One day a hurricane came and the first thing it did was to break the guys but the towers stood. Then it carried away the station buildings and the crew went under the towers for protection.

The 1906 design was made to keep the cost as low as possible, and this controlled shop details as well as weights, of course limited by considerations of safety. This will explain the use of the economical but not entirely satisfactory hitch of the diagonal rods. The first towers were insulated at the base of the legs and were all galvanized, but both of these features have been omitted in later designs. The records of costs of maintenance covering a period of fifteen years show that frequent painting is cheaper than galvanizing. Moreover, 1/16 inch (0.16 cm.) of steel is about as good for protection as the thin film of zinc. In all recent designs the minimum thickness of metal is 5/16 inch (0.79 cm.) for locations in the tropics or near the sea coast, and ¼ inch (0.63 cm.) for the interior in dry climates. All these towers have bolted field connections with ordinary rough bolts, not turned, which have proven satisfactory. They are inspected annually and repainted when required—on an average, about once every two years.

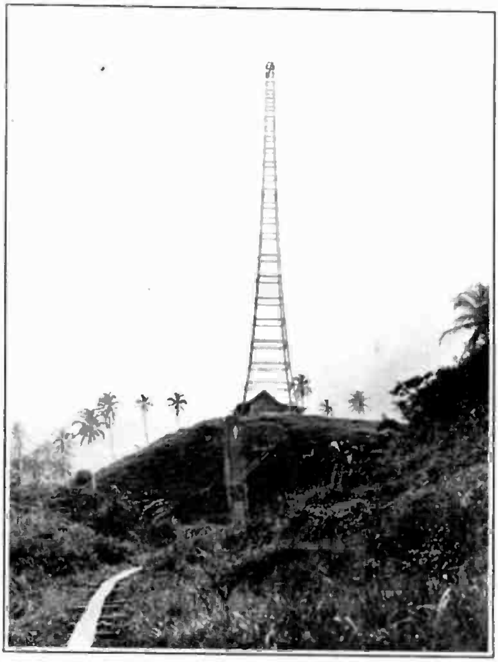


FIGURE 3—United Fruit Company Station, Bocas del Toro, Panama, 1904. First Radio Station to be erected in Central America

The original towers weighed 22.5 tons (21,000 kg.) each, and with the 50 ft. (15 m.) extension, added in 1910, 26 tons (24,200 kg.).

THREE HURRICANE WRECKS AND RESULTING DESIGN IMPROVEMENTS

In 1914, Swan Island was swept by a hurricane which wrecked the upper part of tower number 4 (Figure 4), the lower 75 ft. (22.8 m.) remaining standing and not damaged. The other three towers were not injured. The reports of this wreck were not in sufficient detail to give a very definite idea of the intensity or character of the force that wrecked the tower. As three of the towers and nearly half of the weight of steel in the fourth remained in place and serviceable, and as the excessive cost of general reinforcing in the field had to be considered, together with the fact that we really had no reliable data on what wind force would have to be met in a tropical hurricane, it was decided not to attempt general reinforcement to resist hurricane force, but to make the towers good for the ordinary high wind of 30 lbs. per square foot (14.7 kg. per sq. m.), or about 90 miles per hour (144 km. per hr.), and for the 7,000 lbs. (3,220 kg.) pull of the messenger cables at a height of 250 feet (76 m.).

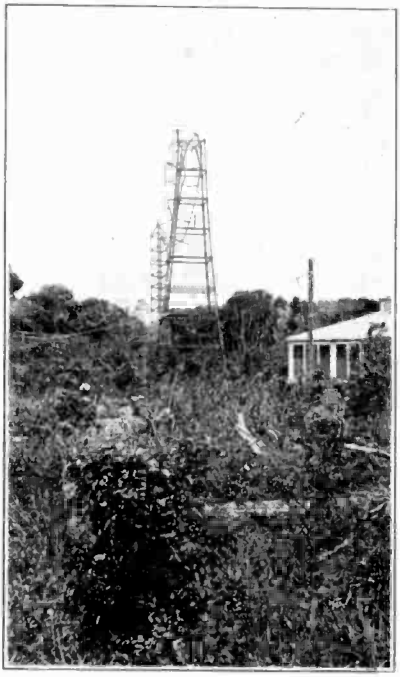


FIGURE 4—Tower, United Fruit Company, Swan Island Station, blown down in hurricane, June 6, 1914

In computing wire pull and sag under wind loads, we take into account the elastic stretch of the wires and cables and deflections of the towers. Some consideration of this problem will make it apparent that these elastic changes have a remarkable influence on the wind increment in wire pull, especially where messenger cable systems are used. In some cases only 17 percent of the wind load on wires acted to stress the towers, the other 83 percent being compensated by deflection of towers, stretch of wires and cables, and consequent increased sag. This taught us two things: first, the advantage of flexibility in radio towers, which is increased by the curved legs; and, second, that the sag of mat under no wind can be so fixed that at maximum wind the pull will not exceed a fixed figure, at the same time allowing a greater average height or less sag under no wind.

It is probable that flexibility was largely responsible for these towers standing up as long as they did, under wire-pull moments over four times those for which they were designed.

Retaining the 50 ft. (15 m.) extension added in 1910, and the messenger cable pull of 7,000 lbs. (3,220 kg.), there was no economical way to avoid the use of guys; but by hitching the guys at a point as far below the top as the strength of the members permitted, we retained considerable flexibility and reduced the length of the guys. This point worked out at "U", Figure 5, 230 ft. (70 m.) above the base.The guys were run at an angle of about 30 degrees from the vertical, down to concrete anchors in the ground, and were placed only on the outside of the mat at an angle of 90 degrees to each other in plan, so as to resist the resultant pull of antenna wires and messenger cable, as shown in Figure 5. (Guys in the quadrant under the mat were not permitted.)

The leg sections P-T were deficient in strength and were made heavier for the new sections of tower number 4. In the other three towers new horizontal and "K" bracing was introduced between P and Q, as indicated in Figure 5, to reinforce these members by reducing the unsupported length of the columns.

With the towers thus guyed and reinforced the station (Figure 6) remained in service until an exceptionally severe hurricane swept Swan Island in 1916. Even then the towers stood until the antenna wires went out and an open hook of a messenger cable turnbuckle opened up, leaving the tower without support or assistance from the guys where the latter were to leeward.

The estimated velocity of the wind in this hurricane, according to the most reliable reports, was 130 miles per hour (208 km.

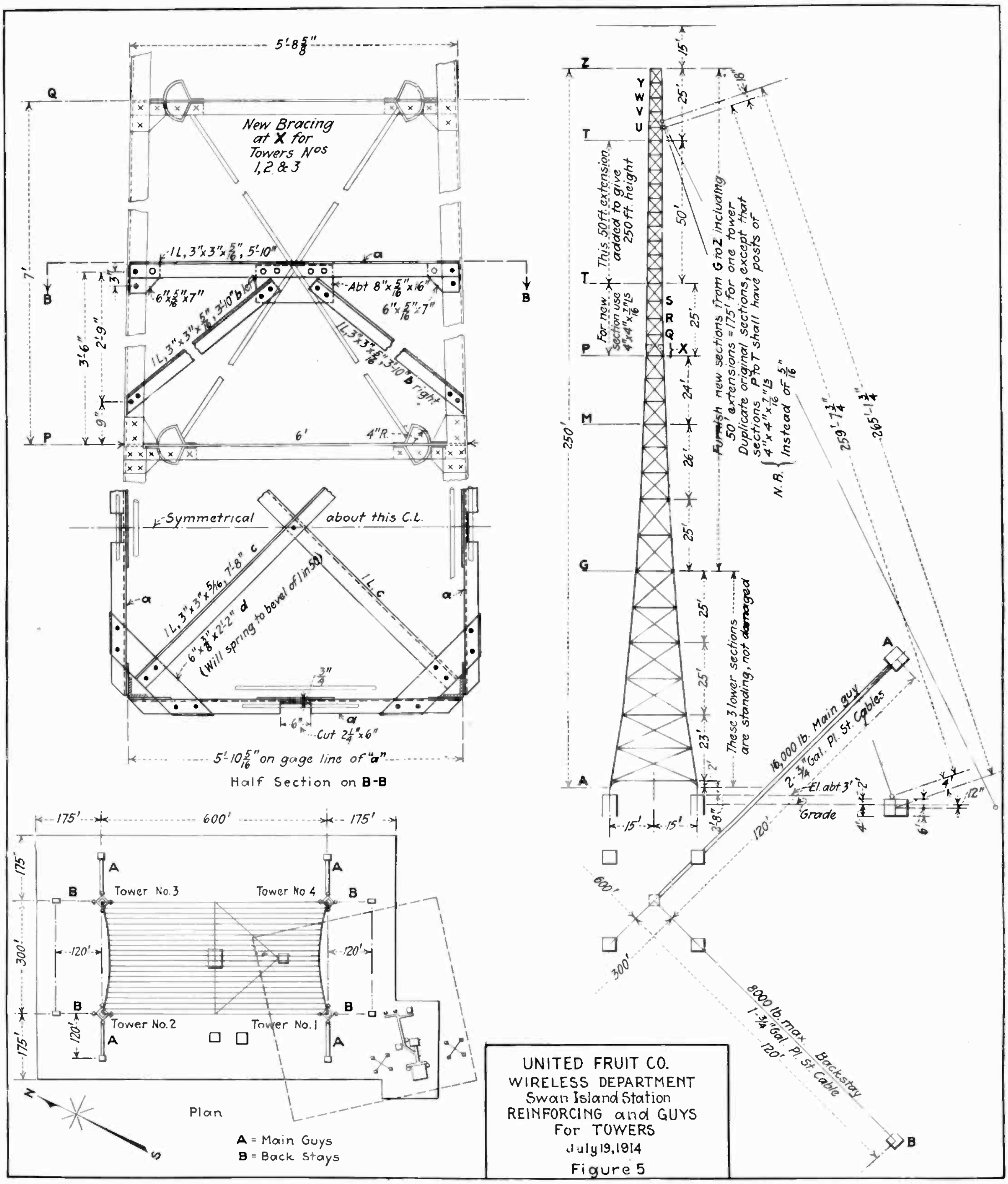

5'-8 5/8"
Q
New Bracing at X for Towers Nos 1,2 & 3
1L, 3"x3"x 5/16", 5'-10"
a
6"x 5/16"x7"
Abt 8"x 5/16"x16"
6"x 5/16"x7"
1L,3"x3"x 5/16", 3'-10" b left
1L,3"x3"x 5/16", 3'-10" b right
7'
3'-6"
2'-9"
3"
9"
B
B
P
6'
4"R.
Symmetrical about this C.L.
a
a
1L, 3"x3"x 5/16, 7'-8" c
1L c
6"x 3/8"x2'-2" d (Will spring to bevel of 1 in 50)
3/4"
6"
Cut 2 1/4"x6"
a
5'-10 5/16" on gage line of "a"
Half Section on B-B
175'
600'
175'
175'
300'
175'
A
B
Tower No. 3
Tower No 4
120'
120'
Tower No. 2
Tower No. 1
120'
N
S
Plan
A = Main Guys
B = Back Stays
Z
Y
W
V
U
T
T
S
R
Q
P
M
G
A
X
15'
25'
50'
25'
24'
26'
25'
25'
25'
23'
2'
250'
This 50 ft. extension added to give 250 ft. height
For new section use 4"x4"x 7/16
Furnish new sections from G to Z including 50' extensions = 175' for one tower
Duplicate original sections, except that sections P to T shall have posts of
N.B. 4"x4"x 7/16" Instead of 5/16"
These 3 lower sections are standing, not damaged
18'
259'-7 3/4"
265'-1 3/4"
16,000 lb. Main guy
2-3/4" Gal. Pl. St. Cables
El. abt 3'
Grade
15'
15'
3'-8"
120'
2'
4'
4'
6'
12"
600'
300'
8000 lb. max. Backstay
1-3/4" Gal. Pl. St. Cable
120'
A
B
UNITED FRUIT CO.
WIRELESS DEPARTMENT
Swan Island Station
REINFORCING and GUYS
For TOWERS
July 19, 1914
Figure 5

FIGURE 5

per hr.), and computations of the ultimate strength of the leg sections in which initial failure took place, indicated a velocity of 137 miles per hour (219 km. per hr.). For these computations Tetmajer's formula, $f = 44,000 - 162.l/r$, was used. This formula has proven most reliable for columns of this particular type; some tests planned by the author and made at the Allegheny Arsenal station of the Bureau of Standards are given on page 600, volume LXXVI, "Transactions of the American Society of Civil Engineers," showing an agreement between computed and actual test loads closer than four percent, and closer than one percent, if totals of all tests are compared. If secondary stresses were not all given sufficient weight, the error would result in too high a figure for the indicated velocity, therefore the true velocity may have been somewhat less than 137 miles per hour (219 km. per hr.), but could not have materially exceeded that figure.

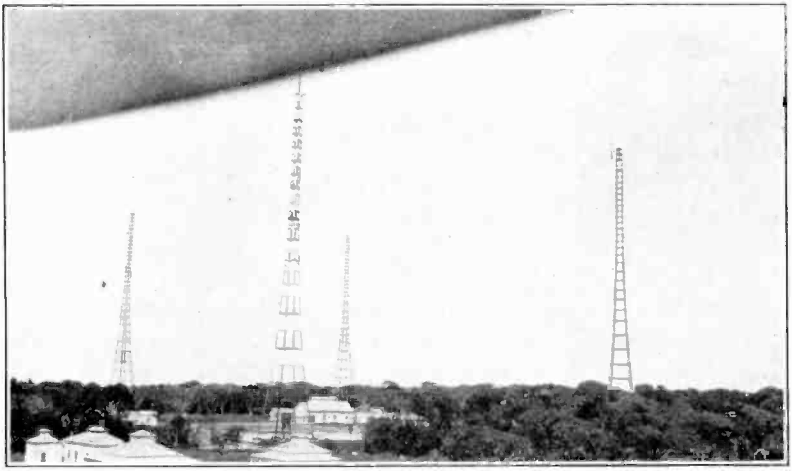


FIGURE 6—United Fruit Company, Swan Island Station before 1916 hurricane and as re-erected

This storm mowed down a cocoanut palm grove 25 years old, with trees 18 inches in diameter—fairly conclusive evidence that its intensity had not been exceeded during that time. Figures 7 and 8 show this grove before and after the storm.

The hurricane started early in the morning, out of the North or Northeast. Between 8.00 and 8.50 A. M. it had gotten around to East by North, when the antenna wires broke loose from the messenger cable between towers 1 and 4, and an open hook of

Figure 7—View in Cocoanut Grove, Swan Island, prior to 1916 hurricane

a turnbuckle on this cable opened up, leaving tower number 1 without support. The wind being nearly East, tower number 1 collapsed. Towers 2 and 3 collapsed several hours later, when

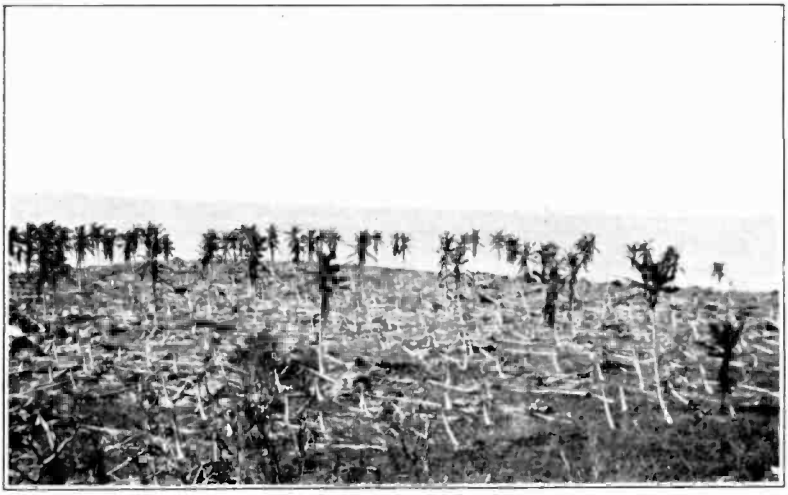


Figure 8—Cocoanut Grove after hurricane (1916)

the wind had swung around into the Southeast quarter. The lay of the wreckage of these two towers indicates a wind from the South-Southeast, but if the messenger cable was still in, it may have anywhere in the Southeast quarter.

Tower number 4 remained standing. Its upper stories had been rebuilt the previous year with a few members made heavier, but it was not constructed to stand hurricane force, nor even a 90-mile-per-hour (144 km. per hr.) blow without support of the guys and messenger cable. It was evidently saved by the fact that the wind did not get around into a quarter where the guys could not lend it their support. If the turnbuckle hook had not opened up, possibly tower number 1 would not have been wrecked.

Figure 9 shows clearly the column buckle in story *Q-R*, just above the reinforcing "*K*" braces added in 1914-15. The bends at panel point *H*, Figures 10 and 11, are plainly due to the pull of the falling upper sections and in no way resemble the buckling caused by column flexure.

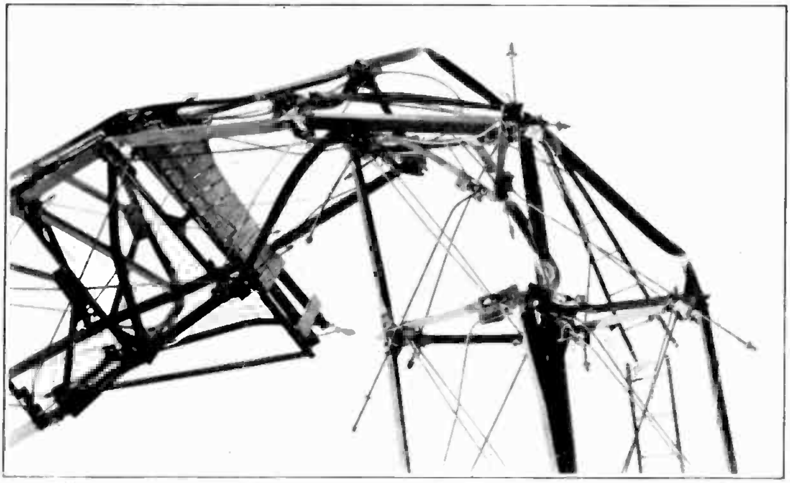


FIGURE 9—Tower 1, between "O" and "S" after hurricane of 1916

Figures 12, 13 and 14, show that towers 2 and 3 failed first by column buckling in story *O-P*, just below the story reinforced with "*K*" braces.

Figure 15 shows how the falling tops tore and stripped the lower stories from *P* to *H*. In no place is there any indication of column failure or tension failure between *P* and *H*, except the tearing clearly due to the stripping effect of the falling tops.

The sequence of the occurrence during the collapse may be closely read from the illustrations as follows:

1. The failure of messenger cable between towers 1 and 4, the wind being nearly East, depriving tower 1 of support from the East guy of tower 4, the leeward legs in story *Q-R* buckled.

2. The top sections above *Q*, falling, pulled down the sections from *O* to *H*, this stripping effect being arrested when the top struck the ground.

3. The cushion effect due to the crushing of section *T-Z* against the ground saved the lower sections, *P* to *T* from total demolition.

4. Several hours later, when the wind had veered towards the South, towers 2 and 3 failed in exactly the same way except that legs buckled in story *O-P* instead of in story *Q-R*. With the wind in this quarter the guys were not effective. Until the wind got around into this direction the guys held the towers safely, the messenger cable co-operating to support tower 2.

In all these cases the primary failure occurred in stories adjoining that in which reinforcing "*K*" braces were inserted

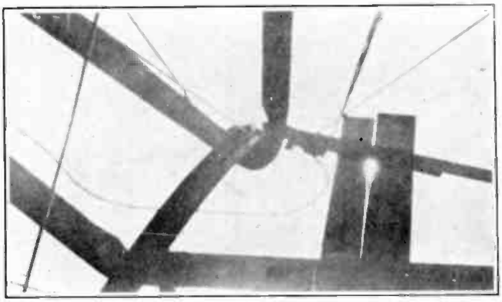


FIGURE 10—Tower 1, at "H" after 1916 wreck

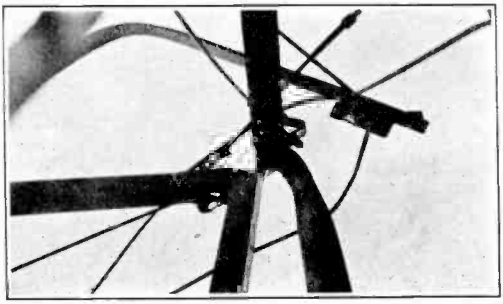


FIGURE 11—Strut at "H", Tower 1, after wreck

in 1914-15, to strengthen this critical point. Had these not been added the initial failure would, undoubtedly, have occurred in leg sections *P-Q* in all cases.

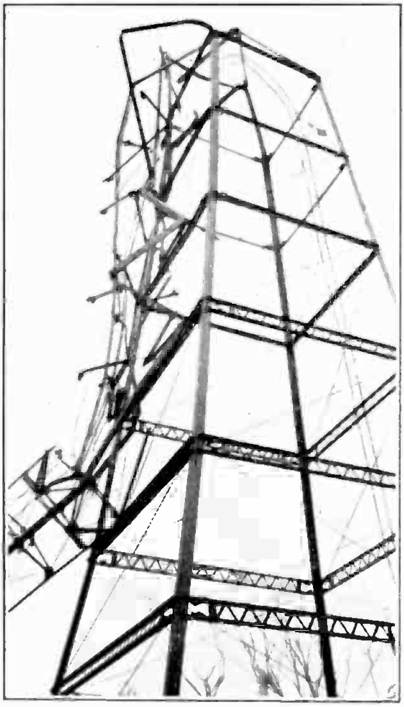


FIGURE 12—Tower 2, fallen part of tower from 'G" to "R"

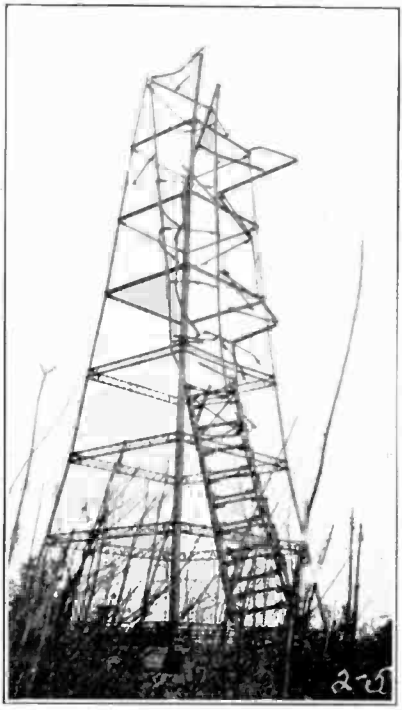


FIGURE 13—Tower 2, wrecked part from "G" to "Q"

A study of the stresses and ultimate strength of the members indicates that the towers failed under an average wind load of about 50 lbs. per sq. ft. (245 kg. per sq. m.). Taking Sir Benjamin Baker's ratio of average pressure on large areas—2/3 of the maximum shown at the same time on small gauges—as shown by the Forth Bridge experiments, the maximum intensity at Swan Island in 1916 probably reached 75 lbs. per sq. ft. (368 kg. per sq. m.) for small areas. In high velocities, according to several authorities, wind is more gusty. Therefore the average pressure on large areas would naturally be expected to be a smaller percentage of the maximum on small areas in high than in light winds. The Forth Bridge experiments showed this to be so for the range of velocities observed, up to 96 miles per hour (154 km. per hr.), and there can be little room for doubt that it is still more true for velocities between 120 and 140 miles per hour (192 and 224 km. per hr.). The velocity corresponding to 75 lbs. per sq. ft. (368 kg. per sq. m.) is, by our formula, 137 miles per hour (220 km. per hr.). This estimate is not claimed to be precise, but it is about the most reliable as yet available.

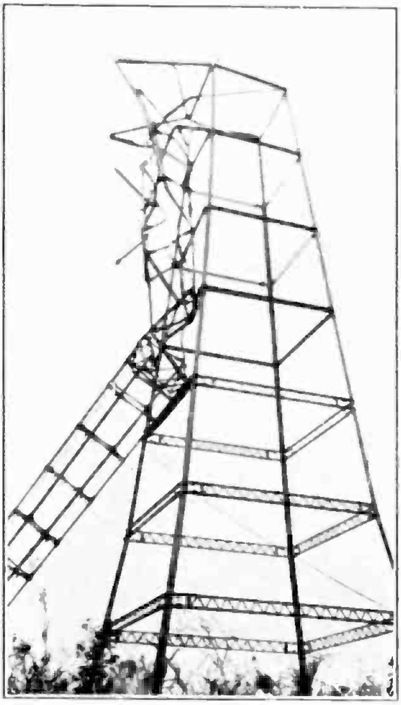


FIGURE 14—Tower 3, showing wreckage from point "H" to point "S"

At any rate, and whether this velocity and the factor of 2/3 for average pressures are correct or not, we can put considerable confidence in the deduction of 50 lbs. per sq. ft. (245 kg. per sq. m.) average, on the area involved at the moment of failure, and that is the value for which we have most need.

If that is true, it is not necessary to know the maximum velocity and intensity of pressure on small areas, but if their relative values were known we might determine the true law of these variations, which would be a great aid in specifying wind loads for different conditions and heights of towers. However, these deductions were considered a sufficient basis to warrant an attempt to build or reconstruct radio towers to be hurricane-proof.

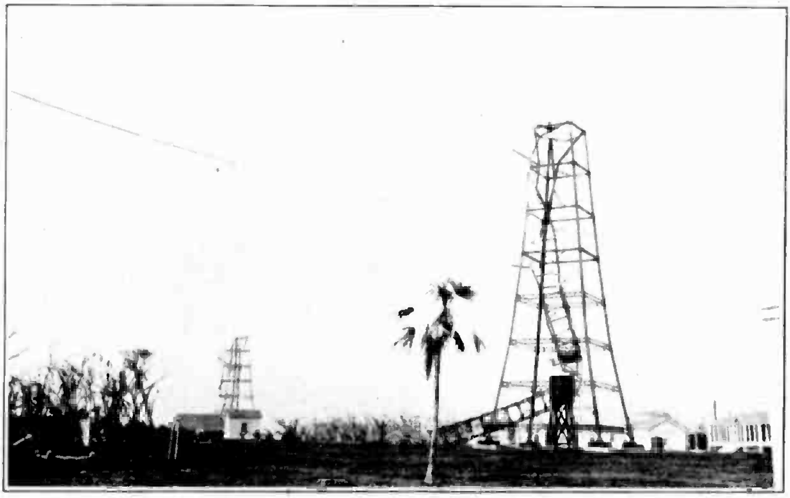


Figure 15—View of 1916 wreck, looking north

In a conference held to discuss specifications for the reconstruction of the Swan Island towers, and also for new construction, in the light of the data disclosed by studies of the wrecks, Mr. Davis laid down a new policy, stating, in effect, that:

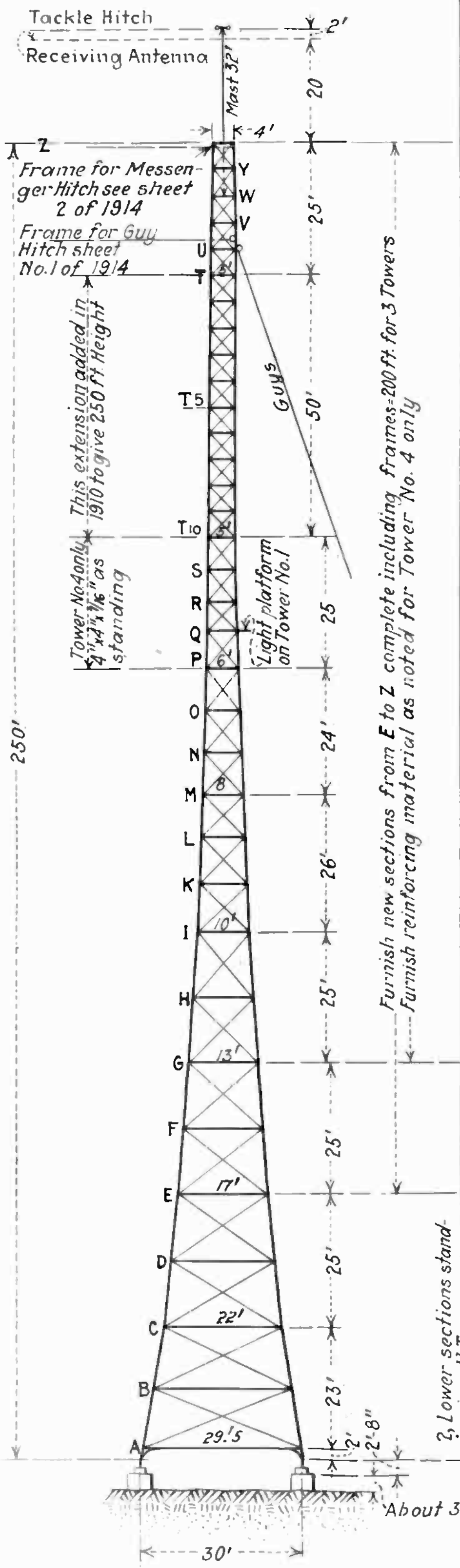
> "Heretofore it has been more or less customary to take the attitude that when a radio station failed, communication could nevertheless be maintained by means of the cable or wire systems. I want to reverse this idea, and make radio communication so reliable in the countries and districts where we operate that in time of disaster, when all other means of communication fail, the public will be served and can confidently look to our radio stations to maintain service. As long as the radio towers and buildings stand we can give service, and even tho the buildings go, if the towers remain standing, we can quickly fix up a 'jury rig' which will give some degree of communication. It is therefore of the utmost importance that as far as is humanly possible to do so, the towers be designed to withstand hurricanes and earthquakes. Heretofore radio towers seem to have been designed with the principal idea of keeping down the cost, and while we are interested in keeping the cost at a minimum, we are more interested in getting up radio towers which will insure, as far as possible to do so, our ability to maintain radio communication when all other means fail.
>
> "To this end, therefore, we want new towers designed to

> withstand what our experience has taught us are the most severe conditions in the countries and districts where we operate. In short, we want hurricane-proof towers and, from such experience, knowledge and data as we have concerning earthquakes, earthquake-proof towers."

As entirely new material was required for two of the towers above point *G*, and for the other above *E* (Figure 1), (it was neither safe nor economical to use any of the fallen members, under conditions of field work existing at Swan Island), the question of field reinforcement of existing members was confined to about half the leg sections of tower number 4, the cost of which, tho high, seemed justified; and, in accordance with Mr. Davis' instructions, the towers were reconstructed to resist the highest wind velocities. The leg sections above point *G* were strengthened, generally, by the addition of two angles 2½ inches by 2 inches (6.35 by 5.08 cm.), as shown in Figure 16. New horizontal lateral frames were inserted at *P* and *T*-5, and new frames for the messenger cable hitch and masts for receiving wires were added. The guys were renewed on the same plan as has already been described for the reconstruction of two years previous. This work was completed in 1917.

In October, 1921, another hurricane, said to have been one of the most severe ever experienced in that section, swept over Swan Island, but did no damage to the towers and did not even put the station out of commission. This gave us a practical service test, under what may be termed maximum hurricane conditions, and a basis on which we feel considerable confidence in designing towers to withstand storms of the type of West Indian hurricanes. That does not mean that towers so designed would be proof against cyclonic storms, which are of an entirely different character, and for which no reliable data for estimating their force is known to be available. Neither does it mean that provision has been made for resisting other cataclysmic forces of nature, as, with our limited knowledge, such an attempt would either prove futile or very uneconomic. But, during the period from August 15th to October 1st (known as the West Indian hurricane season), in certain of the Caribbean regions destructive hurricanes are of frequent occurrence, and their forces we now seem to be in a fair way to master. It is, of course, possible that we may need yet other lessons, but at least we have made some progress.

Whether the typhoon of the Far East is similar in action and force or not the author cannot state, but he hopes the discussion



	WIND LOAD 50 LBS PER SQ. FT. MAX. STRESSES IN POSTS		TOWER NO. 4 REINFORCEMENT							TOWERS NO. 1, 2 & 3 NEW SECTIONS REQUIRED					NEW MAST & FRAMES REQUIRED
	COMPRESSION −	TENSION +	Existing Material	New Reinforcing Material		No of 3/4 Bolts Required at Splices: Double Shear	Single Shear	See original Design sheets of 1906 & 1914	Existing No. of Bolts Single Shear				No. of $\frac{3}{4}$" Bolts Required in Single Shear		
With Mat. and Guys acting	-17.3	+16.1								Same sections as shown on sheet No 1, of 2 of 1906 as revised 1914		Struts and Ladder, same as original, see sheet 1, of 2 of 1906 as revised 1914			Furnish 4 New Receiving Masts as shown - 1 for each Tower 1, 2, 3 & 4 Furnish 3 frames for Messenger Hitch as Detailed on sheet 2 of 1914 One each for Towers 1, 2, & 3.
	-16.5	+14.2											4		Furnish 3 Frames for Guy Hitch as detailed on Sheet 1, of 1914. 1, each for Towers 1, 2, & 3
	-18.9	+15.8											4		Furnish 4 New Horizontal X frames T5 as shown 1 each for Towers 1, 2, 3 & 4
Maximum Stresses from T10 Incl. down, are with Mat down. Guys not acting	-30.1	+25.6			Sub Punch New L^s to fit existing L^s, as per old shop plans	Double Shear	Single Shear 6	Furnish new Splice Plates, sub-punched where required if not practical to effect double shear, or to use larger bolts, Splice Plates may be lengthened	4				6		
	-44.4	+38.3	1, L-4"x4"x7/16"	2, L^s-2½"x2"x5/16"		6	8		4	1, L-6"x6"x3/8"			8		Furnish 1 only light platform at Q for S.W. Side of Tower No. 1 as shown Furnish 4 New Horizontal X Frames P as shown 1 each for Towers 1, 2, 3 & 4
	-52.0	+44.6	1, L-5"x5"x3/8"	2, L^s-2½"x2½"x5/16"			8		8	1, L-6"x6"x3/8"			8		
	-62.4	+53.3	1, L-6"x6"x3/8"	2, L^s-2"x2½"x5/16"		8	10		8 D.S	1, L-6"x6"x3/8"	2, L^s-2"x2½"x5/16"		10		
	-67.9	+56.8	1, 6"x6"x5/8" L	2, L^s-2"x2½"x5/16"			12		12 D.S	1, L-6",x6"x3/8"	2, L^s 2"x2½"x5/16"		12		
	-71.6	+57.8	In addition to bolts required for reinforcement material and new splices, Furnish new bolts throughout for all field connections							1, L-6"x6"x½"	2, L^s 2½"x2x5/16"	All Sways	12	2, Only new Struts E Required 1 each for Towers 2 & 3	
2, Lower sections standing in all Towers, no new material required except Struts noted										All sections A to E standing intact. No new material required except Struts noted and new bolts for all field connections				2, Only new Struts D Required 1 - each for Towers 2 & 3	
	-75.6	+58.1												1, Only new Struts C Required for Tower No. 2.	
	-76.5	+52.9													

UNITED FRUIT CO.
WIRELESS DEPARTMENT
Swan Island Station
RECONSTRUCTION, REPAIRS
and
REINFORCING of TOWERS
January. 11, 1917.
Figure 16

FIGURE 16

of this paper will throw some light on the subject, as well as that of the force of cyclones.

Some of these stations are located in the earthquake belt of Central America and, naturally, the matter has received some consideration, but no special provision has been made to resist such forces except to take special care to have good foundations and details. Observations on the ground in Guatemala City, in company with engineers who were there at the time of the great earthquakes, impressed the author with the almost insignificant damage done to well-designed steel structures. In fact, most structures well tied together, as with well designed and detailed steel and reinforced concrete frames, escaped with practically no damage to their structural parts.

It is possible that earthquake forces will severely strain the cantilever antenna bridges when they have a considerable overhang, but for these we have used unit stresses only 75 percent of those used for main tower members.

After having been seriously damaged in the hurricanes of 1909 and 1910, Cape San Antonio, Cuba, station was completely wrecked by its third hurricane in August, 1915. This hurricane was unusually severe, but as the wind gauge was carried away early in the storm after having recorded 100 miles per hour (160 km. per hr.), we have no record of its maximum velocity. Mr. John A. (Jack) Cole, the operator in charge of the station, says: "The United States Government barometer was destroyed early in the storm. The Cuban Government barometer, graduated to read from 27.6 to 32.00, was down to its lowest mark; in fact, the indicator was against the pin at 27.6. I do not know how much farther it would have gone if the pin had not been there." Approximate estimates from its effects on the wrecked members indicate a velocity of 120 to 140 miles per hour (192 to 224 km. per hr.)

This station had an umbrella type antenna, with one 250 ft. (76 m.) tower, a duplicate of those at Swan Island, but with four 1-inch (2.54 cm.) steel guys. The station has not been reconstructed. Figures 17 and 18 are views of this tower before and after the wreck. The appearance of the wreck is almost identical with those of Swam Island and helps to confirm the conclusions reached in the analysis of the latter.

PRELIMINARY DESIGN OF THREE-LEGGED TOWERS

After the first reconstruction of the Swan Island towers and the final destruction of that at Cape San Antonio, Mr. Davis asked for designs and estimates for self-supporting towers, 250, 300, and 350 feet (76, 91.5, and 107 m.) high, with stiff (angle bar) bracing, and alternates for comparison, with adjustable rod bracing. He suggested that three-legged or "triangular" towers be tried for these designs, to which the author replied that, in his opinion, any advantages or saving in weights that might be expected would be more than offset by the increased cost of fabrication, due to the bent plate connections required. Notwithstanding this, Mr. Davis ordered designs for three-legged towers, "to see how they would work out."

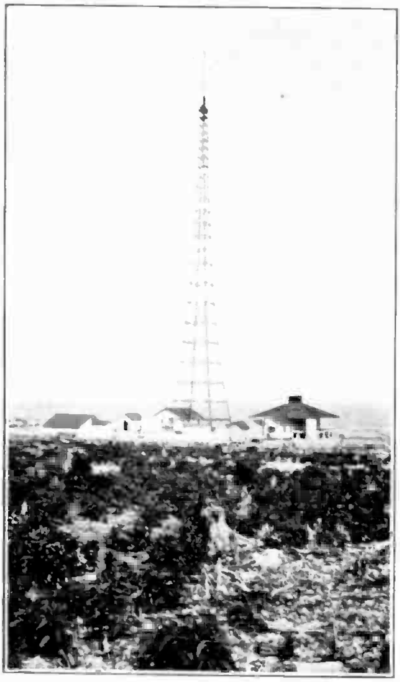


FIGURE 17—United Fruit Company, Cape San Antonio Station before 1915 hurricane

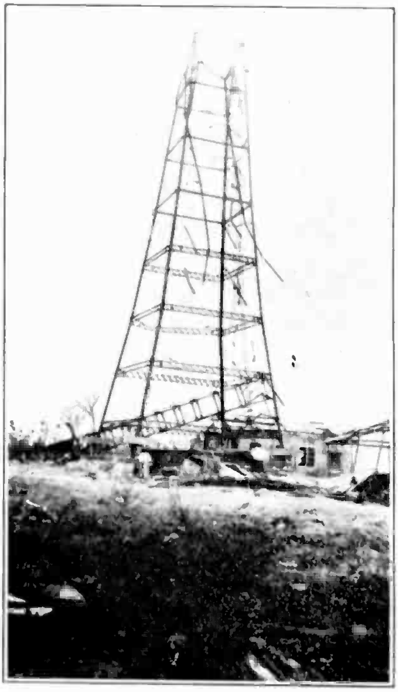
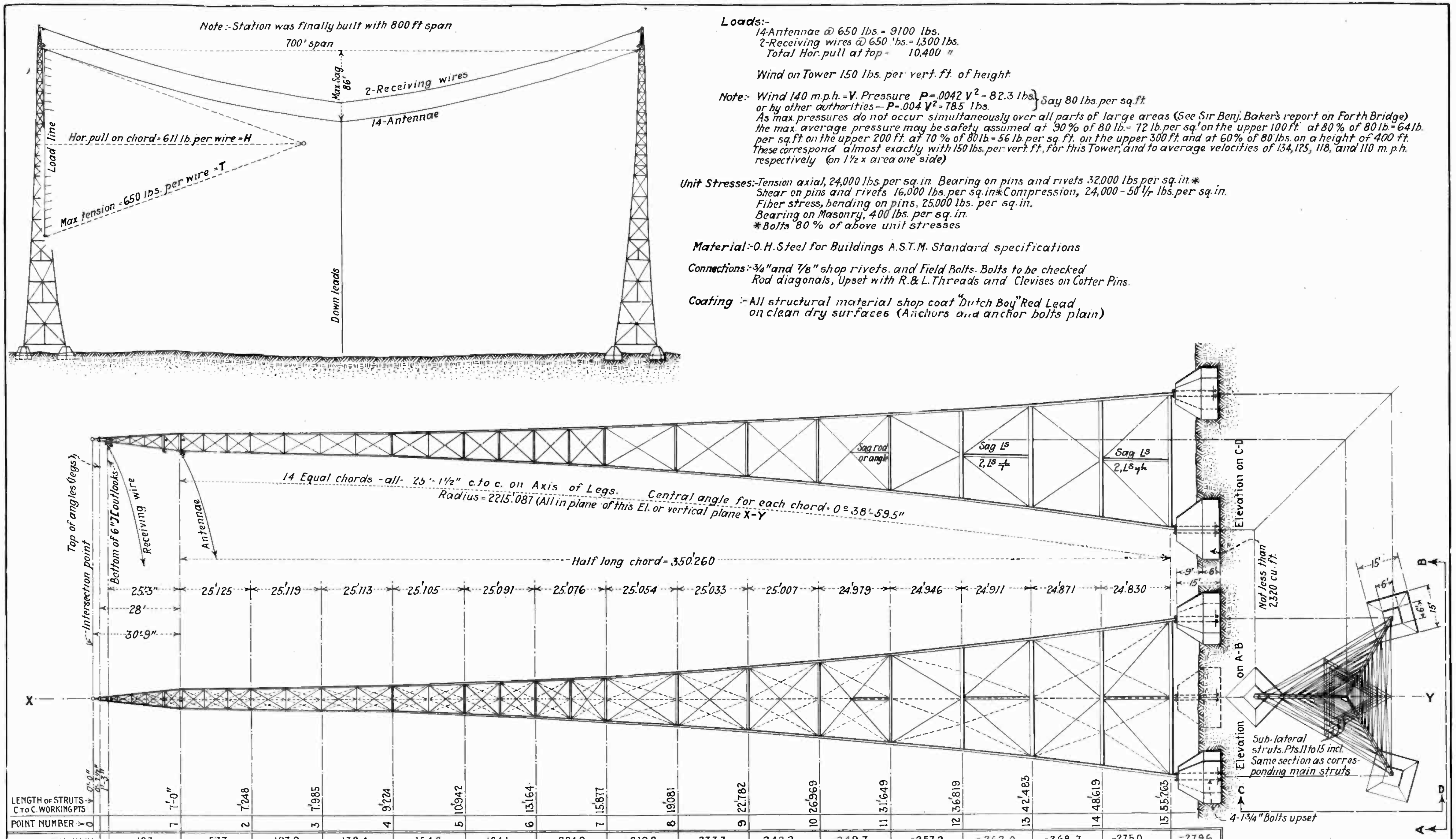


FIGURE 18—United Fruit Company, Cape San Antonio Station in 1915, after hurricane

The designs were made and the results required the author entirely to reverse his preconceived opinion. There is a saving in weight of about ten percent in favor of the three-legged tower when designed under the same specifications, loads, and unit stresses, as compared with the design for a four-legged tower, each tower having its economic width of base. (The side of the



Loads:-

14-Antennae @ 650 lbs. = 9100 lbs.
2-Receiving wires @ 650 lbs. = 1,300 lbs.
Total Hor. pull at top = 10,400 "

Wind on Tower 150 lbs. per vert. ft. of height.

Note:- Wind 140 m.p.h. = V. Pressure $P = .0042\,V^2 = 82.3$ lbs. } Say 80 lbs. per sq. ft.
or by other authorities — $P = .004\,V^2 = 78.5$ lbs.
As max. pressures do not occur simultaneously over all parts of large areas (See Sir Benj. Baker's report on Forth Bridge) the max. average pressure may be safety assumed at 90% of 80 lb. = 72 lb. per sq.' on the upper 100 ft. at 80% of 80 lb. = 64 lb. per sq. ft. on the upper 200 ft. at 70% of 80 lb. = 56 lb. per sq. ft. on the upper 300 ft. and at 60% of 80 lbs. on a height of 400 ft. These correspond almost exactly with 150 lbs. per vert. ft., for this Tower, and to average velocities of 134, 125, 118, and 110 m.p.h. respectively (on 1½ x area one side)

Unit Stresses:- Tension axial, 24,000 lbs. per sq. in. Bearing on pins and rivets 32,000 lbs. per sq. in.*
Shear on pins and rivets 16,000 lbs. per sq. in.* Compression, 24,000 - 50 l/r lbs. per sq. in.
Fiber stress, bending on pins, 25,000 lbs. per sq. in.
Bearing on Masonry, 400 lbs. per sq. in.
*Bolts 80% of above unit stresses

Material:- O.H. Steel for Buildings A.S.T.M. Standard specifications

Connections:- ¾" and ⅞" shop rivets. and Field Bolts. Bolts to be checked
Rod diagonals, Upset with R. & L. Threads and Clevises on Cotter Pins.

Coating:- All structural material shop coat "Dutch Boy" Red Lead
on clean dry surfaces (Anchors and anchor bolts plain)

LENGTH OF STRUTS C. TO C. WORKING PTS	0'-0" 0'-7½" 1'-3"	7'-0"	7'.248	7'.985	9'.224	10'.942	13'.164	15'.877	19'.081	22'.782	26'.969	31'.649	36'.819	42'.483	48'.619	55'.263
POINT NUMBER	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15

LEGS MAXIMUM STRESSES	-10.3 +10.3	-57.7 +59.5	-103.0 +112.9	-138.4 +158.3	-164.8 +194.4	-184.1 +220.7	-204.9 +237.5	-219.8 +248.4	-233.3 +253.7	-242.2 +254.5	-249.7 +254.9	-257.2 +253.9	-262.0 +248.4	-268.7 +244.6	-275.0 +239.5	-279.6 +231.9
LEGS SECTIONS	1,L 3"x3"x5/16"	1,L-4"x4"x7/16"	1,L-6"x6"x½"	1,L-6"x6"x7/16" 2,Ls 3"x2½"x5/16"	1,L-6"x6"x½" 2,Ls 3"x2½"x3/8"	1,L-6"x6"x9/16" 2,Ls 3"x2½"x7/16"	1,L-6"x6"x5/8" 2,Ls 3"x3"x7/16"	1,L-8"x8"x½" 2,Ls 4"x3"x5/16"	1,L-8"x8"x½" 2,Ls 4"x3"x3/8"	1,L-8"x8"x9/16" 2,Ls 4"x3"x3/8"	1,L-8"x8"x9/16" 2,Ls 4"x3"x3/8"	1,L-8"x8"x9/16" 2,Ls 4"x3"x3/8"	1,L-8"x8"x5/8" 2,Ls 4"x3"x3/8"	1,L-8"x8"x5/8" 2,L 4"x3"x3/8"	1,L-8"x8"x5/8" 2,Ls 4"x3x3/8"	4-1¾" Bolts upset Concrete Anchor Not less than 2,320 c.f.
DIAGONALS STRESSES SECTIONS	5/16 Pl. 2½x2½x5/16 L 2½x2½x5/16 L 2½x2½x5/16 L Do Do	+11.0 1-1" +17.8 1-1" +18.6 1-1"	+22.0 1-1⅛" +21.8 1-1⅛"	+18.8 1-1" +18.1 1-1"	+13.9 1-1" +13.5 1-1"	+9.7 1-1" +9.8 1-1"	+7.0 1-1" +7.2 1-1"	+10.2 1-1"	+10.0 1-1"	+9.7 1-1"	+9.7 1-1"	+13.0 1-1"	+12.8 1-1"	+11.5 1-1"	+11.5 1-1"	
STRUTS STRESSES SECTIONS	2½x2½x5/16 2½x2½x5/16 L 2½x2½x5/16 L 2½x2½x5/16 L Do Do Do 1,L 3"x2½"x5/16"	1,L Do + Web. 11¾x5/16" -11.0 1,L 3"x2½"x5/16" -11.4 1,L Do -12.0	1,L Do -11.3 1,L Do -11.6	L,L Do -10.4 1,L-3½"x3½"x5/16" -10.5	1,L Do -8.6 1,L-4"x3½"x5/16" -8.8	1,L Do -6.6 1,L-5"x4"x3/8" -6.9	1,L-5"x4"x3/8" -5.3 2,T-6"x3½"x5/16" -5.7	2,Ls Do -5.9	2,Ls Do -6.5	2,Ls Do -6.9	2,Ls 6"x4"x3/8" -7.3	2,Ls Do -7.0	4,Ls 3"x2½"x5/16" Laced -8.3	4,Ls Do Laced -7.5	4,Ls Do Laced -8.6	4,Ls 3½"x2½"x5/16" Laced

Note: All stresses in thousands of pounds

UNITED FRUIT CO.
WIRELESS TELEGRAPH DEPARTMENT
350 Ft. Self-Supporting Towers
Almerante, Panama
August 1920
Figure 19

FIGURE 19

triangle should be somewhat larger than the side of the square for maximum economy in each case.)

But the three-legged tower has other important advantages: First, the stresses, particularly in the bracing, are not materially disturbed by unequal settlement of the supports, and this is of vital importance where foundation conditions are poor as is frequently the case. It is also important where the tower is carried on distributing girders, which are subject to deflection—a case met with in broadcast stations and others with towers on the top of buildings. Another advantage is the greater rigidity of the triangular cross-section as compared with the square one, thus avoiding all necessity for horizontal "*X*" or cross-bracing.

Computations of areas exposed to wind for a number of cases of comparative designs, showed that stiff, angle-bar, bracing adds about twenty percent to the exposed wind area as compared with a tower with adjustable rod diagonals. Always a large part of the total load, in tropical hurricane sections, where there is no ice load to provide for, the wind on exposed area of tower is the principal force with which to contend, and 20 percent increase in this requires so much additional metal that all advantages of stiff bracing are far outweighed by the increased cost.

Almost all designers of steel structures have used stiff bracing almost exclusively for many years; and for ordinary structures, particularly bridges, it is the correct practice. But the radio tower problem is quite a different case and should be treated on its merits. It is a problem almost unique in the field of framed structures in the fact that the designer has a considerable control over the total of the principal load without reducing the unit loading. No such condition exists to an appreciable extent in bridges or buildings. Moreover, in both bridges and buildings, wind loads are comparatively small and, except in long spans and high, tower-like, buildings, comprise only a very small part of the total stresses.

For these reasons the author has no hesitation in advocating pin connected, adjustable, tension rod diagonals for radio towers. The type has been abandoned so many years for all ordinary steel construction, altho it once was standard even for railroad bridges, that some shops are not well equipped to handle it and have to purchase the rods outside. Moreover, it is a slightly more expensive class of shop work and therefore costs more per pound—but there are not so many pounds. Not only is the bracing itself lighter but the legs are also very much lighter because the loaded wind area is much less, and consequently the leg stresses are materially less. Total cost and not cost per unit is what spells economy. In one case we were able to pay a very much higher price per pound for the steel and still save nearly 20 percent on the cost of the completed towers, due to saving in weight of steel and of one foundation and pedestal per tower.

Another feature introduced in all later designs is that the leg sections are all equal short chords of a perfect circular arc. A little pains taken in fixing the outline, so that leg sections are all of equal lengths, permits the fabrication of these members as duplicates and interchangeable thruout the height of the tower, except where sectional areas have to be adjusted to the stresses, and, of course, excepting the top and bottom sections. This feature makes the fabricating cost of these legs as low as any straight work. That the vertical height of the stories is slightly variable is of no consequence whatever. It is true that the angle between the leg and horizontal strut is different at each full story, requiring special lay-out and template for each point, but as an objection to the design this loses its force when considered in connection with the fact that each tower has at least six duplicate bent plates of each kind; and as several towers are generally fabricated together, on the same order, the duplication is ample to distribute the cost of drawings, special lay-outs, and templates over a sufficient number of duplicate pieces to keep the unit cost down to a low figure. There are now under order eight duplicate towers, for example, which gives forty-eight duplicate bent plates from each template, so that the cost of the items mentioned for each piece cannot be very high. Moreover the angle of the bend is only 15 degrees and, for all practical purposes the slight variation from that figure from bottom to top is negligible, so that all can be made with the same bend angle, and this is the only expense chargeable to the three-legged feature.

RECENT DESIGNS

All the features herein described were used in the design for the towers of the Almirante, Panama, station, built in 1921, and illustrated in Figures 19 and 20, showing, respectively, stresses, sections, general data, and typical details. Figure 21 is a view of the completed towers.

These towers have no antenna bridges, spreaders being used instead.

Most fabricators, at first sight, are inclined to exaggerate the difficulties and cost of these designs, but those who have been

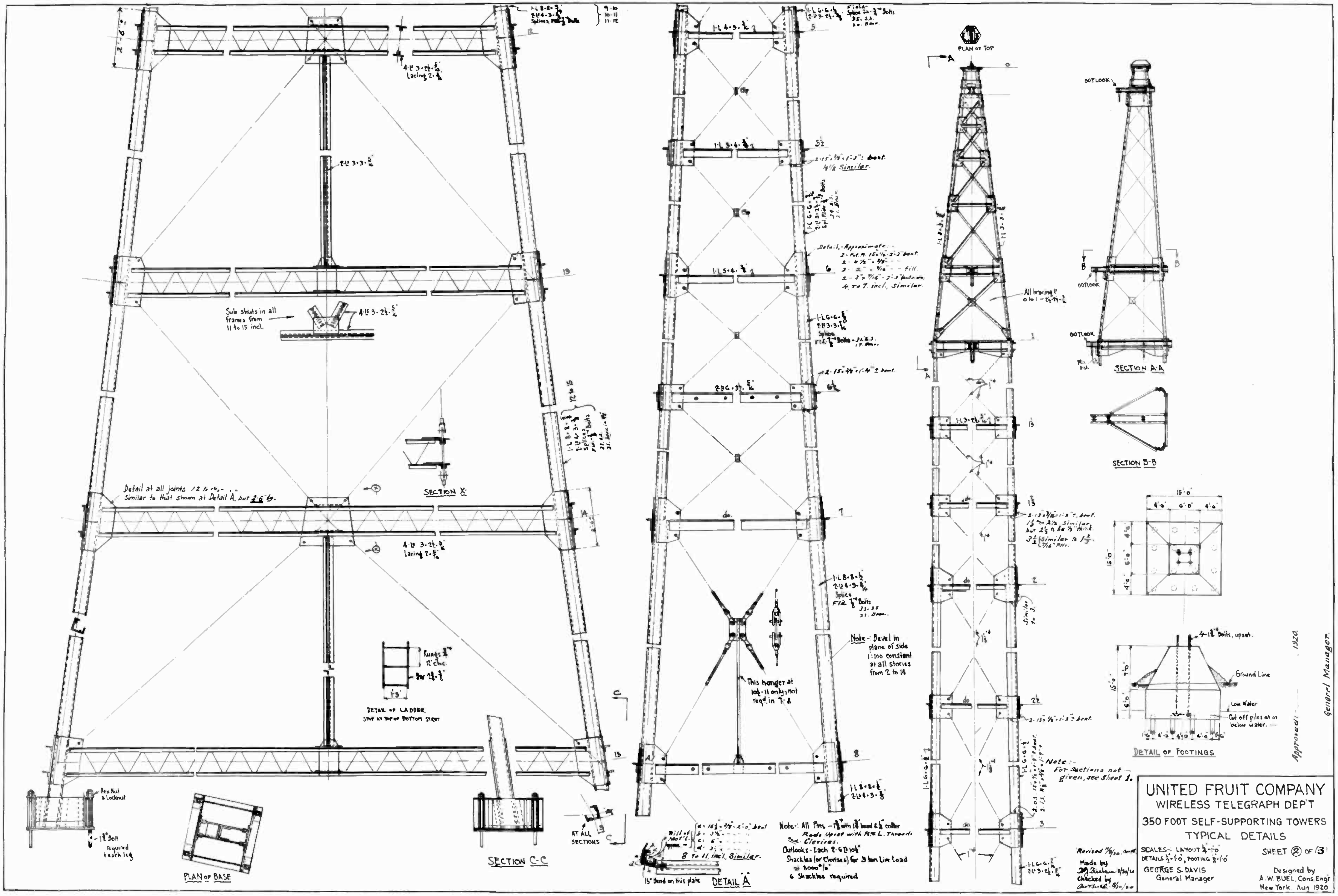

PLAN OF TOP
A
OUTLOOK
SECTION A-A
SECTION B-B
All bracing ¾" to 1 – 2½·2½·¼
Detail at all joints 12 to 14,– Similar to that shown at Detail A, but 2'6" lg.
Sub struts in all frames from 11 to 15 incl.
SECTION X
DETAIL OF LADDER
Rungs ¾" 12" c.to c.
Bar 2½·⅜
4-Ls 3·2½·5/16 Lacing 2·5/16
This hanger at lot 11 only, not req'd in 7-8
Note:– Bevel in plane of side 1:100 constant at all stories from 2 to 14
Hex Nut & Locknut
1⅜" Bolt required to each leg
PLAN OF BASE
SECTION C-C
AT ALL SECTIONS
4-1¾" Bolts, upset.
Ground Line
Low Water
Cut off piles at or below water.
DETAIL OF FOOTINGS
15'-0"
4'-0" 6'-0" 4'-0"
Bill of Mat'l.
a: 16½ × 7/16 – 2'-0" bent
b: 3½
c: 6"
d: 3½
8 To 11, incl. Similar.
15° bend on this plate
DETAIL A
Note:– All Pins – 1⅜" with 1⅞" head & ½" collar
Rods Upset with R. & L. Threads and Clevises.
Outlooks – Each 2-6[10½"
Shackles (or Clevises) for 3 ton Line Load at 8000#/□"
6 Shackles required
Note:– For Sections not given, see Sheet 1.
Approved: 1920. General Manager.
UNITED FRUIT COMPANY
WIRELESS TELEGRAPH DEP'T
350 FOOT SELF-SUPPORTING TOWERS
TYPICAL DETAILS
SCALES:– LAYOUT ¼"-1'-0", DETAILS ½"-1'-0", FOOTING ⅛"-1'-0"
SHEET ② OF 3
GEORGE S. DAVIS General Manager
Designed by A. W. BUEL, Cons. Engr. New York. Aug 1920
Revised 11/9/20
Made by 8/30/20
Checked by 8/30/20

FIGURE 20

properly equipped have found out after fabricating a few that the shop costs were not as high as they anticipated, so that now there is no trouble in obtaining satisfactory prices. The unit prices secured for the later towers are only slightly higher than is asked for towers on fabricators' designs, leaving a substantial net saving in total cost due to the more economical use of steel.

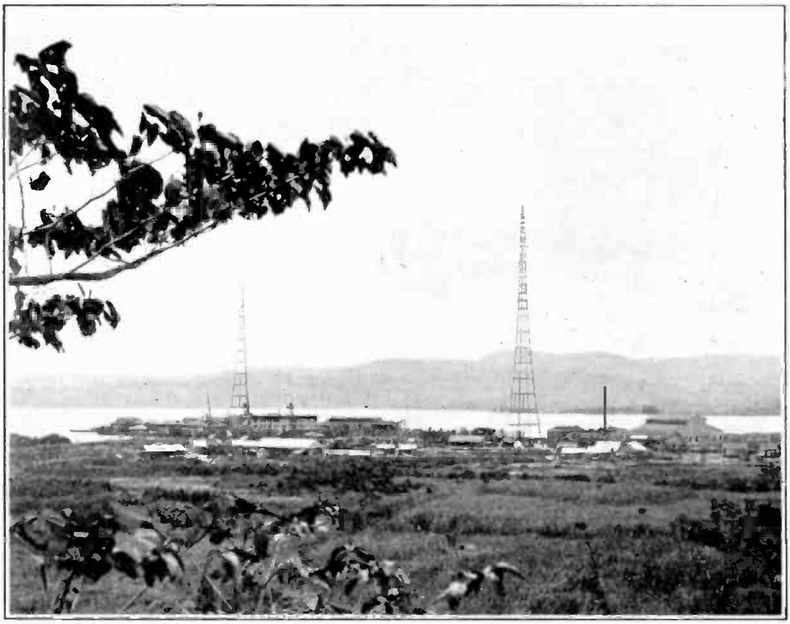


FIGURE 21—United Fruit Company, Almirante Station, 1921

There are, however, a few fabricators who sky-rocket their quotations at the sight of a curved outline or adjustable tension rod, and these are the ones most heard. The type of design preferred by them has four legs, either straight or with only one break in the height of the tower, and stiff bracing; extremely slender struts and, generally, metal only 3/16 inch (0.48 cm.) thick—sometimes only ⅛ inch (0.32 cm.) thick—except for the legs.

Such designs have been perfectly described by the Dean of American Bridge Engineers, Mr. Gustave Lindenthal, in a paper entitled "Some Thoughts on Long Span Bridge Design," (1921), in these words:

> "* * * * * an American design, a typical shop creation, * * *" and "Ugliness is rational beauty to minds who see merit only in geometrical figures and in cheap fabrication."

and, it is to be noted that he was discussing the design of steel towers.

ANTENNA BRIDGES

When, in place of spreaders and messenger cables, fixed antenna bridges came to be required on top of towers, we followed the same general idea:—that of keeping the area exposed to wind down to a minimum. The importance of this increases as the height of the area under consideration and, consequently, its overturning lever arm, increases. It is further intensified where hurricane force must be provided for.

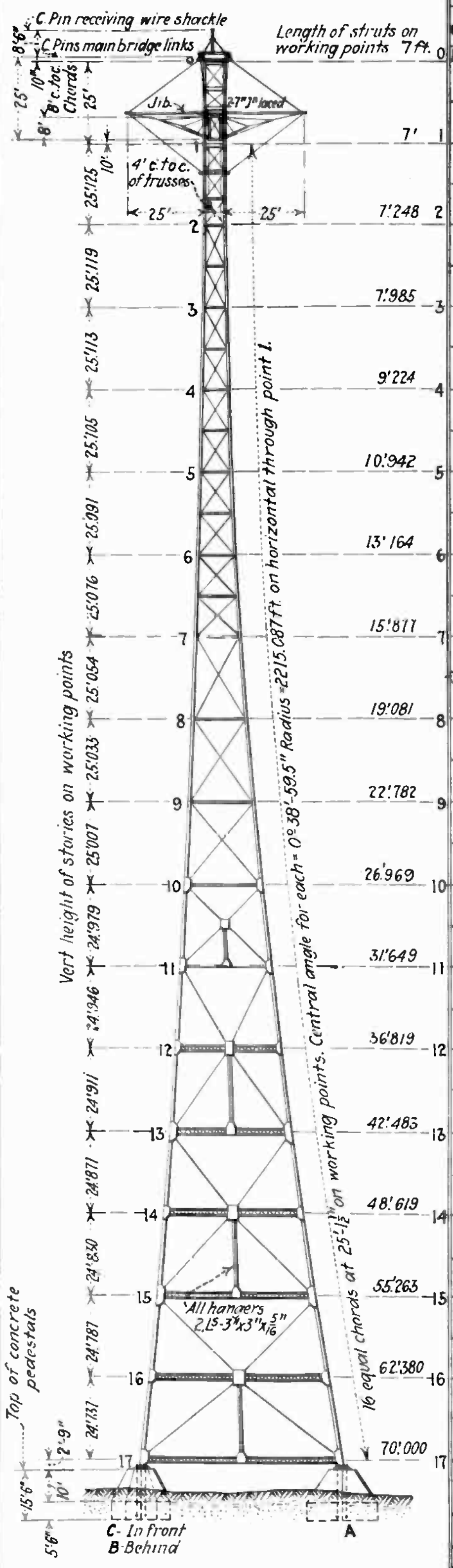
In addition to the use of adjustable rods for all tension members, we used extra strong, galvanized pipe for compression members, in two symmetrical, balanced, suspension cantilevers. The area exposed to wind, including about half that of the leeward truss, is under 200 sq. ft. (18.6 sq. m.) for the 150 ft. (46 m.) of bridge. Compared with fabricators' structural steel designs this means a saving of over sixty percent in the wind load on antenna bridge—quite an item when one considers it acting on a lever arm 400 ft. (122 m.) high.

The trusses act only as stiffening trusses and to brace the lower chord which takes the outboard thrust from the links. The walkway floor is of Irving Subway Grating, type "*L*," ¾ inch (1.9 cm.), which was adopted because it combines with minimum weight, ample resistance to lateral shear, avoiding the use of lower laterals, and with the maximum size of mesh. Tests made by the Irving Iron Works Company, Long Island City, especially for this work, showed that, at the elastic limit, the shearing strength of this grating is 393.7 lbs. (179 kg.) per mesh width of 2⅜ inches (6.03 cm.); and the ultimate strength 448.1 lbs. (220 kg.) per mesh; the tests being made on panels 26⅛ inches (65.2 cm.) wide, having 12 straight bars and 11 meshes of 2⅜ inches (5.95 cm.). Figure 22 shows panel number 2 after testing.

The first towers of the Tropical Radio Telegraph Company with fixed antenna bridges are those erected in 1922 at Tegucigalpa, Honduras. Eight similar towers, for four stations, are now under order.

Figure 23 shows the stresses, sections, and typical details of the Tegucigalpa towers, Figure 24, the antenna bridge, and Figure 25 a view of one of the towers after completion. Figure 26 is a view looking thru the antenna bridge of the East tower at Tegucigalpa.

Figures 27 and 28 are, respectively, the stress, section, general data sheet, and general plan and details, with stresses and sections of the antenna bridge, for the latest, revised standard 400 ft. (122 m.) self-supporting tower with 150 ft. (46 m.)



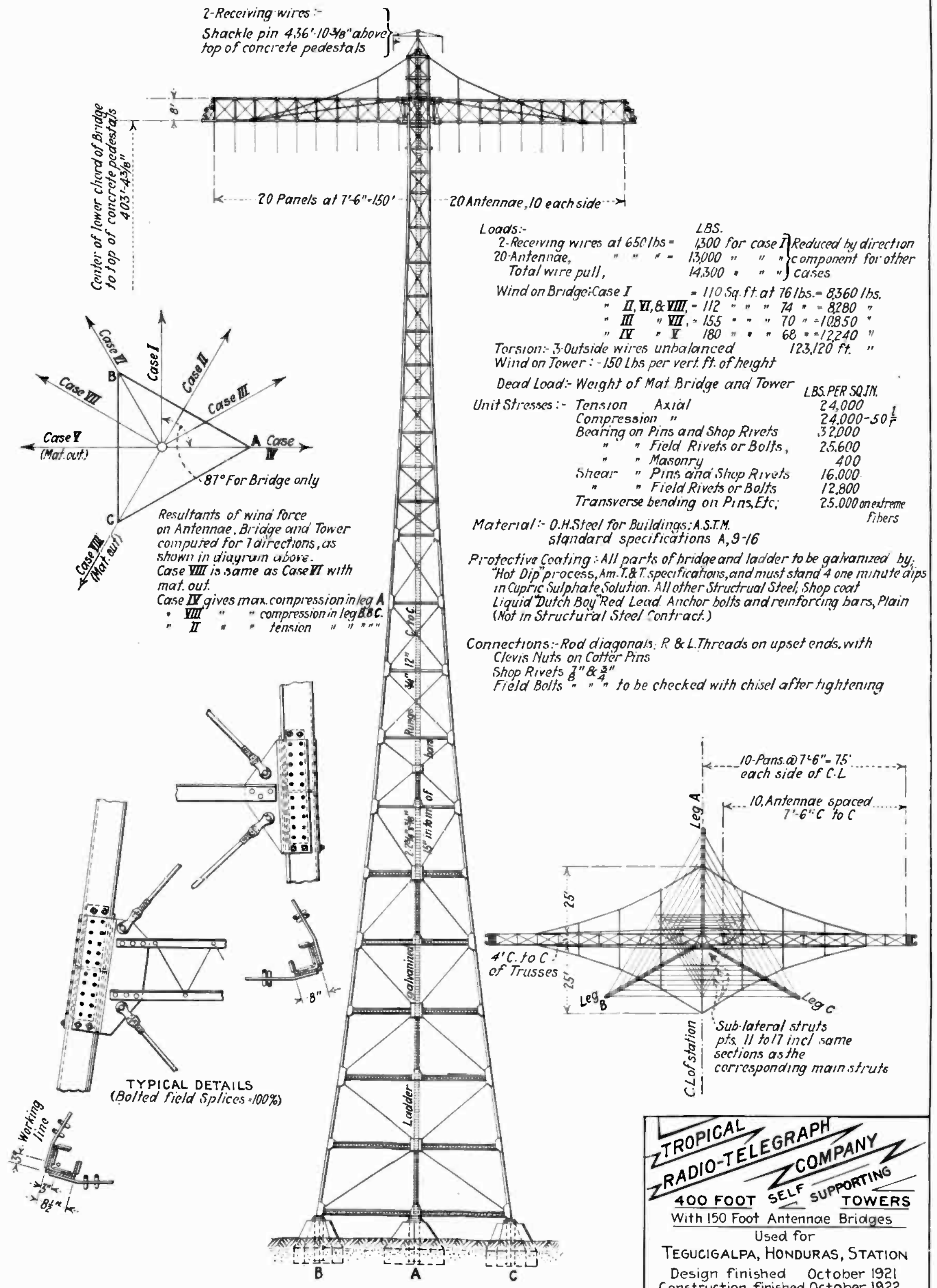
TOWER BOSTS					TOWER STRUTS		DIAGONAL RODS	
LEG-A		LEGS B. & C.						
MAX. COMP 1,000 LBS	SECTIONS AREA SQ INS.	MAX. COMP 1000 LBS	STRESSES TENS 1000 LBS	SECTIONS AREA SQ. INS.	STRESS 1000 LBS	SECTIONS	STRESS 1000 LBS	SIZE
-45.5	1-L,5"x5"x 7/16" 4.18□" Gr. 3.30□" Net	-33.1	+26.6	1-L,5"x5"x7/16" 4.18□" Gr. 3.30□" Net	-3.4	1-12"] @ 25 Lb.		
					-4.0	1-L,4"x3"x5/8"	+5.1	¾"●
					-4.7	1-12"] @ 25 Lb.	+5.0	¾"●
					-35.1	1-12"] @ 25 Lb.	+8.2	⅞"●
-141.2	1-L,6"x6"x11/16" 7.78□" Gr. 64 □" Net	-79.4	+98.6	1-L,6"x6"x½" 5.75□" Gr. 4.75□" Net	-35.6	1-10"] @ 20 Lb.	+54.6	1¾"●
					-35.8	1-L,4"x3"x3/8"	+54.7	1¾"●
					-36.2	1-L,4"x3"x3/8"	+55.3	1¾"●
-233.1	1-L,8"x8"x½" 2-Ls,4"x3"x5/16" 11.93□" Gr. 10.30□" Net 8" b.to b.Ls	-138.9	+184.0	1-L,8"x8"x½" 2-Ls,4"x3"x5/16" 11.93□" Gr. 10.30□" Net 8" b.to b.Ls	-34.2	1-L,4"x3"x5/16"	+65.3	1⅞"●
					-33.5	1-L,4"x3"x5/16"	+61.9	1⅞"●
-293.8	1-L,8"x8"x9/16" 2-Ls,4"x3"x3/8" 13.64□" Gr. 11.76□" Net 8" b.to b.Ls	-189.7	+248.7	Ditto	-30.8	1-L,4"x3"x5/16"	+53.7	1¾"●
					-29.5	1-L,4"x3"x3/8"	+49.1	1⅝"●
-331.9	1-L,8"x8"x11/16" 2-Ls,4"x3"x½" 17.03□" Gr. 14.65□" Net 8" b.to b.Ls	-230.6	+295.4	1-L,8"x8"x5/8" 2-Ls,4"x3"x3/8" 14.57□" Gr. 12.57□" Net 8" b.to b.Ls	-25.2	1-L,4"x3"x5/16"	+39.7	1½"●
					-23.9	1-L,5"x4"x7/16"	+35.8	1⅜"●
-366.4	– Ditto	-260.5	+324.9	1-L,8"x8"x11/16" 2-Ls,4"x3"x½" 17.03□" Gr 14.65□" Net 8" b.to b.Ls	-19.5	1-L,5"x4"x7/16"	+27.4	1¼"●
					-18.8	1-L,5"x4"x7/16"	+25.3	1¼"●
-382.7	1-L,8"x8"x¾" 2-Ls,4"x3"x½" 17.94□" Gr. 15.44□" Net 8" b.to b.Ls	-280.9	+340.2	Ditto	-15.9	2-Ls,6"x3½"x5/16"	+20.3	1⅛"●
					-15.4	2-Ls,6"x3½"x5/16"	+19.1	1"●
-394.8	1-L,8"x8"x¾" 2-Ls,5"x3½"x5/8" 21.28□" Gr. 18.53□" Net 8½" b.to b.Ls	-293.7	+346.8	Ditto	-15.5	2-Ls,6"x3½"x5/16"	+24.7	1¼"●
-402.8	Ditto	-306.6	+349.1	Ditto	-15.4	2-Ls,6"x3½" 5/16"	+22.1	1⅛"●
-398.2	Ditto	-310.9	+341.3	Ditto	-15.2	2-Ls,6"x4"x3/8"	+19.9	1⅛"●
-397.3	Ditto	-315.7	+335.9	Ditto	-15.3	2-Ls,6"x4"x3/8"	+18.7	1"●
-400.0	Ditto	-320.8	+329.4	Ditto	5.0	4-Ls,3"x2½"x5/16" Laced 18" a.to a.	+25.0	1¼"●
-396.3	Ditto	-323.2	+317.6	1-L,8"x8"x¾" 2-Ls,4"x3"x½" 17.94□" Gr. 15.44□" Net 8" b.to b.Ls	-14.7	4-Ls,3"x2½"x5/16" Laced 18" o.to o.	+22.6	1⅛"●
-396.8	Ditto	-328.1	+309.0	Ditto	5.0	4-Ls,3"x2½"x5/16" Laced 18" a.to c.	+20.3	1⅛"●
-397.5	Ditto	-333.0	+298.8	Ditto	-14.5	4-Ls,3½"x2½"x5/16" Laced 18" o.to o	+19.4	1"●
-398.5	Ditto	-337.5	+287.0	Ditto	5.0	4-Ls,4"x3"x5/16" Laced 18" a.to c.	+17.0	1"●
-402.1	Ditto	-344.5	+276.0	1-L,8"x8"x¾" 2-Ls,5"x3½"x7/16" 18.50□" Gr. 16.12□" Net 8½" b.to b.Ls	-14.0	4-Ls,5"x3"x7/16" Laced 18" o.to c.	+17.2	1"●

Masonry reaction,-405.9 | 4.Anchor bolts 1⅞"● upset to 2⅜"● = 11.04□" Net

Uplift on Anchorage,+264.7 | 270.1 Cu.Ft. Concrete @ 150 lb = 405.15 M Lbs. [(16³÷3)+(16²x5.5)]-(6³÷3) = 270.1 Cu.Ft.

Where foundations require piles, use 25 under each pedestals.
(5, rows of 5 piles each; spaced 3' each way)

Note:- 25 Piles per pedestal are sufficient for worst conditions



Resultants of wind force on Antennae, Bridge and Tower computed for 7 directions, as shown in diagram above.
Case VIII is same as Case VI with mat. out.
Case IV gives max. compression in leg A
" VIII " " compression in leg B & C.
" II " " tension " " " " "

Loads:-

	LBS.	
2-Receiving wires at 650 lbs =	1,300 for case I	Reduced by direction component for other cases
20-Antennae, " " " =	13,000 " " "	
Total wire pull,	14,300 " " "	

Wind on Bridge: Case I = 110 Sq. ft. at 76 lbs. = 8,360 lbs.
" II, VI, & VIII, = 112 " " " 74 " = 8,280 "
" III " VII, = 155 " " " 70 " = 10,850 "
" IV " V 180 " " " 68 " = 12,240 "
Torsion:- 3-Outside wires unbalanced 123,120 ft. "
Wind on Tower:- 150 Lbs per vert. ft. of height

Dead Load:- Weight of Mat Bridge and Tower

Unit Stresses:-		LBS. PER SQ. IN.
	Tension Axial	24,000
	Compression "	$24{,}000-50\frac{l}{r}$
	Bearing on Pins and Shop Rivets	32,000
	" " Field Rivets or Bolts,	25,600
	" " Masonry	400
	Shear " Pins and Shop Rivets	16,000
	" " Field Rivets or Bolts	12,800
	Transverse bending on Pins, Etc.;	25,000 on extreme fibers

Material:- O.H. Steel for Buildings; A.S.T.M. standard specifications A, 9-16

Protective Coating:- All parts of bridge and ladder to be galvanized by; "Hot Dip" process, Am. T. & T. specifications, and must stand 4 one minute dips in Cupric Sulphate Solution. All other Structrual Steel; Shop coat Liquid "Dutch Boy" Red Lead. Anchor bolts and reinforcing bars, Plain (Not in Structural Steel Contract.)

Connections:- Rod diagonals; R & L. Threads on upset ends. with Clevis Nuts on Cotter Pins
Shop Rivets ⅞" & ¾"
Field Bolts " " " to be checked with chisel after tightening

TROPICAL
RADIO-TELEGRAPH
COMPANY
400 FOOT SELF SUPPORTING TOWERS
With 150 Foot Antennae Bridges
Used for
TEGUCIGALPA, HONDURAS, STATION
Design finished October 1921
Construction finished October 1922
Figure 23

FIGURE 23

antenna bridge. A comparison of Figures 23 and 24 with 27 and 28 will give some idea of the advance made in one year in the tower practice of these companies. The principal difference is the antenna system provided for, as indicated by the plans, but what may not be clear without explanation is that most of the other changes were required by the increase in wire pull and provision that the pull may be in either direction. Some simplification of details of bridge trusses, particularly in the center panels at the tower, are about the only other changes.

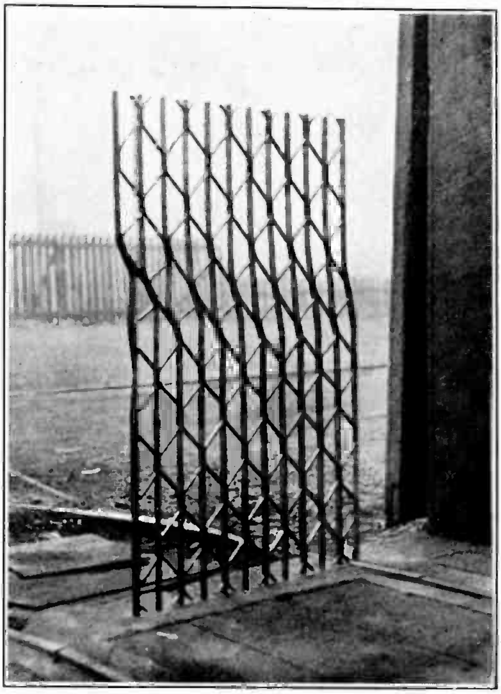


FIGURE 22—Irving Subway Grating

WIND PRESSURE

The wind pressure used for these designs was adopted after a study of all accessible data, but, as our records of the Swan Island and Cape San Antonio hurricanes seem best and most reliable for the conditions required in those localities, they were naturally given the most weight in specifying wind loads. As has been stated, these records indicate probable velocities of about 137 miles per hour (220 km. per hr.), or a maximum pressure on small areas of 75 lbs. per sq. ft. (368 kg. per sq. m.), derived by formulas from the computed breaking load of 50 lbs. per sq. ft. (245 kg. per sq. m.), average, on the 100 feet (30.5 m.) of tower that broke off, and taken on 1½ times the area of the projected elevation of one side. The conversion formula used is $P = 0.004 V^2$ in which P = pressure in pounds per square foot, and V = velocity in miles per hour. The United States Weather Bureau formula is $P = 0.004 V^2. \; B/29$, in which B = barometer reading in inches.

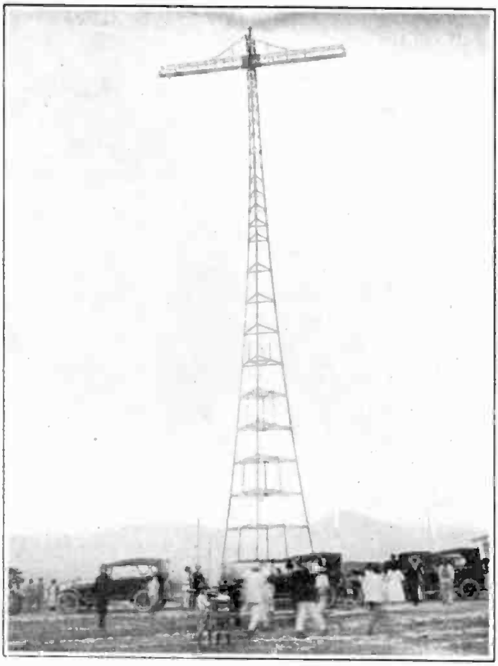
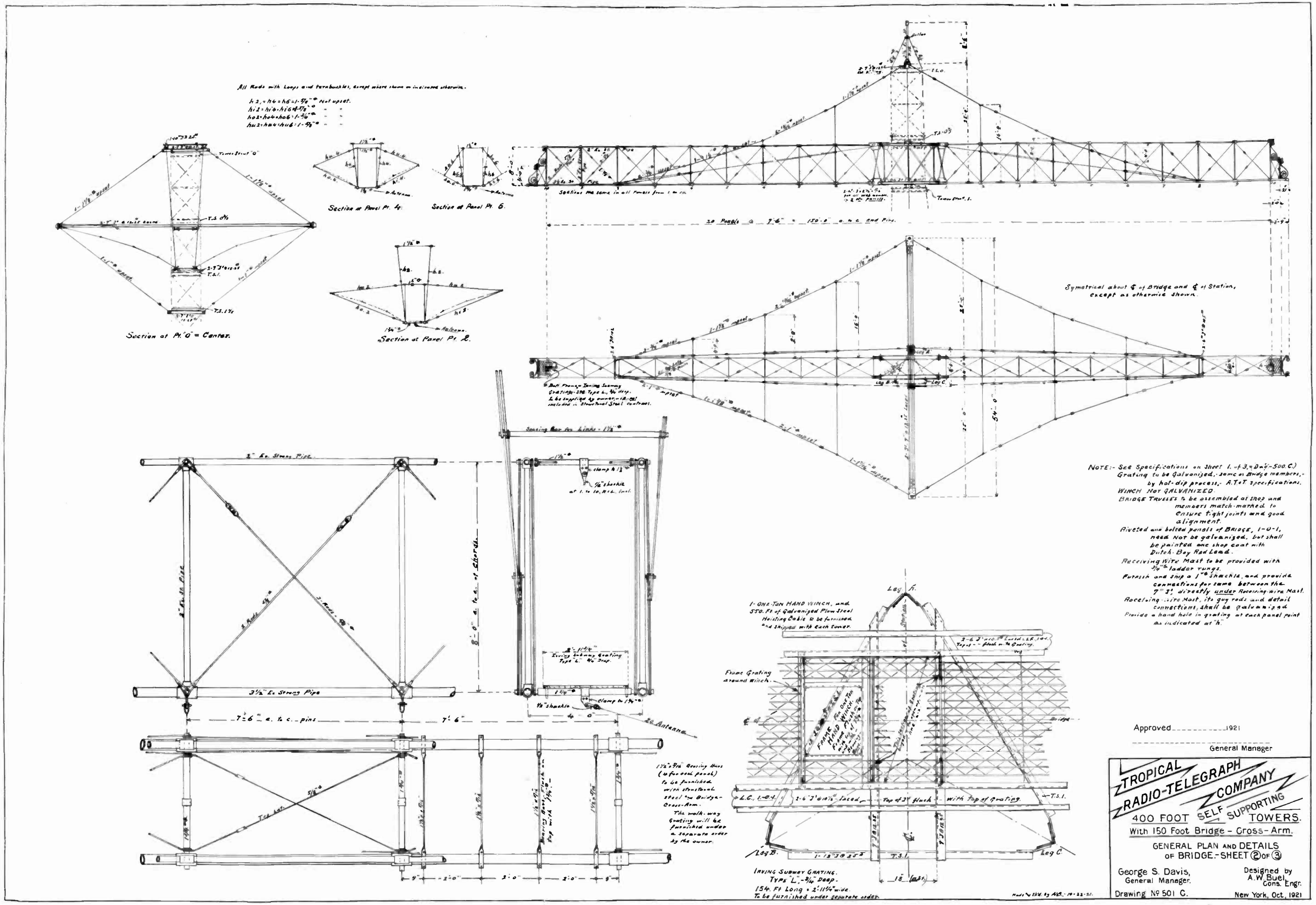


Figure 25—East Tower, Tegucigalpa (Honduras), Radio Telegraph Station of Tropical Radio Telegraph Company, erected 1922

Some authorities give $P = 0.0042 \; V^2$, and an older formula is $P = 0.003 \; V^2$, but the latter is probably nearer the average pressure on large areas than the maximum on small areas which is desired. A number of more complicated formulas have been proposed, some based on rational theories, but they have yet to be proven more correct.

Many authorities make large allowances for reduction in velocity and pressure as ground level is approached, compared with those at high elevations above ground; but while many observations, particularly those on the Eiffel Tower, have shown this to be correct in light winds, they have shown also that at higher



All Rods with Loops and turnbuckles, except where shown or indicated otherwise.

h 2, = h4 = h6 = 1-7/8"⌀ Not upset.
hi2 = hi4 = hi6 = 1-7/8"⌀ " "
ho2 = ho4 = ho6 = 1-3/4"⌀ " "
hu2 = hu4 = hu6 = 1-5/8"⌀ " "

Symetrical about ℄ of Bridge and ℄ of Station, except as otherwise shown.

NOTE:- See Specifications on Sheet 1. of 3. (Dwg-500.C.)
Grating to be Galvanized, same as Bridge members, by hot-dip process,- A.T.&T. specifications.
WINCH NOT GALVANIZED.
BRIDGE TRUSSES to be assembled at shop and members match-marked to ensure tight joints and good alignment.
Riveted and bolted panels of BRIDGE, 1-0-1, need not be galvanized, but shall be painted one shop coat with Dutch-Boy Red Lead.
Receiving Wire Mast to be provided with 3/4"⌀ ladder rungs.
Furnish and ship a 1"⌀ shackle, and provide connections for same between the 7" [, directly under Receiving-wire Mast.
Receiving-wire Mast, its guy rods and detail connections, shall be galvanized.
Provide a hand hole in grating at each panel point as indicated at "h".

1- ONE-TON HAND WINCH, and 550. Ft of Galvanized Plow Steel Hoisting Cable to be furnished and shipped with each tower.

1½"×9/16" Bearing Bars (4 for each panel) to be furnished with structural steel for Bridge-Cross-Arm.

The walk-way Grating will be furnished under a separate order by the owner.

IRVING SUBWAY GRATING.
TYPE "L",-3/4" Deep.
154. Ft Long × 2'-11¾" wide.
To be furnished under separate order.

Approved 1921

....
General Manager

TROPICAL
RADIO-TELEGRAPH
COMPANY
400 FOOT SELF SUPPORTING TOWERS.
With 150 Foot Bridge - Cross-Arm.
GENERAL PLAN AND DETAILS
OF BRIDGE.-SHEET ② OF ③

George S. Davis,
General Manager.

Designed by
A.W. Buel,
Cons. Engr.

Drawing Nº 501 C.

New York, Oct, 1921

FIGURE 24

velocities, "the pressure at the top and that at the ground come nearer together." At the highest velocities it is probable that there is not much difference, and it is only the highest velocities that interest the designer. Until it is shown that high winds and hurricanes have similar properties and effects as light winds, which has yet to be done, we should not give too much weight to deductions from observations in light winds. Unfortunately very few records are available for very high winds, 96 miles per hour (154 km. per hr.), being the highest reported in observations covering six years at the Forth Bridge—equivalent to barely 37 lbs. per sq. ft. (181 kg. per sq. m.). The highest velocity reported by Mr. S. P. Wing in "The Electrician" (London), of July 1st, 1921, was 37 miles per hour (59 km. per hr.), equivalent to less than 5.5 lbs. per sq. ft. (27 kg. per sq. m.). These cannot safely be taken to indicate the characteristics of winds from 100 to 140 miles per hour (160 to 224 km. per hr.), or 40 to 80 lbs. per sq. ft. (196 to 392 kg. per sq. m.).

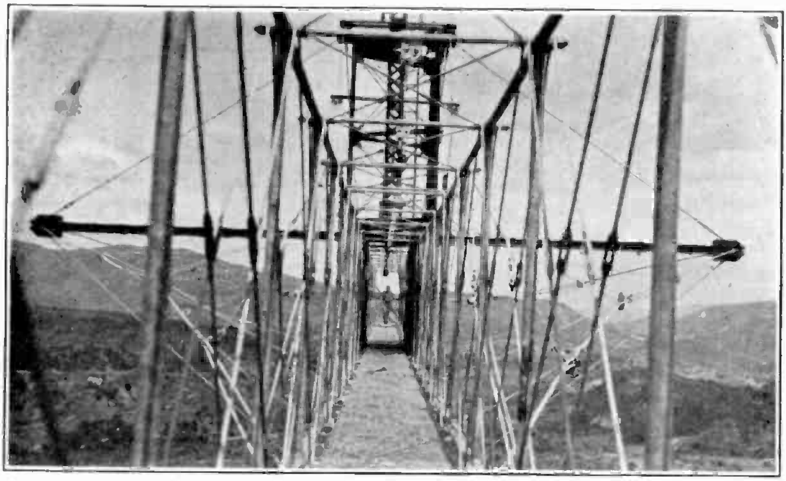


FIGURE 26—Looking through 150 ft. (46 m.) Antenna Bridge, Tegucigalpa

Sir Benjamin Baker, in reporting the Forth Bridge observations, says, "It was found that the large gauge (15 feet by 20 feet (4.6 by 6.1 m.) invariably recorded smaller average pressures than the small, circular, gauges (1.5 sq. ft.) (0.139 sq. m.), never exceeding 80 percent of the latter for observations at the same time, and generally the average pressure on the large gauge varied from 50 to 70 percent of the pressure indicated on the small gauges. Furthermore, small gauges installed in two opposite corners of the central tower of the bridge showed variations of ten to twelve pounds (4.6 to 5.45 kg.) in pressure, sometimes the one and sometimes the other showing the greater registration. The large area does not show more than two-thirds of the pressure indicated by the small gauges as an average."

"Six Monographs on Wind Stresses" and an article in "Engineering News-Record" of March 16, 1922, both by Mr. Robins Fleming, contain some interesting data, but nothing on hurricane velocities and not much on very high winds—nothing appearing so applicable to the case as the Forth Bridge observations.

The wind loads now specified for towers in the hurricane belt—Gulf and Caribbean sections—are as follows:

80 lbs. per sq. ft. (392 kg. per sq. m.) on antenna—(used to fix the sag).

76 lbs. per sq. ft. (372 kg. per sq. m.)—(on the elevation of bridge on a plane 87° from center line of bridge).

68 lbs. per sq. ft. (333 kg. per sq. m.)—(on $1\frac{1}{2}$ times the projected side elevation of bridge).

68 lbs. per sq. ft. (333 kg. per sq. m.)—(on $1\frac{1}{2}\times$the projected elevation of top story of tower).

and 150 lbs. per vertical ft. (226 per vertical m.) of height of tower to lower chord of bridge.

The last item works out as follows: (at $1\frac{1}{2}$ times projected elevation).

61.0 lbs. per sq. ft. (295 kg. per sq. m.) on upper five (5) stories.

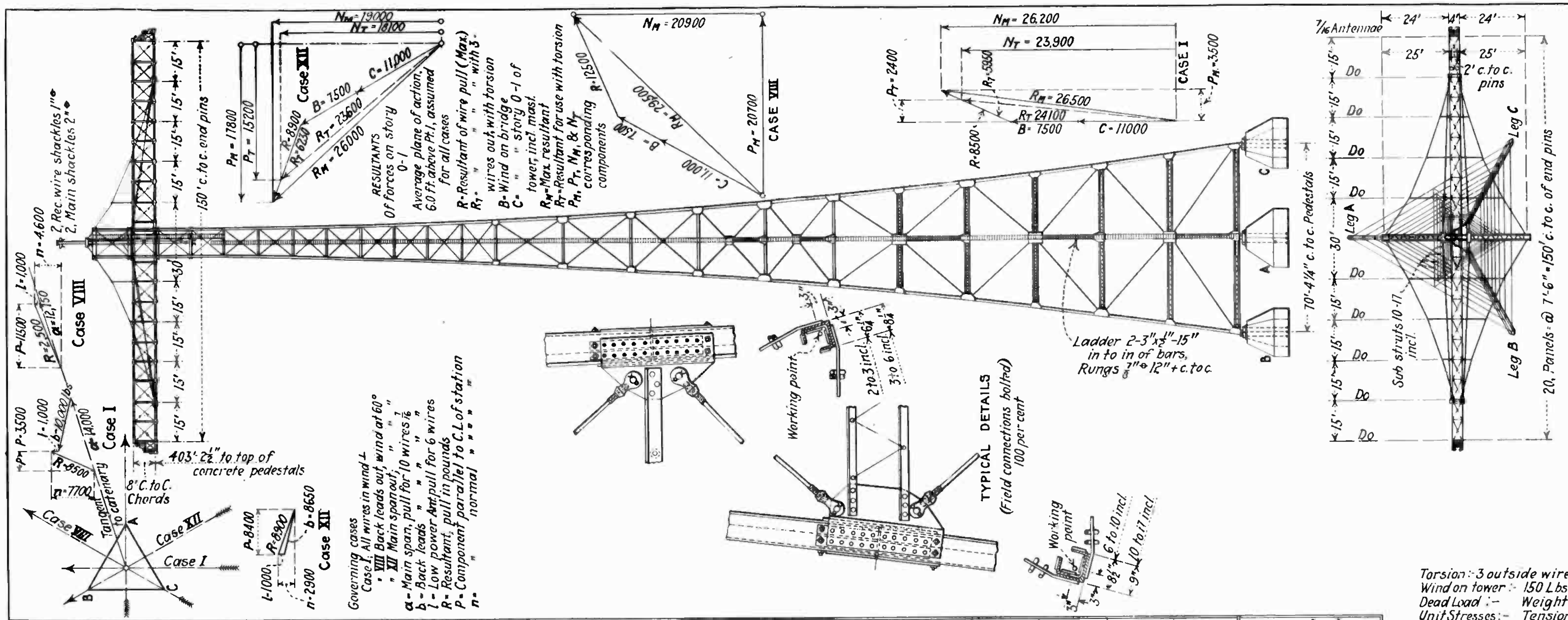
56.8 lbs. per sq. ft. (278 kg. per sq. m.) on upper nine (9) stories.

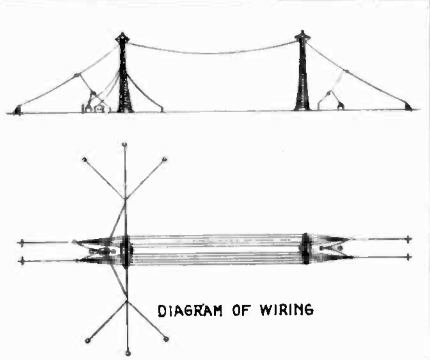
50.5 lbs. per sq. ft. (248 kg. per sq. m.) on upper thirteen (13) stories.

43.2 lbs. per sq. ft. (212 kg. per sq. m.) (the entire tower from base to lower chord of bridge).

These reductions were arrived at empirically, as no rational formula available has been proven correct. They are intended to provide both for the reduction in average intensity on large areas, and also for some reduction of velocity as ground elevation is approached, but the influence of the latter is considered of only secondary importance.

The specified "150 lbs. per vertical foot (226 kg. per vertical m.) of height" was only adopted after a number of computations of loadings per sq. ft., progressively decreasing from top to base,





Loads:- Antennae 10-7/16 wires at 1400 lbs. each = 14,000
Back leads, 10,000 lbs. hor. and 10,000 lbs ver. components = totals.

Low power Antennae 1,000 total at top of tower
See diagrams cases I, VIII and XII for resultant in top story

For loads on bridge see other sheet showing bridge stresses and details

Bridge designed for 17,000 lbs. unbalanced wire pull, which the tower members can take care of with an excess of only 5 4/10 per cent in the stress of any member in the maximun case, which is considered practically negligable, particularlly as the "Maximum Stress" requires the simultaneous occurence of 3 to 5 maximum component conditions

LENGTH OF STRUTS ON WORKING POINTS	STRUT No	TOWER POSTS (Make Legs A.B & C Alike)			TOWER STRUTS		DIAGONAL RODS	
		MAX STRESS		SECTIONS AREA- SQ. INS.				
		COMP	TENS		STRESS	SECTIONS	STRESS	SIZE
Ft. 10.5	0	(MAST):— →		4-Ls 3"x3"x½" ⊔ 15 Laced - 12" b to b	+56,900 lbs - 7.00	1-15"] @ 35 Lb.	1,000 Lbs	1- Rod Upset
10.5	0½	E- Erection Condition -58.5 E-70"	E+60.	1-L 6"x6"x½" 5.75□"Gr. 4.75□" Net	E= 56,900 -47.4	1-15"] @ 35 Lb.	+ 11.7	Rounds Diam. 1⅛"
10.5	1				16170 Ft. Lbs. -44.0	1-12"] @ 25 Lb.	+ 66.0	1⅞"
	1½	-127.3	+50.2	1-L 6"x6"x⅝" 7.11□"Gr.	-44.9	1-12"] @ 25 Lb.	+ 68.3	2"○
10.733	2				-44.5	1-Ls 5"x4"x7/16	+ 68.7	2"○
	2½	-193.7	+123.8	1-L 6"x6"x½" 2-Ls 3"x3"x⅜" 9.97□" Gr. 8.22□" Net 6¼" b to b Ls	-44.2	Ditto	+ 68.1	1⅞"○
11.432	3				-41.9	Ditto	+66.9	1⅞"○
	3½	-253.2	+198.7	1-L 8"x8"x9/16" 2-Ls 4"x3"x⅜" 13.64□" Gr. 11.76□" Net 8¼" b.to b.Ls	-41.2	Ditto	+62.0	1⅞"○
12.597	4				-38.1	Ditto	+59.6	1⅞"○
	4½	-298.7	+260.0	1-L 8"x8"x⅝" 2-Ls 4"x3"x⅜" 14.57□" Gr 12.57□" Net 8¼" b.to b.Ls	-37.3	2-Ls 6"x3½"x5/16"	+53.4	1¾"○
14.228	5				-33.2	Ditto	+50.9	1¾"○
	5½	-340.5	+305.2	1-L 8"x8"x11/16" 2-Ls 4"x3"x7/16" 16.27□" Gr. 14.02□" Net 8¼" b to b Ls	-32.4	Ditto	+44.0	1⅝"○
16.325	6				-28.7	Ditto	+41.7	1½"○
18.887	7	-353.7	+324.7	1-L 8"x8"x11/16" 2-Ls 5"x3½"x⅝" 20.37□" Gr. 17.74□" Net 8½" b to b Ls	-24.2	Ditto	+51.4	1¾"○
21.915	8	-377.1	+355.0	Ditto	-19.8	Ditto	+39.5	1½"○
25.408	9	-391.7	+354.3	1-L 8"x8"x¾" 2-Ls 5"x3½"x⅝" 21.28□" Gr. 18.53□" Net 8½" b to b Ls	-16.0	2-Ls 6"x4"x⅜"	+29.7	1¼"○
29.366	10	-402.5	+362.1	Ditto	-12.8	2-Ls 6"x3½"x5/16" Sub Struts do	+22.3	1⅛"○
33.786	11	-410.0	+366.5	1-L 8"x8"x¾" 2-Ls 5"x4"x11/16" 22.88□" Gr. 20.00□" Net 9" b to b Ls	-10.0	Ditto "	+16.8	1"○
38.668	12	-417.0	+365.0	Ditto	-2.5	4-Ls 3"x2½"x5/16" Sub Strut do 18" a to a	+17.8	1"○
44.016	13	-422.0	+360.8	Ditto	-5.5 +1.1	Ditto " "	+11.1	1"○
49.822	14	-427.4	+354.6	Ditto	-2.0	Ditto " "	+8.3	1"○
56.094	15	-431.7	+347.1	Ditto	-2.1 +3.1	4-Ls 3½"x2½"x5/16" Sub Struts do. Laced 18" a to a	+4.5	1"○
62.814	16	-435.2	+338.1	Ditto	-2.0	4-Ls 4"x3"x5/16" Sub Struts Do. Laced 18" a to a	+3.1	1"○
70.000	17	-437.7	+326.8	Ditto	-6.4	4-Ls 5"x3"x7/16" Sub Struts do Laced 18" a to a	+0.9	1"○

Masonry Reaction -442.9
Uplift on Anchorage + 299.0
Each Pedestal { 4, Anchor bolts 2" diam. upset to 2½" diam - 12.56□" Net
3022 cu. ft. (111.9 cu. yds) @ 150 lb. = 453,500 lbs.

Where foundation conditions require piles, use 30 piles, in 5 rows and 6 piles in each row, spaced 2'-6" x 3' c. to c. of piles. Load - reaction plus weight of concrete = 896,200 lbs = 448.1 Tons ÷ 30 = 14.94 tons per pile

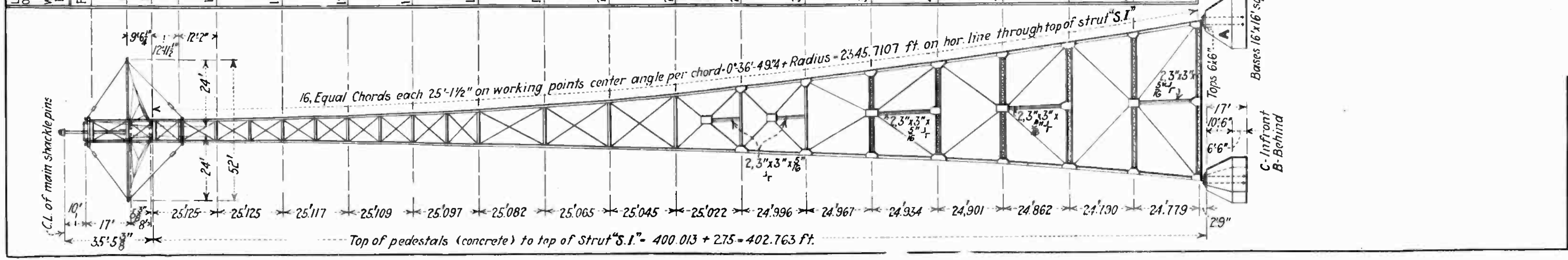
Note: All stresses given in thousands of pounds

Torsion:-	3 outside wires unbalanced	252,000 Ft. lbs.
Wind on tower:-	150 Lbs per vert. ft. of height	
Dead Load:-	Weight of material, Bridge and Tower	LBS. PER SQ. IN
Unit Stresses:-	Tension Axial	24,000
	Compression "	24,000 - 50 l/r
	Bearing on pins and shop rivets	32,000
	" " field rivets or bolts	25,800
	" " masonry	400
	Shear on pins and shop rivets	16,000
	" " field rivets or bolts	12,800
	Transverse bending on pins etc.	25,000 on extreme fibers

Material:- O.H. Steel for buildings, A.S.T.M. Standard specifications A.9-16

Protective Coating:- All parts of bridge to be galvanized by "Hot Dip" process Am. T. & T. Specifications and must stand 4 - one minute dips in cupric sulphate solution.
All other structural steel. Shop coat "Liquid Dutch Boy" red lead
Anchor bolts and reinforcing bars, Plain (not in structural steel contract)

Connections:- Rod diagonals; R & L. Threads on upset ends, with clevis nuts on cotter pins. Shop rivets ⅞" & ¾" Field bolts ⅞" & ¾" to be checked with chisel after tightening.



TROPICAL RADIO-TELEGRAPH COMPANY
400 FOOT SELF SUPPORTING TOWERS
With 150 Foot Antennae Bridges
STANDARD PLAN
Revised September 1922
Figure 27

FIGURE 27

had shown that a uniform load per ft. of height is as near to the probable actual load as any that can be devised with our present limited knowledge, and has the advantage of simplicity with many precedents in bridge specifications. For stiff bracing 180 lbs. per vertical foot (249 kg. per vertical m.) was found to give the equivalent loading per square foot for the Almirante towers.

As has been stated, the Swan Island towers and that at Cape San Antonio failed at about 100 ft. (30.5 m.) from the top, under a wind load very close to 50 lbs. per sq. ft. (245 kg. per sq. m.), as an average, uniformly distributed over 1½ times the area of the projected elevation of the section involved. Also that practically no damage was done to the lower 75 ft. (22.9 m.) of the towers; and that between 75 ft. (22.9 m.) and 150 ft. (45.8 m.) in height the destruction was caused by the stripping action of the falling tops. If these deductions are correct—and we have no better data—the loading adopted is safe and has been so proven to a considerable extent by the hurricane of 1921. Altho the specified loading is only equivalent to 43.2 lbs. per sq. ft. (212 kg. per sq. m.) on the area involved for the lower story members, it is considered safe since these members are good for 60 to 65 lbs. per sq. ft. (284 to 319 kg. per sq. m.) within their elastic limit. This area is over 1,500 sq. ft. (139 sq. m.) (extending 400 ft. (122 m.) vertically and 150 ft. (45.7 m.) laterally), nearly seven times that involved at the initial failure at Swan Island and five times that of the larger gauge at Forth Bridge, with outside dimensions ten to twenty times the latter. The maximum wind pressure assumed is double that of the highest recorded by Sir Benjamin Baker, who says, "The higher wind pressures come more in gusts than in even pressure extending over a large area," which should be given great weight until more comprehensive observations supersede it. With a double pressure it is reasonable to assume the wind more gusty, and the average pressure a smaller percent of the maximum. Also, with the much larger area and dimensions, this factor should be less. Therefore, instead of the average pressure on an entire 400 ft. (122 m.) tower being 2/3 of the maximum, it should be, in all probability, very much less. While we have designed the lower stories for an average pressure only 54 percent of the maximum, within the elastic limit they are good for about ¾ of the maximum, which is considered as large a factor of safety as is warranted, in view of the cost.

In sections where the highest recorded winds do not exceed 90 to 100 miles per hour (144 to 160 km. per hr.), loads of 40 lbs.

per sq, ft. (196 kg. per sq. m.) at the top with small areas involved, graduated down to 25 (123), or, for towers 600 ft. (183 m.) high and over, to 20 lbs. per sq. ft. (98 kg. per sq. m.) for the lower members will meet the average case. In many of these cases an ice load must also be provided for.

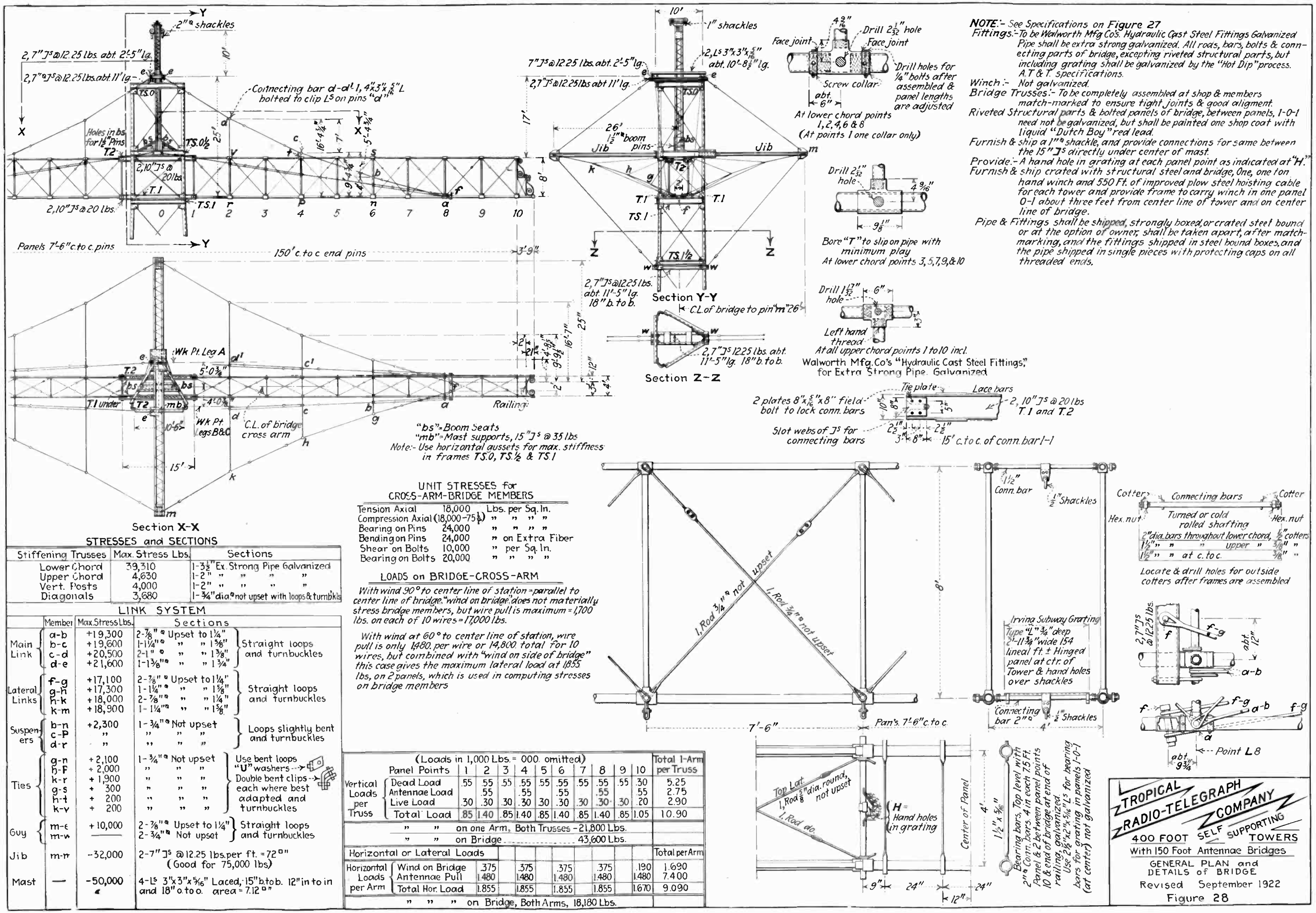
Where municipal building codes have to be complied with, some of which require absurdly low unit stresses for wind loads, something may be gained by absorbing the ice load in the excessive "safety factor."

WIRE PULL, TORSION, AND DIRECTION OF PULL

For wire pull on towers, wind and ice loads on antennas have been provided for by using the strength of the wires, these only being used to compute the sag required for the wires to take the loads. Where high unit stresses are used for the tower members the breaking strength of the antennas may be used, but where towers are designed with low unit stresses, as required by some building codes, the elastic limit of the antennas may be safely used for the maximum wire pull on tower, as the low unit stresses provide an ample margin for the excess load due to wires being pulled so taut as to develop their ultimate strength; but with high unit stresses, 24,000 lbs. per sq. in. (3.720 kg. per sq. cm.), caution should be used not to impair the margin of safety.

Some provision for future increase of wire pull may be advisable, as in the latest standard design of the Tropical Radio Telegraph Company, where an increase of 50 percent is anticipated. The wire pull used for tower design increased from 2,000 lbs. (920 kg.) in 1906 to 14,000 lbs. (6.350 kg.) in 1922, and 32,000 lbs. (14,500 kg.) has been used for high power, intercontinental stations. In one case a change in antenna plan increased the wire pull 30 percent before the towers were erected—an indication of the necessity for some margin in many cases. About the least margin should be to use the ultimate strength of the largest number of heaviest wires proposed at the time, which might permit 20 percent increase, assuming elastic limit at 2/3 the ultimate strength.

For torsion it is customary to consider an unbalanced load equal to the three wires nearest the end of antenna bridge as out. It is extremely improbable that more than three wires would go out on one side before any on the other side went out. To provide for an unbalanced load of all the wires on one side would require a wider top and add considerable to the cost. In the standard design, Figures 27 and 28, the top width has been in-



NOTE:- See Specifications on **Figure 27**

Fittings:- To be Walworth Mfg Co's. Hydraulic Cast Steel Fittings Galvanized Pipe shall be extra strong galvanized. All rods, bars, bolts & connecting parts of bridge, excepting riveted structural parts, but including grating shall be galvanized by the "Hot Dip" process. A.T & T. specifications.

Winch:- Not galvanized.

Bridge Trusses:- To be completely assembled at shop & members match-marked to ensure tight joints & good aligment.

Riveted Structural parts & bolted panels of bridge, between panels, 1-0-1 need not be galvanized, but shall be painted one shop coat with liquid "Dutch Boy" red lead.

Furnish & ship a 1"ø shackle, and provide connections for same between the 15"]s directly under center of mast.

Provide:- A hand hole in grating at each panel point as indicated at "H."

Furnish & ship crated with structural steel and bridge, One, one ton hand winch and 550 Ft. of improved plow steel hoisting cable for each tower and provide frame to carry winch in one panel 0-1 about three feet from center line of tower and on center line of bridge.

Pipe & Fittings shall be shipped, strongly boxed, or crated steel bound or at the option of owner, shall be taken apart, after match-marking, and the fittings shipped in steel bound boxes, and the pipe shipped in single pieces with protecting caps on all threaded ends.

STRESSES and SECTIONS

Stiffening Trusses	Max. Stress Lbs.	Sections
Lower Chord	39,310	1-3½" Ex. Strong Pipe Galvanized
Upper Chord	4,630	1-2" " " " "
Vert. Posts	4,000	1-2" " " " "
Diagonals	3,680	1-¾" diaø not upset with loops & turnb'kls

LINK SYSTEM

	Member	Max. Stress Lbs.	Sections	
Main Link	a-b	+19,300	2-⅞"ø Upset to 1¼"	Straight loops and turnbuckles
	b-c	+19,600	1-1¼"ø " " 1⅝"	
	c-d	+20,500	2-1"ø " " 1⅜"	
	d-e	+21,600	1-1⅜"ø " " 1¾"	
Lateral Links	f-g	+17,100	2-⅞"ø Upset to 1¼"	Straight loops and turnbuckles
	g-h	+17,300	1-1¼"ø " " 1⅝"	
	h-k	+18,000	2-⅞"ø " " 1¼"	
	k-m	+18,900	1-1¼"ø " " 1⅝"	
Suspenders	b-n	+2,300	1-¾"ø Not upset	Loops slightly bent and turnbuckles
	c-P	"	" " "	
	d-r	"	" " "	
Ties	g-n	+2,100	1-¾"ø Not upset	Use bent loops "U" washers Double bent clips each where best adapted and turnbuckles
	h-F	+2,000	" " "	
	k-r	+1,900	" " "	
	g-s	+300	" " "	
	h-t	+200	" " "	
	k-v	+200	" " "	
Guy	m-e	+10,000	2-⅞"ø Upset to 1¼"	Straight loops and turnbuckles
	m-w	—	2-¾"ø Not upset	
Jib	m-n	-32,000	2-7"]s @ 12.25 lbs. per ft. = 72□" (Good for 75,000 lbs)	
Mast	—	-50,000	4-Ls 3"x3"x5/16" Laced, 15" b. to b. 12" in to in and 18" o. to o. area = 7.12□"	

UNIT STRESSES for CROSS-ARM-BRIDGE MEMBERS

Tension Axial	18,000	Lbs. per Sq. In.
Compression Axial	(18,000-75 l/r)	" " " "
Bearing on Pins	24,000	" " " "
Bending on Pins	24,000	" on Extra Fiber
Shear on Bolts	10,000	" per Sq. In.
Bearing on Bolts	20,000	" " " "

LOADS on BRIDGE-CROSS-ARM

With wind 90° to center line of station = parallel to center line of bridge. "wind on bridge" does not materially stress bridge members, but wire pull is maximum = 1,700 lbs. on each of 10 wires = 17,000 lbs.

With wind at 60° to center line of station, wire pull is only 1,480. per wire or 14,800. total for 10 wires, but combined with "wind on side of bridge" this case gives the maximum lateral load at 1,855 lbs, on 2 panels, which is used in computing stresses on bridge members

(Loads in 1,000 Lbs. = 000. omitted)

	Panel Points	1	2	3	4	5	6	7	8	9	10	Total 1-Arm per Truss
Vertical Loads per Truss	Dead Load	.55	.55	.55	.55	.55	.55	.55	.55	.55	.30	5.25
	Antennae Load		.55		.55		.55		.55		.55	2.75
	Live Load	.30	.30	.30	.30	.30	.30	.30	.30	.30	.20	2.90
	Total Load	.85	1.40	.85	1.40	.85	1.40	.85	1.40	.85	1.05	10.90
" " on one Arm, Both Trusses - 21,800 Lbs.												
" " on Bridge .... 43,600 Lbs.												
Horizontal or Lateral Loads												Total per Arm
Horizontal Loads per Arm	Wind on Bridge		.375		.375		.375		.375		.190	1.690
	Antennae Pull		1.480		1.480		1.480		1.480		1.480	7.400
	Total Hor. Load		1.855		1.855		1.855		1.855		1.670	9.090
" " " on Bridge, Both Arms, 18,180 Lbs.												

TROPICAL
RADIO-TELEGRAPH
COMPANY
400 FOOT SELF SUPPORTING TOWERS
With 150 Foot Antennae Bridges
GENERAL PLAN and
DETAILS of BRIDGE
Revised September 1922
Figure 28

FIGURE 28

creased to 10 ft. 6 in. (3.2 m.) from 7 ft. 0 in. (2.1 m.) of the Tegucigalpa towers, Figures 23 and 24, principally on account of the greater torsion due to increase in size and arrangement of the wires. However, excessive torsional stresses will be relieved to some extent by the elastic twisting of the towers, so that they could not equal the stresses as computed by rigid statics. The elastic equilibrium between the twist of the towers and the sag, stretch, and pull of the antenna can be computed, but it is a tedious problem, and a small variation in the wires, their arrangement and initial sag, would entirely change the result and the computations would then be valueless.

Several devices have been designed to release an entire line of wires when a break occurs in any one span, which, were it safe to count on it always being maintained in working order, would permit a considerable saving in weight and cost of towers; but that seems a rather unsafe assumption, as it is so easy and simple for any one to make a wire fast at any time, and would require constant vigilance to make sure it was never done. The only safe assumption is to consider the antenna as fixed at each point of support.

With the ends of the antenna held by counterweights or supported from triatics (instead of antenna bridges), the maximum wire pull could be very greatly reduced. Such devices may be made reasonably secure against tampering, but the tower designer must take the antenna plan from the radio engineers, just as the bridge designer must use the rolling loads fixed by the locomotive and car builders.

Under maximum wind load the catenary of the antenna lies in a nearly horizontal plane, and the tangent to the curve at the point of support is the direction of the pull on the tower. For this reason, in a two-tower station, the apexes of the triangles should face each other, as this gives the most favorable distribution of loads on the legs of a three-legged tower. Altho some experienced engineers set the towers with the sides of the triangular cross sections facing each other, instead of the apexes, precise analyses show that such an arrangement increases the maximum compressive stress due to wire pull in the legs, in some cases as much as 20 percent.

With four-legged towers, however, the sides and not the corners should face each other for most economical distribution of compressive stresses in the legs, the difference being more pronounced than in three-legged towers and, therefore, a more important matter. In other words the stresses in three-legged towers are less sensitive to direction of wire pull, because, for one reason, even with the most favorable arrangement the maximum leg stress is a larger proportion of the total and, consequently, subject to less variation due to change of direction of wire pull; which is another point in favor of three-legged towers.

STRESSES, SECTIONS, AND DETAILS

The total wire pull and its direction having been determined, and also the resultant if the tower carries more than one span or set of antenna wires, a convenient method of stress analysis is to find the resultants of wire pull, wind loads on top story of tower, and wind loads on the antenna bridge if there is one, and then find the components of these resultants normal and parallel to the center line joining the towers, as shown in Figure 27. This must be done for several directions of wind, as no one direction will give the maximum for all members. The maximum wire pull due to wind occurs with wind normal to the axis of the antenna, but this will rarely give the maximum combination of simultaneous stresses in a member. For other wind directions the wire pull may be reduced by the co-efficients of direction.

In combination with torsion the total wire pull should be reduced in the proportion that the number of wires remaining in bears to the full number. The principal effect of torsion is on the diagonal rods in the upper stories where the lever arm of resistance is small. In the legs torsional stresses are not cumulative, but are balanced in each story.

In computing stresses, some prefer one method and some another. Those accustomed to analytical methods and the slide rule may find, as did the author, that it pays to compute an influence table for all members, or the stress co-efficients for unit loads, both at line of resultant of the top loads and for the center of action of wind on the part of tower involved for each member. If the method of moments is used, the lever arms may be found either graphically or computed from similar triangles by slide rule. It is necessary to find the stresses in the legs for at least two conditions to get the maximums of compression and tension. The maximum combinations of stresses from the several loads, which must be found, are somewhat complicated, so that. until one has computed a few similar towers, it may be necessary to try several cases to be sure of having the maximum combination.

The unit stresses used to fix the sections of tower members are specified in Figures 23 and 27, and those for the antenna bridge members in Figure 28. The latter are lower than those for the tower members for the following reasons: (1st) The bridge is subject to more sudden loading, being the first part of the structure to receive the wire load, in which there may be an element of impact. (2nd) It will be subject to heavy loading more frequently and is more liable to maximum loading than the tower members as its total loads are composed of fewer elements, while in tower members proper a full maximum load can only occur when three or four elements or conditions occur simultaneously with maximum wind—a rare probability. (3rd), and last, but not least, an excess wire pull will cause much larger proportionate excesses in stresses of bridge members than in tower members.

The unit stresses for tower members are justified by precedent, by many authorities and by the merits of the case: A base unit stress of 24,000 lbs. per sq. in. (1,710 kg. per sq. cm.) has been used for many years for the lateral wind bracing of highway bridges. It is permitted for wind loads by the building codes of several cities, including New York. It is now proposed for wind stresses in members carrying no load stresses (dead or live) for railroad bridges by the board of engineers of the American Institute of Steel Construction. Practically all stresses in both tower and bridge are due to wind and dead loads, the dead load stresses being only a small part of the total, particularly for the tower members.

The sections for the legs are built up of three angles, except those of the two top stories, and are economical and compact, with not too large area exposed to wind. This type of section is good for towers up to about 450 ft. (137 m.) in height designed for hurricane force, and for towers up to about 600 ft. (183 m.) designed for the ordinary wind loading of 30 lbs. per sq. ft. (147 kg. per sq. m.), average. Higher towers require sections of different design.

The sections of most all the horizontal struts are fixed by the ratio of slenderness (length divided by radius of gyration), those in the lower stories requiring sub-struts and hangers to reduce the unsupported length. In towers much exceeding 400 ft. (122 m.) in height, the economic width of base is too much for the economic use of horizontal struts, and for export work the members would be so long that shipping difficulties would be encountered. In such cases resort has been had to some form of "A" frame bracing, similar to that shown in Figure 32. Possibly a better, and certainly a more graceful solution of this problem would be a base section in an arch form, for which the gothic-lancet lines seem most adaptable. Such a solution, however, would require very painstaking work in detailing, to avoid fabricating difficulties and high cost.

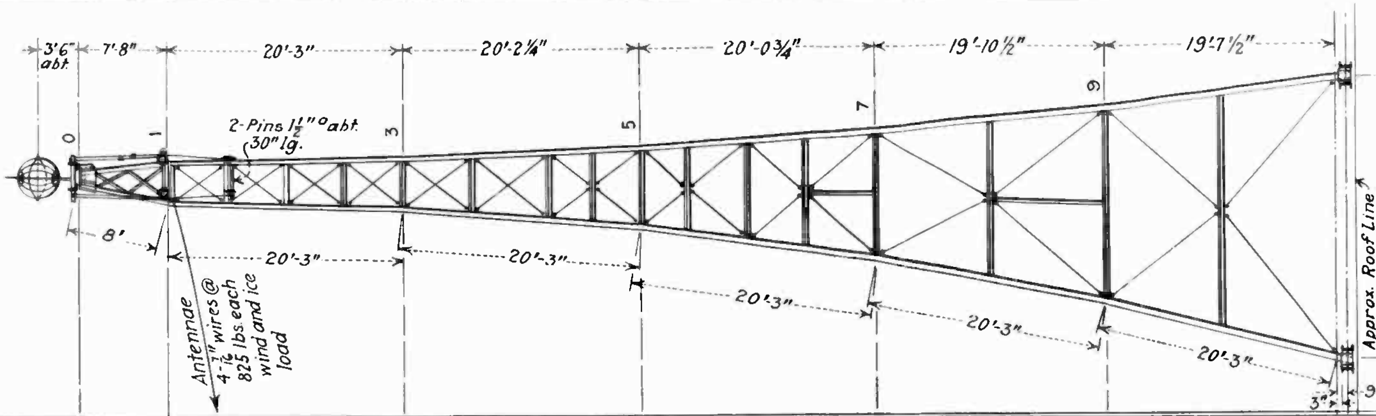
Figure 33 shows a plan proposed but never executed, for constructing reinforced concrete tower bases arranged as station buildings. The plan is not economical and is only available for locations where an architectural effect, with elaborate station buildings, are desired.

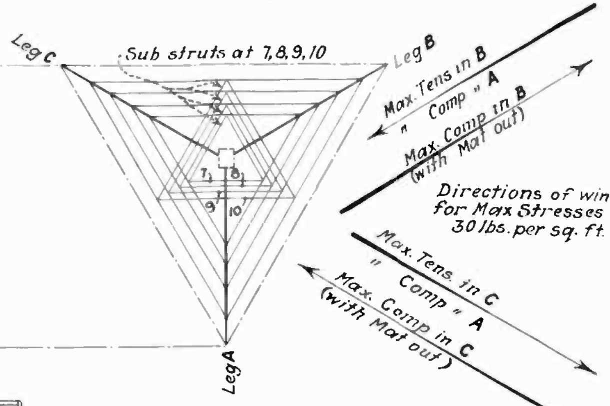
All details, even the minor ones, should receive the same degree of care and attention as the most important member, or satisfactory results and even safety will not be attained. The details of the anchorages, and the pin connections of the diagonals must be efficient and mechanically correct; splices must be centric and proportioned for the full strength of the members connected; and every detail must be planned with a view to facilitating the transportation and erection.

The diagonals have right and left threads on upset ends, with clevis nuts on cotter pins. Socket type safety set-screws in the clevis nuts serve to lock the rods after adjustment, as a precaution against the tendency of all maintenance men to screw up all slack rods, ignorant of the fact that some of the rods should be slack when there is any wind blowing, and to pull them up simply throws the tower out of line when the wind changes. It is a very difficult job, requiring an expert, to line up a crooked tower under wind—and the wind blows a stiff breeze most of the year in the trade wind belt.

Broadcast Station Towers on Buildings

Two pairs of 100 ft. (30.5 m.) towers for broadcast stations, designed on the lines of the Fruit Company's standard plan, have recently been constructed for the Radio Corporation of America, one pair in Washington, D. C. (station WRC), and one on Aeolian Hall, New York (stations WJY-WJZ), the latter shown with permission in Figure 29. The only feature of these broadcast station towers which departs from the lines already described is the base girder system, introduced to distribute the loads to the structural frame of the building. In the case of Aeolian Hall, an existing building, it was necessary to distribute the load on a number of columns to avoid reinforcing the latter down thru the building at a prohibitive cost. At first glance it appeared that four-legged, square base, towers would fit best on a building with rectangular bays, but the three-legged towers with triangular bases actually proved





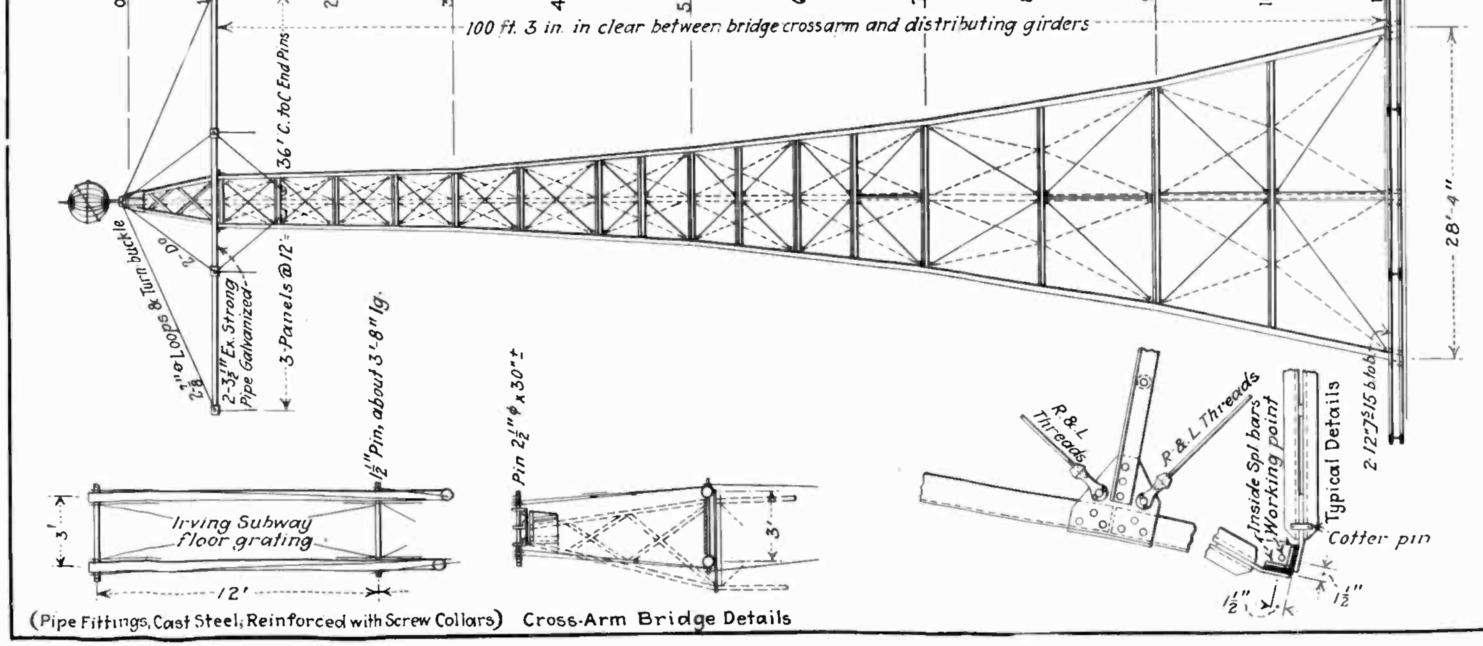
	LENGTH OF STRUTS ON WORKING POINTS	TOWER POSTS				STRUTS		DIAGONAL RODS	
		MAX. STRESS			SECTION AREA □" GR & NET "R"	STRESS M LBS	SECTION AREA □" / "R"	STRESS M LBS	SIZE NET □"
		LEG A COMP (1000's OF LBS)	LEGS B&C COMP	LEGS B&C TENS					
0	1'-0"						3-Ls-6"x4"x⅜"x20"Lg		1-Pin 2½"⌀x30"lg.
		+ 6.0	+ 6.0	– 5.0	1-L-2½"x2½"x¼" 1.19□"Gr. 0.75□"Net R-0.49	8.5	Cap Pl. 16"x⅜"x20", Ls 6"x6" & 6"x4"x⅜"-12 to 16" lg., 4-Stiff Ls-6"x6" & 6"x4"x⅜" abt. 16" lg		Pat Plt. 16"x5/16" 1-L-2"x2"x¼"
1	4'-0"	r=Res'lt wire pull. w=Wind on tower d=Dead l'd. stress t=Torsion on tower T=Total Stress				8.3	1-L-5"x3"x5/16"-2.4□" R=0.66 I=6.3 S=1.9 1-L-2½"x2½"x¼" 1.19□" R=0.49	12.30	1-1"⌀ 0.55□"Net
2		r. 13.4 w. 2.9 d. 1.1 t. 5.2 T. 22.6	— 5.1 1.1 — 6.2	-7.7 -5.1 +1.1 — -11.7	1-L-3"x3"x5/16" 1.78□"Gr. 1.16□"Net R-0.59	8.0 7.7 6.3	1-L Do 1-L Do. 1-L Do	11.79 11.33 10.90	1 Rod Do 1-Rd do 1-Rd.do
3	4'-11½"								
4		r. 17.1 w. 5.2 d. 1.7 t. 3.1 T. 27.1	— 9.4 1.7 — 11.1	-9.8 -9.4 +1.7 — -17.5	1-L-3½"x3½"x⅜" 2.48□"Gr. 1.72 Net R-0.69	5.3 4.7 Nominal 3.1	1-L-3½"x3½"x5/16" 2.09□" R-0.69 1-L- Do 2 Ls-3"x2"x¼" 2.38□" R-0.88 ⊓ ⅜" b.to b. 2-Ls do	8.90 7.85 7.02	1-Rod ⅞"⌀ 0.42 Net Do Do
5	7'-10"								
6		r. 16.0 w. 6.3 d. 2.5 t. 1.8 T. 26.6	— 11.7 2.5 — 14.2	-9.2 -11.7 +2.5 — -18.4	1-L-3½"x3½"x⅜" = 2.48□"Gr. 1.72 Net R-0.69	Nominal 2.6 Nom'l 2.4	2 Ls Do 2-Ls 3½"x2½"x¼" 2.88□" R-1.09 ⊓ ⅜" b.to b. 2-Ls Do. 1-L-3½"x3½"x5/16" 2.09□" R-0.69 Sub.Struts do	5.49 4.63	Do Do
7	12'-7¾"								
8		r. 14.0 w. 6.7 d. 3.5 t. 1.9 T. 26.1	— 12.7 3.5 — 16.2	-8.0 -12.7 +3.5 — 17.2	1-L-5"x5"x7/16" 4.18□"Gr 3.30□"Net R-0.98	Nom'l 2.4	2-Ls 3"x2"x¼" 2.38□" R-0.88 ⅜" b.to b.⊓ Sub-Struts do 2-Ls 3½"x2½"x¼" 2.88□" R-1.09 ⅜" b.to b.⊓ Sub-Struts do.	6.1' 3.92	Do Do
9	19'-4¼"								
10		r. 12.2 w. 7.8 d. 5.0 t. 0.8 T-25.8	— -14.9 5.0 — 19.9	-7.0 -14.9 +5.0 — 16.9	1-L 5"x5"x7/16" 4.18□"Gr. 3.30□"Net R: 0.98	Nom'l	2-Ls 4"x3"x¼" 3.38□" R-1.28 ⅜" b.to b. ⊓ Sub-Struts do	4.01 3.61	Do Do
11	28'-0"	28'4"							
		Vertical Reactions +24.5	+19.6	-16.4	5-¾"⌀ Tap Bolts 1.48□" Net	Hangers 6½-7 and 8-9 1-L 2"x2"x¼" Ladder Rungs on Leg A ¾"⌀-12" c.to c.			

Specifications:- N.Y. Building Code:-
Wind, 30 lb. on 1½ projected area of one side
Unit Stresses: Tens. 16,000 lb. per sq. in.
Cols 16,000 - 70 l/r
Pins and Rivets, Shear 12,000 Bearing 24,000
For wind stresses, 50% increase in the above unit stresses per □"

Overturning M ≈ 75% of moment of stability
Shop assembling of sides of towers will be required and field connections reamed and all members match - marked.
Field holes shall generally be reamed to 15/16" from 13/16" holes for shop rivets and bolts shall generally be 13/16" and 11/16" diam.

Specifications on sheet (2) shall apply to the material and work called for on this sheet so far as applicable.
Material. Am. Soc. for Test Mat'ls, steel for bldgs.
Workmanship, Am. R.E. Asso. Spec. of 1920 for punched work.

Globe 16 half hoops - 1¼"x3/16" galvanized 2-full hoops - after punched and assembled with galvanized bolts.
Details of globe all to be galvanized.



(Pipe Fittings, Cast Steel, Reinforced with Screw Collars) Cross-Arm Bridge Details

RADIO CORPORATION of AMERICA
100 Ft. Self-Supporting Towers
of
Aiolian Hall, New York
Broadcast Stations
W.J.Z. and W.J.Y.
Designed and Built, 1922
Figure 29

FIGURE 29

more adaptable. Each tower is supported on ten building columns, so that the load added to any one column was within the limits allowed by the code and regulations of the Building Department. Figure 30 is a view of the towers on Aeolian Hall.

FIGURE 30—Broadcast Central, WJY-WJZ, Radio Corporation of America, at Aeolian Hall, New York

The Washington Station presented quite different conditions. There the buildings were of reinforced concrete under construction and the columns were designed to carry four additional future stories—giving ample column capacity for the tower loads. Some complication was met with in the irregular dimensions of the bays and their skew of about 30 degrees due to the street angles. Here, also, the three-legged towers proved the more adaptable, but required a base width of 24 ft. (7.3 m.) instead of the 28 ft. (8.5 m.) base of the Aeolian Hall, New York, towers, where the building bays are 14 ft. 2 in. (4.3 m.) wide.

One of the Washington towers is carried by four building columns and the other by five, but not equally distributed as to loads. Three columns would have been ample for the loads of one tower, but their arrangement did not permit a symmetrical base. This was met by putting in distributing girders, resting on the building columns, and supporting the towers; the three points of support on the girders forming equilateral triangles.

While one pair of towers required a base width of 28 ft. (8.5 m.) and the other pair 24 ft. (7.3 m.), the leg sections are duplicates for all and were made from the same drawings and templates, which are also designed to serve for other 100 ft. (30.5 m.) towers with bases of 20 ft. (6.1 m.) and 16 ft. (4.9 m.) should they be required for other locations. Sixteen feet (4.9 m.) is about the economic width of base for three-legged towers 100 ft. (30.5 m.) high, considering the tower alone, but when it is necessary to fit the bays of a building and keep the loads on the columns down, it will generally be found cheaper to get the spread in the legs of the tower rather than to make the base or distributing girders excessively heavy.

For the tower itself, the economic width of base is that which makes the weight of the legs about equal to the weight of the bracing.

The antenna bridges of these broadcasts station towers are 36 ft. (11 m.) long and 3 ft. (0.92 m.) wide, formed of two lines of $3\frac{1}{2}$ inch (8.87 cm.) extra strong, galvanized pipe, connected together by Irving Subway Grating, and supported by truss rods to the top of the tower. The grating not only serves as a walkway, but also to take the shearing stresses due to wire pull and wind. The bridges on the Washington towers are set perpendicular to a side of the towers, making the antenna axis parallel to a side, which arrangement is not economic as it increases the stresses and sections of the front legs so that they have to be made specials and not duplicates of the other legs. It also increases the total weights somewhat, but it did not seem to be avoidable in this case on account of the skew angle of the buildings.

SEMI-GUYED TOWERS AND GUYED STEEL MASTS

The Swan Island towers as reconstructed and shown in Figure 5 are, in fact, semi-guyed or semi-self-supporting, but this plan was only adopted as an economic expedient for salvaging a considerable part of the old steel which had not been injured.

The question has been asked—are there any advantages in a semi-guyed tower for new construction? The answer, as a general proposition, is no; but there may be rare conditions where the relative costs of the several kinds of material and facilities for putting them in the work are exceptional, which might, possibly, give some advantage to such a design. The author, however, has yet to meet such a case. The first cost of the guys, if put into additional material in the legs, would make the towers nearly if not quite self-supporting and, moreover, the maintenance and renewal of guys is many times more costly than of structural steel members. Guys increase the number of parts and also require anchorages, and they generally have to be insulated. They occupy a larger ground area, and probably increase the absorption of power.

Economically the problem has no intermediate solution:—the only alternative to the self-supporting tower that has any advantage at all is the guyed mast, and the only advantages of the guyed mast are rapidity of erection and low first cost.

The United Fruit and Tropical Radio Telegraph Companies have a number of guyed steel masts in service. Figure 31 is a view of the New Orleans station, showing four guyed steel masts. Maintenance records show that, in the tropics, guys require renewal about every five years, and that after the second renewal the cost is more than the self-supporting towers. It has been stated that, in dry climates, a set of guys is good for eight years. If these estimates are correct, the self-supporting tower is the cheaper after ten years in the tropics and after sixteen years in dry climates.

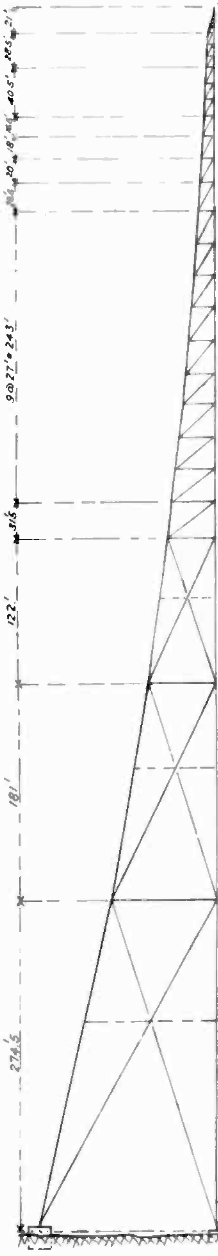
Disadvantages of guyed masts, in addition to the greater cost of maintenance, are: greater area of ground required; absorption of power by the guys, even when insulated; and impossibility of attaching an antenna bridge. Often, therefore, two guyed masts are required to do do the work of one tower.

DESIGN FOR 1,000 FOOT (305 M.) TOWER

Figure 32 shows a design for a tower 1,000 feet (305 m.) high, which, however, was not built. It was proposed for three-tower stations, with the antennas supported on messenger cables and equalizing bridles in place of spreaders, with a maximum wire pull of 40,000 lbs. (18,400 kg.). With this layout, there would always be compression in the front leg and tension in the rear legs except when the mat might be blown out, in which case there would be no wire pull. This condition of stress distribution, requiring especially heavy sections for the front leg—the main compression member—suggested the attempt to introduce in a self-supporting tower the mast element, substituting stiff legs for guys. The front leg, as shown in the figure, is a straight, vertical line—the most favorable for a heavy compression member, other things being equal (which generally they are not), and the rear stiff legs are subject to tension only when under full load, and therefore require only sufficient compressive strength to hold the tower when the mat is out. The rear, stiff legs are curved to reduce the weight of the bracing, and to add flexibility to the tower.

FIGURE 31—STATION OF THE TROPICAL RADIO TELEGRAPH COMPANY AT NEW ORLEANS, ERECTED 1914

The plan worked out well on paper, the weight estimate showing it to be very economical in material, but it will probably never be used in just this form, since the antenna lay-out which led to it has been superseded, and also because no two members in such a tower could be made duplicates except the rear leg sections and some of the diagonals, and of these there would only



Length of Struts	[illegible]	Front Leg Stress 1000 Lbs	Back Stays Stress, 1000 Lbs. Mat Up	Back Stays Stress, 1000 Lbs. Mat Down	Diagonals Stress in 1000 Lbs	Struts Stress in 1000 Lbs.
5.0	0	Horizontal Mat Pull, Ice and Wind, 40,000 Lbs, Maximum Resultant				
5.52	1	−71.8	+0.0	7.5	+44.3	1.0
6.05	2	−127.3	+53.8	−8.7	+46.3	−3.1
6.57	3	−176.5	+106.6	−12.9	+43.8	−5.1
7.31	4	−239.2	+153.2	−19.0	+53.2	−7.3
8.06	5	−295.0	+211.9	−30.5	+51.6	−9.8
8.80	6	−346.6	+262.9	−44.4	+50.3	−12.2
9.71	7	−404.6	+308.4	−60.5	+55.4	−14.8
10.70	8	−464.3	+358.6	−81.8	+60.2	−17.4
11.87	9	−524.1	+411.7	−106.8	+61.9	−20.0
13.35	10	−586.7	+458.8	−135.7	+64.6	−22.3
15.21	11	−661.9	+503.9	−171.1	+66.9	−26.1
17.22	12	−710.4	+548.2	−210.7	+64.4	−28.1
19.40	13	−764.9	+585.3	−248.1	+63.4	−30.6
21.74	14	−812.6	+613.9	−284.6	+59.6	−33.1
24.24	15	−860.3	+634.8	−314.3	+61.9	−36.3
26.91	16	−896.6	+652.3	−347.7	+63.2	−38.1
29.74	17	−943.0	+662.7	−374.8	+66.9	−39.8
32.72	18	−983.9	+676.5	−406.0	+67.2	−41.7
35.88	19	−1023.7	+685.6	−430.3	+68.4	−43.3
38.76	20	−1067.2	+692.4	−457.1	+73.5	−40.6
	21					
56.89	22	−1226.3	+679.8	−201.2	+162.8	−71.1
	23					
88.36	24	−1452.0	+675.3	−597.2	+190.8	−88.8
	25					
(150.0)	26	−1792.3	+644.8	−711.2	+208.0	

Notes

WIND LOAD
40 Lbs. Per Sq Ft on Mat.
180 Lbs Per Vert. Foot of Tower

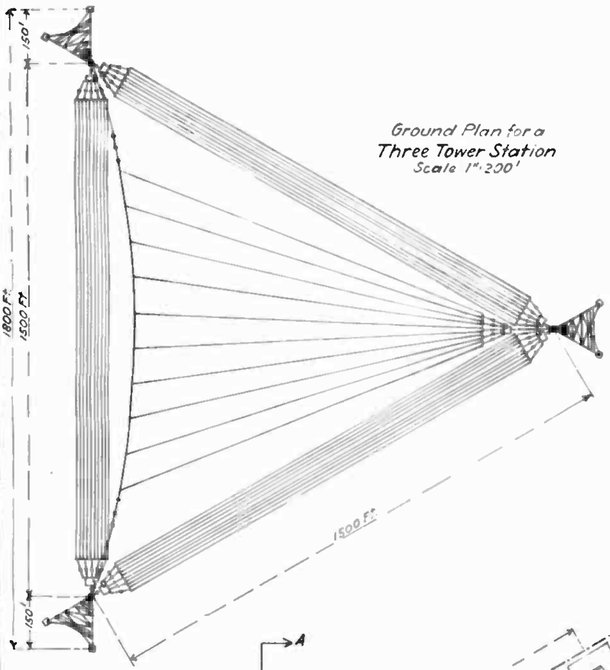
DEAD LOAD
Weight of Steel in One Tower 1,370,300 Lbs.
Weight of Mat., on Each Tower, 7320 Lbs.
(Which is ⅓ Total Weight of Mat.)

N. B. DEFLECTION of Towers Under Wind and Ice Loads Computed by Formula

$$\Sigma p\mu l \div E$$

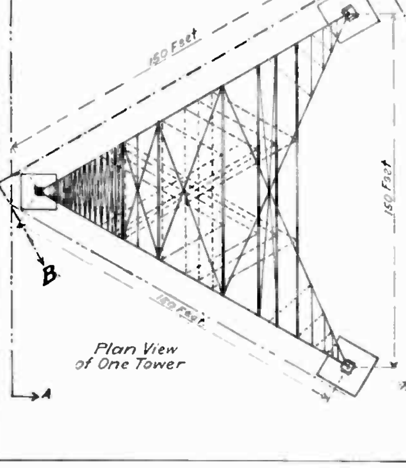
and Resulting New Sag of the Antennae and Messenger, to Find Maximum Horizontal Pull

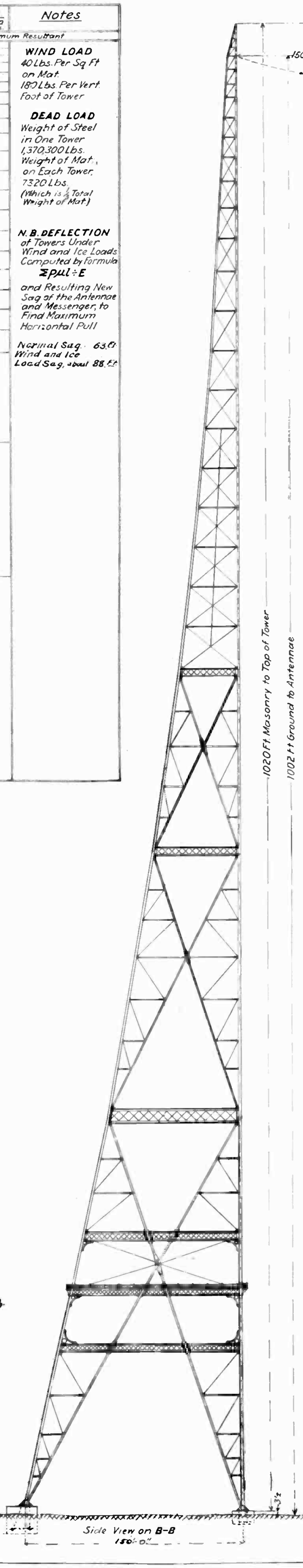
Normal Sag 63 Ft
Wind and Ice Load Sag, about 88 Ft


Ground Plan for a Three Tower Station
Scale 1"=200'

Design of 1000 Feet
Self Supporting Steel
RADIO TOWERS

Designed by
A W Ruel
May 4, 1916


Plan View of One Tower


Side View on B-B

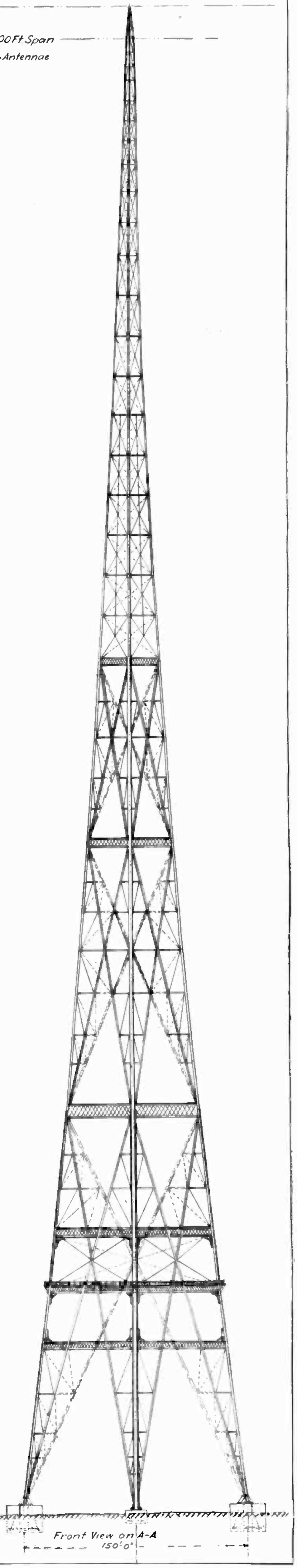

Front View on A-A

FIGURE 32

be two pieces alike in a tower, thus greatly increasing cost of fabrication.

The photographs of the Swan Island wreck of 1916 were taken by Mr. H. O. Easton, Superintendent, Radio Department, United Fruit Company, whose comprehensive selection of views, with his report on the wreck, made possible the studies of wind pressure in hurricanes.

Lieut.-Col. W. P. Rothrock, Member of the American Society of Civil Engineers, assisted in the analysis of the 1916 wreck, superintended the erection of the Almirante, Panama, and the Tegucigalpa towers, and suggested a number of improvements in details which make for efficiency and facilitate erection.

The fabricators and their engineers have given fine co-operation in solving problems of details and construction. Included in the list are Baltimore Bridge Works (now Carnegie Steel Company, Baltimore Warehouse); Virginia Bridge and Iron Company; Fort Pitt Bridge Works; Dietrich Brothers, Baltimore, Maryland, and the McClintic-Marshall Company (Riter-Conley Manufacturing Company).

CONCLUSION

In conclusion it may be stated that nothing has been added to any of the towers described in this paper for the purpose of producing effects or pleasing appearance, except the skeleton globes on top of the 100 ft. (30.5 m.) broadcast station towers of the Radio Corporation of America, which globes are practically that corporation's trade mark. The observation platform and railing at the 150 ft. (46 m.) level on the design for the 1,000 ft. (305 m.) tower has a self-evident purpose. Neither has line or form been influenced by any consideration except the requirements of the mathematical statics and economics of the problems, save for the scroll railing braces at the ends of the antenna bridges.

In the preliminary design of the 150 ft. (46 m.) antenna bridge, the ends were shown cut off square at the panel point, the blunt appearance of which drew a criticism from Mr. Davis. who asked if something could not be added to improve it. The author's reply was that he had tried several ways to improve this, each of which only made it worse, and that nothing could be added which lacked an obvious purpose without detriment to appearance. Up to that time, the railing braces seemed to serve no useful purpose, but when worked out in detail it was evident that a man fixing the end antenna would be in a difficult and dangerous position without these braces. Therefore the lower chords were extended 3 ft 9 in. (1.15 m.) beyond the panel point to support a two foot (0.65 m.) extension of the walkway and braces to a railing around the end. The scrolls in the railing braces are a conventional and common treatment of this detail. In Figure 26 a man may be seen sitting on the end railing.

The appearance of these towers has been commended by many people of taste, including some architects. This is greatly appreciated but, if it is merited, it should be credited entirely to the effect of the theorem that a structure designed by the rules of statics and economics, if the solution is truthful, will conform to all the rules of aesthetics, and vice versa. It is hoped that the discussion of this paper will throw more light on these points, which are generally better understood by European than by American engineers, and full and free criticism is therefore invited.

SUMMARY: This paper is an historical review of the United Fruit Company's Radio Towers, and describes the origin of a 1906 design for 200 ft. (61 m.) towers; of 50 ft. (15 m.) extension added in 1910; of the hurricane wrecks of 1914, 1915, and 1916, of data deduced from them, and of the reconstruction of the towers. It discusses the effect of a new policy that "radio communication should be made so reliable that, when all other means fail, the public can confidently look to the radio stations to maintain service, which can be done if only the towers remain standing."

The preliminary designs for three-legged towers made in 1915 are described, and their economy and advantages as compared with four-legged towers, the saving due to adjustable rod bracing and the low cost of shop work effected by making all leg sections equal short chords of a circular arc, are pointed out.

The design of the Tegucigalpa (Honduras) towers, with antenna bridges and the latest revised, "Standard Plan of 400 ft (122 m.) self-supporting towers, with 150 ft. (46 m.) antenna bridges," are shown with the specified loads, unit stresses, and notes on the most favorable direction of wire pull in relation to cross-section of tower. The design of sections and details are briefly referred to, with the limiting heights of towers to which similar sections are applicable.

Two pairs of 100 ft. (30.5 m.) broadcast station towers of the Radio Corporation of America are illustrated, and the methods adopted to distribute the loads to the building frames are described.

The economic comparison of semi-guyed towers and guyed steel masts with self-supporting towers is discussed, and the preliminary design for a tower 1,000 ft. (305 m.) high is shown.

In conclusion, the theorem is proposed that the truthful application of the laws of statics and economics will yield aesthetic results in tower design, and vice versa, and the bearing of this theorem on the appearance of the foregoing towers is given.

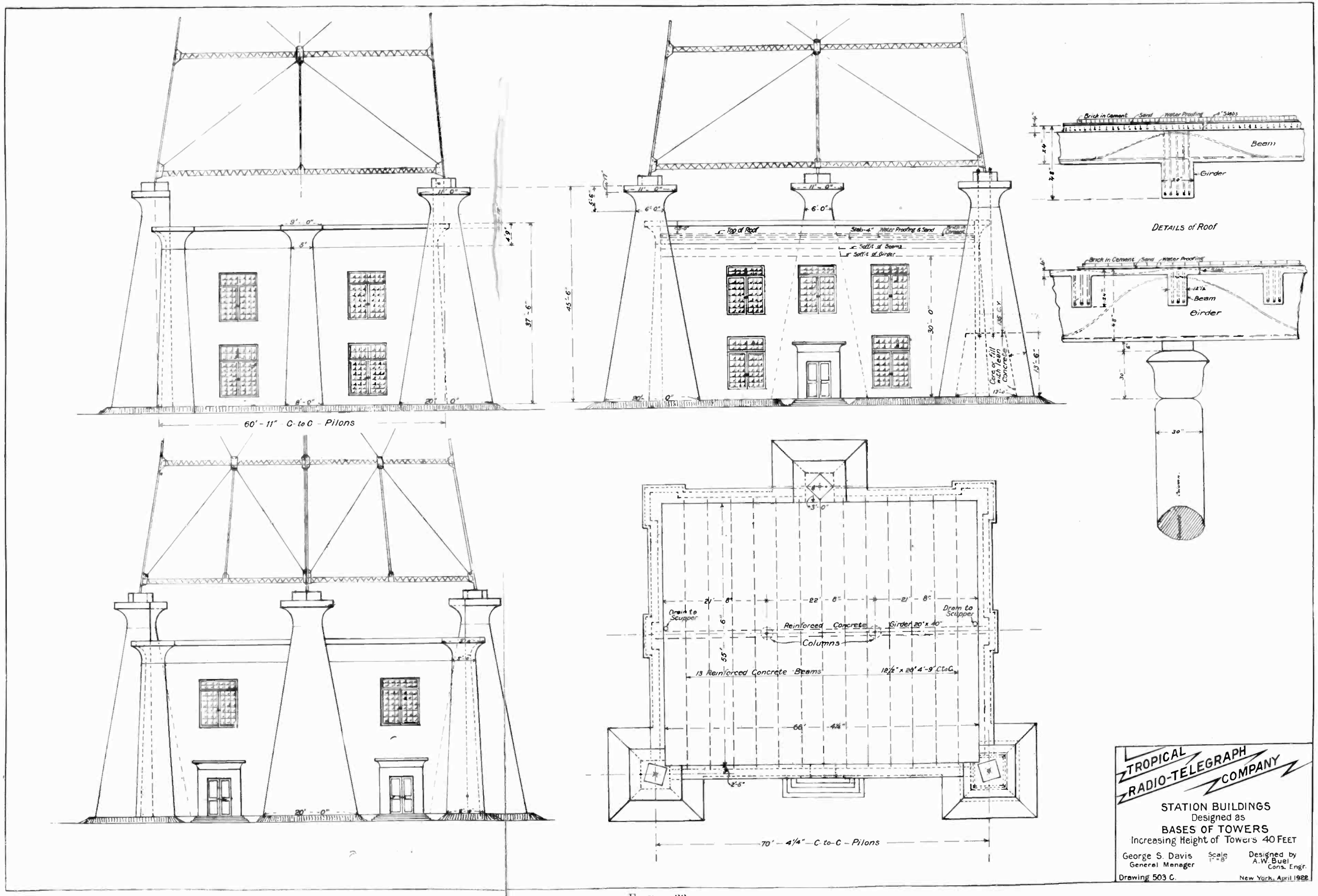

9'-0"
5'
4'9"
37'-6"
11'-0"
6'-9"
20'-0"
60'-11" C-to C - Pilons
5'-6"
11'-0"
6'-0"
6'-0"
45'-6"
Top of Roof
Slab-4" Water Proofing & Sand
Brick in Cement
Soffit of Beams
Soffit of Girder
30'-0"
135 C.Y.
Core of fill with lean Concrete
13'-6"
13'-0"
20'-0"
Brick in Cement
Sand
Water Proofing
4" Slabs
Beam
Girder
24"
48"
20"
DETAILS of Roof
Brick in Cement
Sand
Water Proofing
Slab
12½"
Beam
Girder
6"
30"
30"
Column
3'-0"
21'-8"
22'-8"
21'-8"
Drain to Scupper
Drain to Scupper
Reinforced Concrete Girder 20"x 40"
Columns
55'-6"
13 Reinforced Concrete Beams 12½" x 20" 4'-9" C to C
66'-4¼"
2'-5"
70'-4¼" C-to-C - Pilons
TROPICAL RADIO-TELEGRAPH COMPANY
STATION BUILDINGS
Designed as
BASES OF TOWERS
Increasing Height of Towers 40 FEET
George S. Davis
General Manager
Scale 1" = 8'
Designed by
A.W. Buel
Cons. Engr.
Drawing 503 C.
New York, April 1922

FIGURE 33

DISCUSSION

Robins Fleming (by letter):[*] Mr. Buel has presented a valuable paper on the design of self-supporting radio towers that must withstand high wind velocities. The detail and thoroughness with which he has treated the subject make the paper one that will long be turned to for reference. Some comments may be in order, even if at times they dissent from the opinions of the author.

Since the pressure of wind varies as the square of its velocity, the pressure from a velocity of 140 miles per hour is 1.96 times that fron a velocity of 100 miles and 2.4 times that from a velocity of 90 miles. From the well-established formula $P = 0.004\ V^2$ the respective pressures on vertical surfaces from horizontal winds of 140, 100, and 90 miles per hour are 78.4, 40, and 32.4 lbs. per sq. ft. But the actual velocity is less than the indicated velocity with a corresponding reduction in pressure. (The velocities recorded and published by the United States Weather Bureau are those indicated by a Robinson anemometer, not the actual). Again, average pressure on large areas are less than those on small areas. On the other hand, the published maximum velocities are those maintained for periods of 5 minutes duration, but for shorter periods, say for a minute, these velocities may be exceeded. The writer considers the 30 lbs. per sq. ft. of exposed surface which he has recommended for towers not over 300 ft. high to be sufficient when the indicated wind velocity does not exceed 100 miles per hour. For triangular towers the area of exposed surface is assumed to be 1½ times and for square or rectangular towers two times the vertical projection of one face. For the upper parts of towers more than 300 ft. high, 2½ lbs. is added for every 100 ft. additional height. For towers within the hurricane belt these pressures would be modified, probably near to those used by Mr. Buel.

A working stress of 24,000 lbs. per sq. in. net tension is used by Mr. Buel against the 20,000 lbs. of the writer. This is not excessive for high wind velocities tho there is little left for emergencies. A decided objection, however, is raised against the use of the compression formula: $24{,}000 - 50\ l/r$. On a basis of 24,000 lbs. for tension the widely-used formula $16{,}000 - 70\ l/r$ becomes $24{,}000 - 105\ l/r$. Mr. Buel cites for justification of his use of 24,000 lbs. for tension the specifications of the American Institute of Steel Construction. According to these same speci-

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[*]Received by the Editor September 5 1923.

fications the formula for compression due to wind pressure would be $\frac{24,000}{1+l^2/18,000\,r^2}$. The respective values obtained by the three formulas for $l/r=1,000$ are 19,000, 13,500, and 15,400; for $l/r=140$ are 17,000, 9,300, and 11,500; for $l/r=160$ are 16,000, 7,200, and 9,900. It is believed that the values obtained by the Buel formula are excessive and should not be used.

The discussion of square versus triangular towers will be left to others. The triangular towers weigh less, but most structural firms will quote a price for fabrication and erection that will more than offset the saving in weight, especially if the towers are of the outlines shown in Figures 23 and 27. Just here a tribute is paid to Mr. Buel for the graceful outlines he secures. Will the additional expense warrant him in so doing? His 350- and 400-ft. towers are not in New York or Boston, but at Almirante and Tegucigalpa.

Mr. Buel advocates the use of rods instead of angles for diagonals in the faces of towers. It is true he thus reduces the area exposed to wind, but he encounters serious difficulties in erection. The rods must be adjusted and he writes—"it is a very difficult job, requiring an expert, to line up a crooked tower under wind—and the wind blows a stiff breeze most of the year in the trade wind belt." From the hazardous nature of the work the only "experts" available are the workmen engaged in the erection of the towers. However skilled some of these men may become, it may be questioned whether they are ever able at a height of two or three hundred feet to tighten some rods and leave others slack so that when the wind reverses, the tower will not be thrown out of line. With angle diagonals no adjustment need be made and a tower can be kept plumb as it is erected. Angles are not as liable as rods to be bent in transportation and handling and have greater rigidity when in place.

It should also be noted that the stresses in rods are indeterminate, owing to the initial tension brought upon them in their adjustment. An initial tension of 3,000 lbs. on a rod 1 in. diameter under the thread adds a stress of 3,800 lbs. per sq. in. of sectional area. The total stress is thus brought to 27,800 lbs. per sq. in. if the rod is designed for 24,000 lbs. per sq. in. The initial tension also causes additional stresses in columns and struts.

Mr. Buel favors painted instead of galvanized towers. He states. "The cost of maintenance covering a period of fifteen years shows that frequent painting is cheaper than galvanizing."

A difference of opinion exists on this subject. A letter, before the writer, from another designer of radio towers reads, "The cost of repainting these radio towers in the field from time to time is such that the galvanized are much preferable and more economical." As the cost of painting high towers is quite formidable there will probably be a tendency to neglect it, thus furthering corrosion.

The use of Irving Subway grating for walkway floors and galvanized pipe for compression members in suspended cantilevers is novel and unique.

The writer thoroughly agrees with the author in what he says regarding the superiority of self-supporting towers over semi-guyed towers or steel masts.

The thanks of structural engineers are due the author for including in his paper brief descriptions of the broadcast stations on Aeolian Hall, New York City and on a reinforced concrete building, Washington, D. C.

In conclusion, the behavior of the United Fruit Company's towers during the next ten years will be watched with interest.

R. D. Coombs, M.A.S.C.E. (by letter):* Mr. Buel's paper is a valuable contribution to the somewhat meagre literature on a most interesting field of engineering, as well as an expression of practices in a new part of that field—the radio tower. The general field embraces transmission line towers and radio towers, the difference between these classes being that the usual transmission tower is not a dead end structure while the radio tower is even normally a dead end for part of its load.

In this general field the designer must depart from the shelter of the usual working stress or factor of safety and work thru a more logical and professional analysis of the actually expected loads and the practicable unit stresses. He must also very clearly set forth just what load conditions are economically justified and must realize that the usual handbook unit stesses are not for him. The designer of towers may not take refuge behind an assortment of hidden factors of safety or relief on the imaginary factor of safety of four of the usual building codes.

In most steel construction the wind load is not given much active consideration. The assumed live and dead loads may be so great that the structure can carry a very considerable wind load, provided the other loads are not all present. Or with small dead and live loads the structure might simply be unable to carry

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*Received by the Editor, September 12, 1923.

the usual wind loads and would probably never receive them.

In towers, however, the wind load is of the most inportance both in its direct effect and as greatly increasing the pull of conductors, antennas, and so on.

Further, since the designer knows that some time the tower will receive a wind load of considerable amount, the question is as to the amount to be provided for in this event. Is it the greatest recorded pressure in that locality, or more to provide for contingencies, or less to allow for probability of occurrence some five, ten, or more years hence?

The author's examples are believed to be unique as scattered installations deliberately calculated to withstand "hurricane" pressures. The apparent procedure of determining the greatest wind reasonable for the installation in question and then providing a known, or closely known, factor of safety in the unit stress alone is to be commended.

The author's examples of failures are amongst the few service failures of larger towers of which much is known. It is unfortunate that except in tower tests the actual loads are never known because there is never any accurate measure of the wind load that was imposed on the structure.

In the writer's opinion the formula used by Mr. Buel for the ultimate stress, $44{,}000 - \frac{l}{r}$, is about as accurate for towers as indicated by the data available. The writer would, however, question Mr. Buel's bolt values, which seem to be relatively low.

It would appear that painting every two years does not indicate a very dry climate, and the writer is not prepared to admit that 1/16 inch (0.16 cm.) of steel is as good protection as a film of zinc—provided the film is continuous.

The author is requested to enlarge on the question of lock washers versus finger-loose nuts in view of the difficulty of access to such high structures.

The writer is aware of the opinion and practice of the average field crew regarding washers and that most of the transmission towers have none, but is not sure that lock washers may not be a good investment.

The use of rod bracing for such structures appeals to the writer as logical, but involves careful erection since it is very easy to build a "wind" into a tall tower. The writer's company has designed and built both rod-and angle-braced towers of medium height, about 150 feet (45.7 m.), and have believed that the rod-braced were not commercially economical for such heights. Rods commend themselves from a wind pressure, and maintenance painting standpoint altho thought to be noisy and difficult of erection.

Referring to the Swan Island towers, were they not relatively weak in the upper half? The parabolic outline, also used by the writer, will produce a graceful appearance and a very gradual decrease of main leg stress, so that the upper half may readily be kept below the stress of the more usually critical sections. In this connection it may be noted that the technical press recently illustrated, but without descriptive detail, a tall tower on the Rhine that indicates a reversed parabola, convex outward, and a far from graceful outline.

George A. McKay (by letter):* 1. The article prepared by Mr. Buel is a most valuable contribution to an important branch of structural engineering. As in all special branches, progress is marked by steady growth based on past experience, and Mr. Buel, in putting into print the record of his achievements, has enabled the engineering profession in general to benefit thereby.

2. The Bureau of Yards and Docks of the Navy Department, which has the responsibility for the design and construction of all radio towers for the Navy Department, started in 1912 with towers of square cross section, installing one 600-foot (183 m.) and two 450-foot (137 m.) towers at Radio, Virginia. These three towers were developed to withstand a wind pressure of 30 lbs. per square foot (147 kg. per sq. m.) over one and one-half times the projected area of one side in accordance with the usual viaduct practice, and in addition to the wind load, a pull of 10,000 lbs. (4,600 kg.) from the antennas. In May, 1913, however, when the 600-foot (183 m.) radio towers for Darien, Canal Zone, were being designed, it was decided to adopt the triangular cross section type of tower, principally on account of the economy thus effected. It will be noted from the above that the adoption of the triangular cross section by the Bureau antedated its adoption by the companies representated by Mr. Buel.

3. A number of triangular towers, ranging from 150 to 820 feet (45.7 to 250 m.) in height, have been erected in the past 11 years by this Bureau in latitudes varying from south of the equator to Alaska, and these towers have been subjected to hurricanes and ice loads. The Bureau has yet to record a single failure.

4. An interesting comparison exists in the fact that the

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*Received by the Editor, September 12, 1923.

Bureau's standard design for 200-foot (61 m.) towers weighs approximately 13 tons (11,800 kg.) on the basis of a triangular cross section, whereas the 200-foot (61 m.) square towers which collapsed, as mentioned in Mr. Buel's paper, weighed 22½ tons (20,400 kg.), or approximately one and seven-tenths times as much as the Bureau type.

5. An examination of Mr. Buel's original design, indicated on Figure 1, before the towers were strengthened, indicates that the rivets in the splices for the main column sections at Panel *P* were considerably weaker than the columns themselves, considered either in tension or compression. The method of connection of the diagonal rods to the struts is also subject to criticism. In addition to this, the use of ordinary bolts, with possible line bearing instead of bearing over the semi-periphery, would also militate strongly against the towers withstanding abnormal loadings.

6. The Bureau adopted in May, 1914, in connection with the radio towers for New Orleans, rod bracing instead of stiff bracing, in order to reduce the superficial wind area, and has retained this detail for all towers constructed since that date. It is to be noted from examination of the Bureau's drawings that the details of the connections of the diagonals to the main columns are such as to practically preclude torsional or bending stresses in riveted connections.

7. It is sincerely to be hoped that the publication of the article by Mr. Buel, with comment by various engineers thruout the country, will give designing engineers, generally, the necessary data to develop satisfactory designs for future towers which the progress of radio communication will demand.

Schuyler B. Knox, Member American Society Civil Engineers (by letter):* The fixed, triangular type of radio tower construction has advantages over a greater-sided system in its better resistance to deformation thruout its height and the saving in weight of steel by the elimination among other things of at least a column leg and the horizontal sway-bracing at panel points. Also one should not overlook the less number of masonry pedestals required for column leg footings.

In the case of high structures designed to carry wind loads of great intensity even in our temperate zone, the designer is to be commended for his employment of tension rods on which the exposed wind surface is one-half, or less than one-half, that

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*Received by the Editor, November 14, 1923.

of angle diagonals of equivalent cross-sectional area. The materials used in the "bridge" construction at top of the tower also present a minimum surface exposed to wind action.

By reducing exposed surfaces in the very high radio towers in localities subject to violent hurricanes, Mr. Buel has solved the problem economically, for in this way he has lessened the amount of steel required to resist the intensity of wind stresses in legs and web members without changing the strength of the structure or causing additional cost in the aggregate over square and other types. The higher unit cost of fabricating due to adjustable, upset rods, including pins, clevises and "safety" set-screws is generally offset by the smaller total tonnage in the triangular type structure.

In the fabrication of the 350-ft. (107-m.) triangular towers for the United Fruit Company's Almirante Station, Panama, for which the Fort Pitt Bridge Works (with which the undersigned is connected) had contract in 1920, no difficulty was experienced in the shops, due to co-operation between the engineers and the fabricator in the matter of details and determining methods for handling. Both towers were assembled at the shop, lined up with transit, adjusted, and match-marked while so assembled. In this position the adjustable rod diagonals were fixed in length by keying the clevises with "safety" set screws so that no variation would be possible after the work was knocked down, thus insuring greater accuracy in plumbing during erection. The members were then separated and packed for shipment.

Quoting from Mr. Buel's report of one of those conferences: "Since tensile and compressive stresses in legs are nearly equal, and as bolts at splices must take all tension and as end bearing is unreliable owing to flexure of tower and angles and might set up very objectionable eccentric or bending stresses in the leg sections, it was agreed to put 100 percent field bolts in all splices and leave joints ¼ inch (0.64 cm.) open—same as established practice with hip joint in bridge chords."

While the fabrication costs per unit weight of steel may be higher than for other forms of towers, the saving in the number of masonry footings, the less number of, and lighter weight of members, not to mention the lightness and appropriateness of the "bridge" at the top of the towers, tend towards making the total cost of installing this tower, from a purchaser's point of view, as low as, if not lower, than for many other forms. Mr. Buel's design is scientifically developed.

Reginald A. Fessenden (by letter): Mr. Buel's paper is very interesting and valuable, and puts radio tower construction on a sound footing.

The three-legged tower with pin connection is undoubtedly the right type. Anything which concentrates the material into few and large pieces minimizes the effect of corrosion and saves a great deal more steel in the end, and adds greatly to reliability, which is, of course, the main thing. And with the wind whipping the towers about the way it does, there is great danger, in a four-legged tower, of getting very concentrated stresses at certain points, which will not occur with a three-legged pin-connected tower.

About corrosion, two things occur to me. First, what would be the comparative costs of one of the new non-corrosive chrome steels compared with standard material? Possibly much too high; yet a comparison would be interesting.

Second, what would be the effect of always keeping the tower hydrogen polarized to ground? Possibly nothing; and yet I have found that corrosion increases very much faster when oxygen polarization is superimposed upon alternating current flow, and of course one gets this alternating current flow from the radio sending. So there might be some good effect with hydrogen polarization.

The curved legs are a fine idea, and it is well worth knowing that it can be carried out in practice with so little expense.

Can Mr. Buel tell us if there would not be some advantage in using isolated guy wires between the towers themselves, so all would act as a unit. I note he refers to the loss from eddy currents in the towers themselves and in long guys, but this can be got over very easily by slipping very small coils of a few turns of soft iron or nickel steel wire over the guys or tower members. This has the same effect as putting in insulators, so far as eddy currents are concerned, and without any of the expense or bother. See United States patent 706,746, "Wave Chute," August 12, 1902.

The fact that the foundation can settle with the three-legged type without hurting anything is very important, and they are also better for twisting stresses. In this connection, any concrete foundation pillars should have the reinforcement arranged for twisting stresses, as these may be very bad in earthquakes. Another good point which strikes me is the adjustable tension rods.

About the wind stresses, has any one tried making these measurements on different shaped elements while mounted on an aeroplane? It would look as if this would be a very simple way, and the models or full-sized cross section members could be made of wood. On the Brant Rock tower I used a fine wire of gold, with one-half of it mounted in a thin metal tube and the other in the wind, and a tap from the center, and found how much current must be passed thru the outside half to make it the same resistance as the shielded half. This gave me the instantaneous wind velocity, as it responded in about one-tenth of a second. If made recording, this might be useful for getting maximum gust velocities.

I certainly like the appearance of the towers. They look like something. It will not be long before we have one million volt transmission lines, and Mr. Buel has shown us that it is possible to get something which will not disfigure the landscape.

Jacob Feld, 1077 East Twelfth Street, Brooklyn, New York (by letter):* The author is to be congratulated for his very clear and instructive presentation of a comparatively recent type of structure which the engineer is called upon to design. Much more can be learned from a description of a failure with a careful analysis of the causes than from the usual account of a successful (or rather, untested) structure. From this point of view, this paper is especially valuable.

The predominating characteristic of self-contained radio towers are their flexibility. As Mr. Buel has pointed out, the deformation of the tower relieves the tension in the antenna by decreasing the chord length of the antenna wires under wind-load. It is noteworthy that there is only an increase of 17 per cent over the dead load tension, when the antenna is exposed to maximum wind. This requires considerable deflection of the towers, introducing a rather complicated stress distribution in the legs of the tower. The relieving effect of the towers permit considerable sag of the antenna wires (in the direction of the resultant of wind and dead load). The changed geometrical shape of the antenna has some effect upon the electrical characteristics of the system. The writer hopes that the discussion will bring out an explanation of the magnitude of this effect, and what limits are permissible. It seems to the writer that too much deflection causes trouble electrically as well as structurally.

The description of the mast shown in Figure 5 is especially instructive and emphasizes some of the usual rules for economical

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*Received by the Editor, December 13, 1923.

design of structures. The mast was strengthened by the addition of two guys placed at 30° to the vertical. It would have been more economical to have increased this angle, requiring, of course, a longer guy and more room, but decreasing the effect of the guy upon the tower and increasing the beneficial effect of the guy in taking wind loads. The tower failed because of the absence of windward supports after the antenna broke from the mast. This points out an important feature—the necessity of symmetry in supporting a tower subjected to a wind force from any direction and the necessity of observing the fundamental principle of making each unit of a structure self-supporting.

In the case under consideration, Mr. Buel states that no guys were permitted inside the quadrant covered by the antenna. That did not prevent the placing of a system of four guys at 90° to each other, or three guys at 120° to each other. In either way, wind from any direction can be taken care of. A careful analysis, too lengthy for this discussion, will show that the three-guy system is more economical, as far as weight is concerned, but not so rigid as the four-guy system. A tower or mast with three main legs, or triangular in section, naturally lends itself to simple connection details for the three guys; similarly for the four guys with a square tower. The writer was very much astonished to see the description of the tower which failed after the antenna gave way. It is the basic idea of design to make, in as far as possible, each section of a structure self-dependent for its stability. It seems that a radio system should consist of a stable tower or mast, which in addition to being capable of holding up itself and any loads which may act upon it, can also resist certain external forces caused by the antenna.

An almost analogous case is the usual bridge design: a substructure, self-supporting, with additional stability to hold up the superstructure. Certainly, no one would think of designing a bridge so that, should the superstructure fail, the substructure was no longer stable.

Mr. Buel describes how a tower was increased in height and exposed to a greater antenna pull without strengthening and without informing the designer. Unfortunately, this state of affairs is very common. The radio engineer must remember that a design according to specifications, in order that it be economical, is made to withstand safely the loads specified, and no more. If the radio engineer continues to increase the loads upon the towers, failures are certain to occur. Perhaps some simple method of rating the towers, according to their excess stability, will help prevent the overloading of towers.

It is interesting to note that the towers failed in the panel just below those which had been reinforced by the substitution of "K" bracing for the flexible tie-rod bracing. This is an example of the very frequent error made in strengthening a structure by increasing the stiffness of assumed or tested weak points, thereby making certain isolated portions more rigid than the rest. An accurate analysis is tedious, but it may be stated without computation that the transmission of stresses across the section between two portions of unequal rigidity causes some extremely localized summations of stress. This has been very clearly pointed out in the recent researches on the transmission of stresses along cracked and punctured members. Sudden changes in section of the tower as a unit, as well as of the individual legs and secondary members must be avoided. This is especially true for high members affected by relatively high bending and twisting moments.

The author is to be congratulated for his clear description of the advantages of the three- over the four-leg towers. The writer questions the advisibility of using bent plates and curved legs with such high unit stresses, 24,000 pounds for tension and $24{,}000-50\frac{l}{r}$ for compression. Even tho the torsion is taken into account, some allowance must be made for the secondary stress and the reversal of stress. The writer is fully aware of the high unit stresses under which transmission towers have failed when tested to destruction. The only justification for such high unit stresses is the rather high unit pressures assumed for the specified wind velocities. Mr. Buel uses a conversion formula, the relation between wind pressures and velocity, which is probably at least 20 percent excessive.

The use of rods for wind bracing in place of stiffer sections is certainly desirable, because it eliminates so much wind load. It must be remembered, however, that one stiff diagonal will replace two rods in each panel, so that the saving is not so large as it seems at first glance. The main advantage is in the smaller exposed wind area, especially since the effect on a cylindrical rod is less than on a flat surface. The writer believes that we can go one step further and, where possible, use steel wire rope for the tension members. It would hardly be possible to use wire strands for the bracing in the towers, but it certainly can be used for the ties connecting the ends of the antenna bridge with the mast. Initial tension can easily be provided for stiffness, and, in place of the upset rods which are liable to bend and twist under high wind, a lighter and stronger steel strand can be used. The saving may be small if figured by weight, but the leverage is large and every square inch of exposed area at that height counts. The chief advantages of the wire rope are the high allowable unit stress and the safety from bends.

With such small ratios of base width to height, it is especially important that there be no unequal settlement of the footings. The writer would like to know whether Mr. Buel has noticed any trouble from this source and how he prevents it.

The author's statement that the maximum stress in the antenna can be controlled by attaching the antenna to a counterweight is noteworthy. Such devices have been used in several tower designs, especially those of foreign types. This method relieves some of the antenna pull upon the tower and decreases the deflection under wind load, but it increases the vertical load upon the tower.

It seems to the writer that Mr. Buel has not fully appreciated the value of guys. With the high unit stresses allowed, they form most efficient tension members, both from the point of view of economy in weight and because they are less affected by wind. Not only are they thinner than the stiff members, but the unit pressure of wind upon a circular rope or rod is also less than the unit pressure upon a flat surface. Mr. Buel's objection to guys on the ground that they do not last is not substantiated by experience with wire cables and strands in suspension bridges. The suspenders of the Brooklyn Bridge are in very good condition. The wire ropes removed from the old Niagara suspension, after 50 years of service, were remarkably unchanged. As far as maintenance is concerned, Mr. Buel points out that the steel of the towers must be painted on the average of every two years. Of course the use of guys necessitates land areas, but radio stations of great heights are seldom located in districts where land is expensive, and it will be found that the percentage of increase in the land required is small, even tho the actual area may seem large.

Albert W. Buel (by letter):* Mr. Coombs questions the bolt values used for the designs shown, which, he says, "seem relatively low." These were adopted to permit the use of rough bolts, not turned, and also to provide for the reversals of stress—the ten-

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*Consulting Engineer, 29 Broadway, New York. Received December 15, 1923.

sion running as high as 90 percent of the compression in some leg sections.

Spring lock washers have given some trouble by breaking and dropping out. Moreover, it is thought that the plates will be gripped more tightly without them and, after all, the frictional grip should not be neglected. The nuts are gone over, tightened, and checked with a chisel after erection and periodically thereafter. Very little trouble has been reported.

Rod bracing will not show much economy in towers much under 200 feet (61 m.) in height, but for the higher towers the saving is as much as 20 percent in weight. By adjusting the rods at the shops the towers can readily be erected out of wind.

The Swan Island towers were weak in the upper half, particularly between O and R, about 100 feet (31 m.) below the top, due to the insertion of the 50 ft. (15 m.) extension, T-10 to T in Figure 16, without reinforcing the members below. There was originally some excess section in the legs at some stories, but this is often unavoidable in light compression members where practical considerations are given due weight.

Mr. Fleming says the tensile unit stress used for the later designs (24,000 lbs. per square inch, against his 20,000 lbs.) "is not excessive for high wind velocities." It is not clear to the author what wind velocities have to do with unit stresses, nor why 24,000 lbs. per square inch is not just as good where the loads and stresses are computed for 90 or 100 miles per hour wind velocity (if such is the maximum anticipated for the locality), as where hurricane velocities have to be provided for. By using the maximum probable loads we make reasonable provision for "emergencies," as far as is economically justified, and avoid the confusion of loads with unit stresses. Then and only then can unit stresses be considered on their own merit.

The compressive unit stress used ($24{,}000—50\ l/r$) is two-thirds the ultimate strength of long columns as shown by the studies that have been made of the most recent tests. ("Transactions American Civil Engineers, volume LXXXIII, pages 1583 to 1688 and 1960.) While the results of these tests showed variations of 15 to 20 percent above and below the mean values, it is not thought that such extreme values are truly representative of these tower legs, and that the Tetmajer formula ($44{,}000-162\ l/r$), which gives 27,800 pounds per square inch for $l/r-100$, is nearer the correct value for these sections.

The higher values of l/r mentioned by Mr. Fleming occur only in struts where the sections are not determined by stress, but by limiting values of l/r, and the column formula does not apply.

Mr. Fleming says of three-legged towers: "most structural firms will quote a price for fabrication and erection that will more than offset the saving in weight, especially if the towers are of the outlines shown in Figures 23 and 27." The only additional item of cost of the three-legged feature is the 15 degrees bend in the gusset plates, of which each tower of Figure 27 has 144. About 200 such plates can be bent cold on a bending machine in eight hours, at an outside cost of $50.00, or $36.00 per tower. Each tower weighs 246,000 pounds, while a four-legged tower on the same specifications would weigh about 25,000 pounds more, at an additional cost for "freight or boat" shops of about $1,750.00, showing a net saving of $1,714.00 for the three-legged feature, without considering freight and erection. Freight charges would be about 10 percent more for the four-legged tower, and, in erection, there would be about one-third more members to handle and set and connections to make than there are in the three-legged tower. Erection equipment has been worked out avoiding interference with sub-struts, and the like.

If by "outlines" Mr. Fleming refers to the curve, of which the leg members are short chords, the only cost of this feature is that the gusset plates require a special lay-out and template at each story. There are six duplicate plates of each pattern in a tower and the last order was for eight towers, giving 48 duplicate plates from each template. Surely, with such duplication, the extra cost of layouts and templates could not much exceed $50.00 per tower.

Mr. Fleming intimates that appearance is wasted in "Almirante and Tegucigalpa," but might be warranted in "New York or Boston." On the contrary, the author is inclined to reverse that idea where the countries are of Latin extraction and civilization. But it should be noted that the curved outline has real and practical advantages on the side of economy which determined its adoption, and that its appearance was only a by-product.

The difficulty of adjustment of rods in the field is overcome by setting them to calculated lengths and locking them with safety set-screws at the shops. Very little adjustment has to be done after they are erected in place. The initial tension in rods does not act to increase the total maximum stress unless it is greater than the stress from loads.

Mr. McKay says that "the Bureau (of Yards and Docks) has yet to record a single failure," and his next paragraph sets up a comparison which is misleading and not based on the facts stated in the paper. No failure has yet occurred in any tower designed by the author except where the 50 foot extension was added by others and the wire pull increased from 2,000 to 7,000 pounds, without increasing or reinforcing the sections below, and without consulting the designer. Excluding the shoes and anchors, the original towers weighed only 20 tons. Mr. McKay gives the estimated weight of the Bureau's 184-foot design for comparison with the original 200-ft. design described in the paper. Moreover, while the Bureau's design specifies "minimum thickness of material 5/16 inch. except as shown," the webs of the channels composing the legs for the lower 178 feet of the 300-foot design are under ¼ inch thick—under 7/32 inch for two stories—and the same is true for the main struts up to 116 feet above the base, and the main connections are on these thin webs. Such sections are theoretically economical and permit much longer unsupported lengths with fewer struts and diagonals, showing a very large saving in weight, but leave small margin for deterioration by corrosion. Such thin webs are weak links which, in the author's opinion, should be used only for temporary work or where conditions are most favorable for protection. Laced channel columns, with flanges turned in, are much more expensive to fabricate than the sections shown in the paper, and, as has been noted, final costs and nor weights alone should be compared to determine relative economy. The original 200-ft. design had single angle legs, so much cheaper to fabricate compared with the sections used by the Bureau, that weight alone loses significance. The design was modified in some details to suit a certain shop with limited facilities, to which the order was allotted, which explains the economical diagonal hitch used. It has served its purpose as most of the original towers are still in service, but in all later designs an improved connection has been used, with small eccentricity and no tension on bolts or rivet heads.

Figure 1 shows the top of tower four feet square, providing for considerable resistance to torsion, but adding considerably to weight and cost as compared with the Bureau's design with its top only about seven inches on centers of gravity of the angles and negligible resistance to torsion. Where loads, specifications and details are so different, comparisons of weights are likely to be misleading.

The author has made designs for towers 600 ft. and 1,000 ft.

high, for loadings similar to those used by the Bureau, from which the interpolated weight of an 820-ft. tower is only 350 tons as against 560 tons, the estimated weight of the Lafayette Station towers on the Bureau's design, as given by Mr. D. Graham Copeland. This shows a saving in weight of 37.5 percent with the Bureau's design.

Estimated weights from the design in Figure 19 are, for a 240-ft. tower, 26 tons, and for a 300-ft. tower, 37.5 tons, which give when reduced to the Bureau's loadings, 17.25 tons and 25 tons, respectively, as against 19 tons and 30 tons from the Bureau's design. This indicates a saving of 10 to 16 percent, notwithstanding Figure 19 shows a top width of seven feet compared with the seven inches of the Bureau's design.

The photographs of the wrecks show that all splices and connections held, confirming out judgment that the bolted connections were properly proportioned. Practically the bolts by friction, and theoretical bearing and shear do not act until slipping takes place. When and if bearing comes into play, the theoretical line contact is enlarged, elastically, as has been conclusively shown in the case of locomotive drivers on rails.

Commenting on the discussion by Mr. Knox, credit for the method of locking the adjustable rods with safety set screws and for a number of tower details is due to the Fort Pitt Bridge Works.

All details and connections of the walkway grating on the bridge were developed by the Irving Iron Works Company.

Professor Fessenden asks for comparative costs of non-corrosive alloy steels. About two years ago the author made some inquiries along this line with discouraging results. The tonnage of single orders has not yet been sufficient to warrant the use of alloy steels with the delay in deliveries which would probably ensue. These preliminary inquiries indicated that the cost would be excessive.

The nearest approach to a system of towers guyed to each other, "so that all would act as a unit," are the four Swan Island towers connected by two messenger cables and the antennas—see Figure 5. Unless outside guys are added, as at Swan Island, the connection between the towers is of small advantage, as the windward tower receives no support. The paragraphs on semi-guyed towers seems to apply to this case.

Professor Fessenden's suggestion that concrete pedestals should be reinforced for the twisting stresses due to earthquakes, deserves careful consideration. The pedestals of Las Vacas

Viaduct went thru the four severe shocks and many minor shocks of December, 1917, and January, 1918, which were of several different types, without any reported injury.

The Bureau of Standards has made many tests or experiments on wind pressure in wind tunnels, which, altho not directly applicable in cases of tower design, are instructive and helpful.

Referring to Mr. Feld's discussion, it is important to note that only with messenger cable or triatic systems is the wind increment in wire pull as low as 17 percent of the dead load pull, and tower deflections are not unprecedently large. If "rather complicated stress distribution in the legs" refers to secondary stresses due to deflection, the author considers that they are considerably less than in cantilever bridges, and a remark made in a similar case by that eminent bridge engineer, the late Paul L. Wolfel, "it is an elastic structure and will take care of itself," seems applicable. Under wind loads the antennas blow out of line, which may be objectionable, but the maximum sag is fixed at the minimum at which the strands will carry the loads. A "T" system, with anchored downleads, holds them nearer in line. The economical angle of guys—45 degrees—compared with that of Figure 5, would not have saved over $110.00 for the four towers, and other considerations favored an angle of about 30 degrees. At that time guys were not considered permissible except in the outside quadrant, and not near the mat rectangle. They were used only as an expedient to salvage the undamaged parts of the towers, and six years of service, during which they resisted a severe hurricane, has justified their use. Considering the history of Swan Island Station, it is not quite clear to the author at just what Mr. Feld was "astonished."

Mr. Feld is right as to the effect of the "K" bracing in story P-Q in principal, but they were additional reinforcement—not a "substitution," and it is important to note that they did not tie into the upper intersection at "Q," but left an unsupported length of 3′ 6″ for the 4″ leg angle. Also that stories M-N-O-P and Q-R-S-T were nearly as weak and, after P-Q was reinforced, they were the critical ones. As one of the towers failed in story Q-R, above the "K" bracing, the influence of the latter could not have been very great except to prevent failure from occurring in story P-Q. Quite likely this was sufficient to cause two towers to fail in O-P instead of in M-N, as might have been expected. (Since they were generally reinforced from G to T, they have behaved very satisfactorily in a severe hurricane.) The only importance this now has is the effect on the author's computations of probable average wind pressure at the instant of failure due to neglect of secondary stresses. but this error is on the side of safety and less than the limit of accuracy assumed for the method. The wind pressure adopted from these studies is considered safe, but not excessive for that locality.

Mr. Feld says "one stiff diagonal will replace two rods," but the slenderness ratio would then require sections for diagonals heavier than the horizontal struts, excluding a single system of bracing with reverse stresses from serious consideration. The substitution of wire rope for tension members, which he suggests, would require the fabrication to be split up between structural shops and wire mills. Even with pin-connected, adjustable rods and pipe frames for antenna bridges, several large fabricators have not considered the work very desirable, and it is considered preferable to simplify and standardize rather than to introduce new complications which might prove very costly, altho invitations have not yet failed to get several satisfactory proposals. Inquiries for steel guy lines, protected and wrapped like the cables of large suspension bridges, have not found any manufacturer equipped to supply them. Increases in vertical loads within reasonable limits would not cause proportional increases in total stresses, as the wind stresses are the larger component, and vertical loads increase resistance to overturning.

Mr. Feld says "it is especially important that there be no unequal settlement of the footings." With four-legged towers such settlements would be serious, but with three-legged towers the only effect would be to throw the tower out of plumb, and very considerable inequalities in settlement of the three pedestals would have to occur before the stability would be in danger or the stresses dangerously increased. On the other hand, a very small inequality in settlement of a pedestal of a four-legged tower might increase stresses to the point of failure, especially in the diagonals.

The author thanks all contributors to the discussion, especially for analytical and critical comments, which have helped to clear up some points and to direct attention to others that might have remained obscure.

FURTHER DISCUSSION
ON
"AN IMPROVED SYSTEM OF MODULATION IN RADIO TELEPHONY*

BY

CHARLES A. CULVER

R. A. Heising (by letter):† In looking over Mr. Culver's paper entitled "An Improved System of Modulation In Radio Telephony," I find a few points on which I differ from him. The system which he describes is not new to us because of its having been previously disclosed by Lockwood and Beauvais, as he mentioned, and also because it was independently invented by Mr. L. J. Sivian of this Company in 1917 or 1918. At that time, Mr. Sivian made a study of the system and his results did not show the system to be quite such a favorable one as Mr. Culver claims. Mr. Sivian tried out, not only the specific form which Culver showed, but numerous modifications of it. The best one of these modifications compared favorably with the constant current system as regards efficiency and completeness of modulation, but in some other respects it was inferior. Its greatest defect was that it had a curved control curve which would indicate that considerable distortion would occur in process of modulation. This curvature was such as to give distortion considerably greater than that in the constant current system. The system also would work with only certain tubes. One requirement was a high amplification constant. It also appeared to work better with tungsten filament tubes, that is, with tubes which did not operate with a wide margin of temperature saturation. In many of the circuits which he tried, difficulty in adjustment was encountered. In order to make the control curve as straight as possible, specific adjustments had to be made which made it more difficult to operate or manipulate than some other circuits. He felt, at first, that he had found a system which was superior to any others, as has Mr. Culver, but after an exhaustive

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*See PROCEEDINGS OF THE INSTITUTE OF RADIO ENGINEERS, volume 11, number 5, October, 1923.

† Received by the Editor, September 12, 1923.

study of the subject, he came to the conclusion that, in almost every respect, it was considerably inferior to what we were using.

As regards modulation in general, there are a few points which I think would be worth while to emphasize. One of these is that whatever the modulation system, the over-all efficiency depends largely upon the efficiency of the generator of radio frequency power. A study of this efficiency over the power range that the generator operates during the modulation cycle will usually show where any shortcomings lie. If we do this for a system in which the antenna resistance is varied to do the modulating, we find that the efficiency drops to such low values and for such periods as to render such a modulation system no more efficient, and usually less so, than our present types. This is particularly true in vacuum tube oscillator or amplifier generators. The efficiency of any vacuum tube generator is high only when the impedance attached to the plate circuit is greater than the output impedance of the plate circuit. Varying the antenna circuit resistance will cause this attached impedance to vary. Since reasonable modulation cannot be secured unless the antenna resistance varies over a wide range, the attached impedance will vary over a corresponding range. It happens that reasonable modulation will not be obtained unless such a range extends on both sides of that value which corresponds to the condition for delivering maximum power and it will be found that on one side the efficiency will be so low as to result in a lowered over-all efficiency of the system.

For high efficiency in a vacuum tube generator, it is not sufficient to maintain the impedance of the attached circuit at a value equal to or greater than that of the tube, but the tube must also be operated at approximately full power. The reason for this is easily deductible from the principles pointed out by Professor J. H. Morecroft in his "American Institute of Electrical Engineers" paper of 1919. He shows that the losses within a power tube can be kept low only when the alternating potential of the plate approaches the direct potential in magnitude. Therefore when a vacuum tube is operated in any manner whatsoever so as to reduce the ratio of alternating voltage on the plate to direct voltage, the efficiency will drop. Any method of grid control or antenna resistance variation cannot but help reduce this ratio, and the efficiency of the generator will fall to such a value that the over-all efficiency of the set will, at the best, be the same as that of the constant current system, if not falling much below. This element in operation is fundamental in Mr. Culver's circuit, and, reasoning from that premise, I would say, without ever trying out the circuit, that its over-all efficiency could not be greater than that of existing systems.

This leaves, of course, only two ways for securing high efficiency in the generation of modulated power. One is always to operate the vacuum tube at full power, keep the impedance of the attached circuit at a large and fixed value and to do the modulating by varying the plate voltage. This keeps the efficiency of the generator up during almost the entire modulating cycle, especially during that part when very large power is being delivered. It is the method which is made use of in the constant current system. The other method is to vary, in some way or another, the coupling between the vacuum tube and the tuned circuit, keeping at all times the coupling above the amount necessary to give maximum power. That is, the coupling should be varied between the limits of the maximum power value and infinity. The variation of any constant in the generator circuit other than the coupling between these limits, will cause a reduction in efficiency during part of the cycle which will reduce the over-all efficiency to an undesired low value.

Another point on which I do not agree with Mr. Culver is the magnitude of the non-signaling current. The strength of a received signal is dependent, in the average detector, upon the magnitude of the variation of the antenna current and not upon the non-signaling current at all. It makes no difference whether the non-signaling current is *A* or 2 *A* as Mr. Culver mentions. In the constant current system the non-signaling current is *A* and the variation is 2*A*. His method of operation is to make the non-signaling value 2*A* and the variation 2*A*. By making the non-signaling value 2*A*, he does not contribute in any way to the loudness of the signal, but does waste more power in the oscillator tubes than it is necessary to do.

In any kind of a system the tubes must be built to produce an antenna current of 2 *A* amplitude. If a given number of tubes are provided and all tubes are used as oscillators, we can assume that at the voltage they are operated at, say 1,500 volts, they will give an antenna current of 2*A*. If this adjustment is for maximum power, than there is no possible method of control operating upon the oscillator circuit (other than plate voltage control), which will cause these tubes to give more than 2*A* current, and the modulation must be entirely downward, which is the way I understand Mr. Culver intends to operate. If, however, we should take one-half of these vacuum tubes and adjust them for maximum power on the same voltage, this number of tubes will give one-half the power that all would give, but half the power would be 0.7, the current that all would give. Under ideal operating conditions with one-half as oscillators in the constant current system and the other half as modulators, the non-signaling value of the current would, therefore, be 0.7 of 2*A* and the maximum current would approach twice that or 1.4 of 2*A* or 2.8*A*. This indicates that at a given voltage with a given number of vacuum tubes, the constant current system can produce in the antenna a greater variation in antenna current than where all are used as oscillators. In order to get the same power into the antenna with all tubes as oscillators, it will be necessary to increase the voltage on them by a factor between 1 and 1.4 or we would have to raise the voltage nearly to 2,100 volts, and then in order to prevent over-heating of the tubes we would have to adjust our modulating device so that the non-signaling current would not be 2.8*A*, but would be 1.4 *A*, the same as with the constant current circuit, and we find ourselves with no advantages but with a disadvantage of requiring a higher plate voltage.

In comparing his set with some other set, Mr. Culver ties his comparison to the fact that the non-signaling power to the antenna in all these cases is supposed to be 500 watts. In the sets manufactured by the Western Electric Company to give a non-signaling value of 500 watts, approximately 1,000 watts are delivered to the oscillators, 450 to the modulators, and something under 200 to all of the speech amplifiers. This, of course, includes filament currents. The oscillators deliver a steady power of 500 watts to the antenna, but under the condition of maximum modulation, the radio frequency power reaches a value close to 2,000 watts. In Mr. Culver's arrangement, the 500 watts is the maximum delivered to the antenna under any condition, so that as a matter of fact, the two sets should be compared on the basis of 2,000 to 500 rather than considering them equal power sets. Instead of showing his system to be an improvement, the total power consumption would indicate the reverse. Actually, however, the system which he describes can be adjusted so that it would not show his system up to as great a disadvantage as the preceding would lead one to believe. Under the very best conditions, he could secure equivalent power efficiency, but would have the disadvantage of having somewhat more distortion as well as requiring a higher plate voltage if he used tubes having the same constants.

Quoting distances over which a set or a system has been heard gives no reliable information regarding the efficiency of a modulation system. Many people, for example, in the vicinity of New York write that they listen regularly to Havana, Denver, Iowa and other distant places. However, the amount of power necessary to span such distances at broadcasting wave lengths varies thousands of times, depending on atmospheric conditions. In the case of amateur reception we have added the large variations in receiving conditions, receiving apparatus, and the personal equations of the listeners. The only satisfactory comparative test of modulation systems is successively to operate similarly power-rated sets embodying the systems, on a real or dummy antenna, measure the radio frequency power and the degree of modulation of each, in which case the results should be exactly in proportion to the product of these two factors.

This does not mean, however, that the system Mr. Culver describes is of no use. Except for the disadvantages, which in many cases are not very serious, it has much to commend it. It will give quality good enough for commercial communication. It has an "apparent" simplicity which lends itself readily to helping sales. It does not require as much amplification of the speech energy as other satisfactory systems. It is a practicable system. However, I think Mr. Culver has given it too broad a name. If he called it instead "An Improved System of Grid Circuit Modulation in Radio Telephony," there could be no question on that point.

DIGESTS OF UNITED STATES PATENTS RELATING TO RADIO TELEGRAPHY AND TELEPHONY*

Issued October 30, 1923–December 18, 1923

By

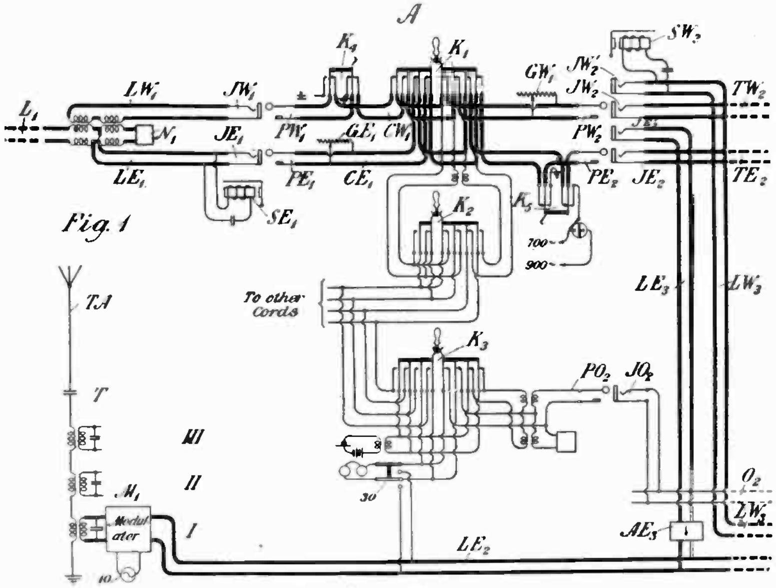
John B. Brady

(Patent Lawyer, Ouray Building, Washington, District of Columbia)

1,472,092—J. H. Round, filed July 9, 1921, issued October 30, 1923. Assigned to Radio Corporation of America.

Receiver for Radio Telegraphy, with a circuit for eliminating atmospheric disturbances, consisting of an antenna system which is slightly out of tune with the signal waves and a rectifying circuit connected with the antenna which rectifies the resultant current due to the forced and free oscillations in the antenna system. A circuit is then employed which is resonant to the beat frequency and the resulting signal is employed to actuate a responsive device.

1,472,289—R. Bown et al, filed April 26, 1921, issued October 30, 1923. Assigned to American Telephone and Telegraph Company.



Number 1,472,289—Radio-Wire Connecting Circuits

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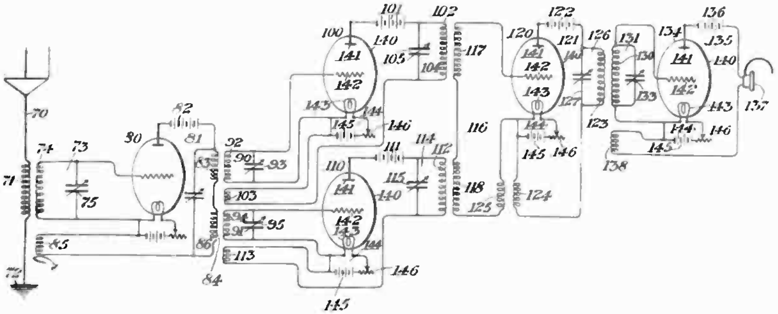
*Received by the Editor, January 12, 1924.

RADIO-WIRE CONNECTING CIRCUITS, in which existing line wire systems are made to function simultaneously with radio transmission and reception systems. Link circuits are provided and so organized as to interconnect wire lines with radio channels. It is necessary that the two-wire toll line be brought up to the radio station and be split into a four-wire circuit before connection with the radio transmitting and receiving channels. There are two possible places in the circuit where the necessary switching and operating arrangements may be introduced. These are in the two-wire line or in the four-wire part of the circuit.

1,472,218—J. H. Hammond, Jr., filed August 5, 1919, issued October 30, 1923.

Fig. 2



NUMBER 1,472,218—Transmission and Receiving System

TRANSMISSION AND RECEIVING SYSTEM, in which signals are transmitted on a series of waves upon which are impressed a plurality of series of periodic modifications of different frequencies. A series of irregular modifications corresponding to a message are then impressed on said waves and modifications, which are then received with extreme selectivity.

1,472,470—R. V. L. Hartley, filed March 30, 1918, issued October 30, 1923. Assigned to Western Electric Company, Incorporated.

METHOD OF AND MEANS FOR PRODUCING ALTERNATING CURRENTS by use of an oscillating electron tube having input and output circuits inductively coupled to each other with a condenser connecting the electrically remote terminals of the inductance to form with the inductances a closed oscillation circuit, which circuit determines the frequency of the oscillations produced by the oscillator. Another tube may be associated with the oscillator to impose a limiting effect upon the amplitude of the oscillations so that they will be the same during both positive and negative portions of the cycle.

1,472,477—R. W. King, filed August 14, 1919, issued October 30, 1923. Assigned to Western Electric Company, New York.

ELECTRON DISCHARGE DEVICE, in which a supporting standard for the electrodes is located centrally in the tube. The supporting standard is tubular in form and projects inwardly of the tube. The grid, plate, and filament are substantially mounted within the tube upon the inwardly projecting stem.

1,472,583—W. G. Cady, filed May 28, 1921, issued October 30, 1923.

METHOD OF MAINTAINING ELECTRIC CURRENTS OF CONSTANT FREQUENCY in an electron tube generator which consists in connecting a piezo-electric resonator having two pairs of coatings with one pair connected to the output circuit and the other pair connected to the input circuit, so as to cause an alternating current to flow in the output circuit, the frequency of which is determined by the mechanical vibrations of the piezo-electric resonator. This resonator has been previously described in these columns with reference to patent 1,450,246, and it consists in general of a plate of a piezo-electric crystal with coatings on its opposite faces.

1,472,822—H. A. Affel, filed September 24, 1919, issued November 6, 1923. American Telephone and Telegraph Company of New York.

CALLING ARRANGEMENT FOR RADIO SYSTEMS, in which the usual voice currents are impressed upon a modulator at the transmitter, causing radiation of energy in accordance with speech, and wherein an alternating ringing current may also be impressed upon the modulator for radiation by the antenna to operate a ringing signal at the distant receiver.

1,472,987—P. B. Murphy, filed August 28, 1920, issued November 6, 1923. Assigned to Western Electric Company, Incorporated.

SIGNALING SYSTEM for transmitting a ringing current from a radio transmitting station to a distant radio receiver and causing a bell signal to be operated at the receiver. A carrier wave transmission system is provided at its transmitting station with means to cut off the local talking circuit from the outgoing carrier wave channel and to connect in its stead to the ourgoing channel a source for alternately applying two alternating currents of different frequencies in a regular sequence. These alternately applied currents are caused to modulate the outgoing carrier wave in the same manner that it is modulated by special currents when carrier wave telephony is in progress. At the receiving station, the modulated carrier wave is detected or demodulated by the same apparatus used for detection of speech modulated waves and the detected alternate frequency currents are caused to energize selective circuits to control the operation of a differentially acting relay, which in turn operates the local signal element or applies the ringing signal to the receiving circuits as the case may be. By making the receiving apparatus responsive only to the conjoint action of the predetermined frequencies applied in a predetermined manner, the possibility of false signals being received is remote.

1,473,070—S. T. Woodhull and G. T. Waller, filed September 15, 1919, issued November 6, 1923. American Radio and Research Corporation.

GAP for radio transmitters of the spark type. The patent covers construction of quenched spark gap which consists in a series of thin metal plates of uniform thickness each having a centrally disposed sparking area and an annular recess surrounding the area. Separate lengths of conducting and non-conducting material are provided which engage the front and back faces of the plates, respectively. An insulated gasket is provided between the plates forming a substantially air-tight sparking chamber.

1,473,179—R. A. Fessenden, filed November 10, 1920, issued November 6, 1923. Assigned to Submarine Signal Company, Portland, Maine.

METHOD FOR ELIMINATING UNDESIRED IMPULSES at a receiving station, which consists in providing several channels in the antenna circuit for receiving the disturbing noises more effectively than the signals on one portion of the receiving system, recording the indications as received, and receiving said disturbing noises and desired signals in a more equally effective manner on another portion of said receiving system, and recording the indications so received, and detecting and eliminating the disturbing effects by comparison of said records.

1,473,220—H. F. Elliott, filed August 23, 1921, issued November 6, 1923. Assigned to Augustus Taylor, San Francisco, California.

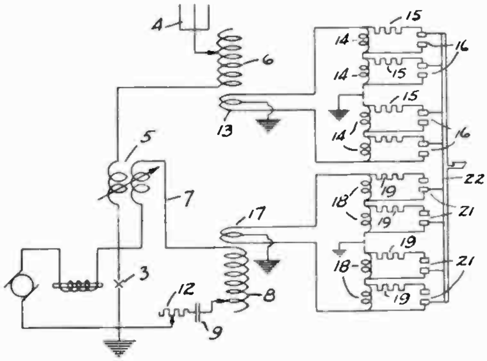


FIG. 1.

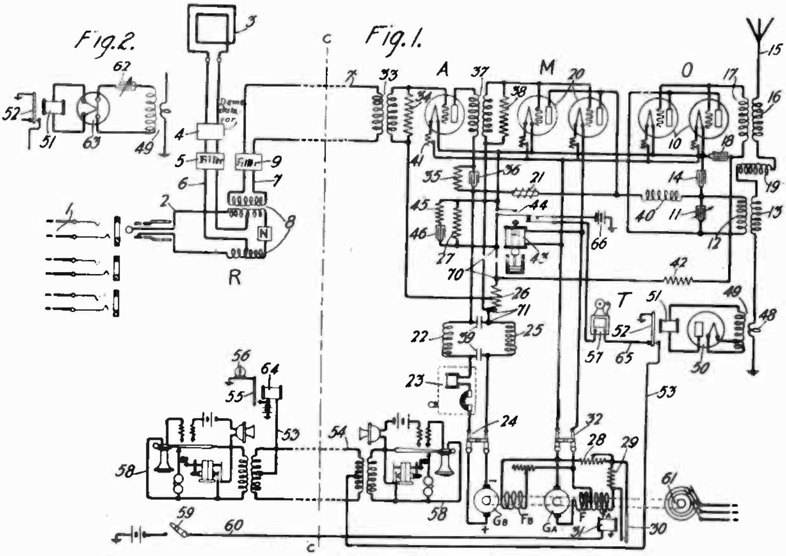
Number 1,473,220—Radio Telegraphy Signaling System

Radio Telegraphy Signaling System utilizing an arc at a radio transmitting station. The arc transmitter is provided with the usual oscillatory radiating circuit. An oscillatory non-radiating circuit is connected with the source of oscillations. A loop circuit is inductively coupled to one or both of the oscillatory circuits and a plurality of reactors, connected in series, are provided in each loop circuit. Shunting keys are arranged simultaneously to short-circuit each of the reactors for oppositely varying the impedances of the loop circuits, thus enabling the non-radiating circuit to absorb energy during the intervals between which the radiating circuits are transmitting energy.

1,473,417—F. G. Beetem, filed June 16, 1920, issued November 6, 1923.

Radio Receiving Apparatus, in which the filament current for the electron tubes in the receiver is maintained constant by a circuit connection which includes a resistor of high positive temperature coefficient connected between the source of energy and the filament circuit. A resistor is also connected in parallel with the filament to divert a portion of the current whereby the current in the filament is maintained constant at a different value from that of the current from the source.

1,473,433—A. W. Kishpaugh, filed May 3, 1921, issued November 6, 1923, Assogned to Western Electric Company, Incorporated.



Number 1,473,433—Carrier Wave Transmission System

Carrier Wave Transmission System, in which the radio apparatus is located at a central station and arranged to be controlled from a switchboard which may be located at a distance. The generators which supply filament heating current and space current for the transmitting tube are controlled from the switchboard. An indicator is provided for showing the presence of the proper frequency in the transmitting antenna and for giving an alarm when the current varies or the frequency changes materially. Provision is also made for preventing injury in the transmitter circuits from excessive space current before the cathodes have become fully energized.

1,473,719—R. R. Beal, filed February 19, 1920, issued November 13, 1923. Assigned to Augustus Taylor of San Francisco, California.

Radio Telegraphy by means of an arc transmitter. This patent shows a circuit for an arc transmitter in which the continuous signaling waves are converted into wave trains or wave groups at the transmitter so that signals so transmitted are readily received and identified by all receiving stations. The signaling is accomplished by varying the core losses n a magnetic core having a winding associated therewith and connected in the antenna circuit. An audio frequency flux is impressed on the core from a keying circuit reducing the hysteresis and the effective resistance of the antenna circuit, thus increasing the antenna current to signaling value. Normally the losses effectively increase the resistance of the antenna circuit to such a value that current therein is reduced below signaling value.

1,473,921—J. Bethenod, filed May 6, 1922, issued November 13' 1923.

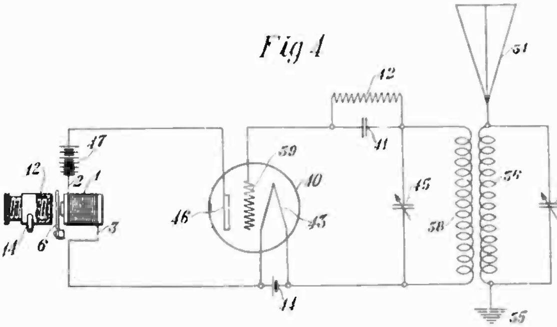
HIGH FREQUENCY SIGNALING SYSTEM utilizing high frequency generators such as alternators for the transmission of signals. A synchronizing connection is provided, enabling a plurality of high frequency generators to be operated in parallel. The synchronizing connection consists of a pair of impedances in series shunted by a condenser and an inductance in series. The radiating system is connected to the junction point of the impedances.

Reissue 15,722—R. A. Heising, filed December 27, 1918, issued November 13, 1923. Assigned to Western Electric Company, Incorporated.

SYSTEM FOR PRODUCING MODULATED WAVES in an arc transmitter. An electron tube circuit is provided in association with an arc oscillator. An auxiliary arc oscillating circuit is also provided which has a period which tends to vary as the signal wave varies operating to control the main arc discharge for transmission of signals.

1,474,242—C. A. Culver, filed October 23, 1919, issued November 13, 1923.

Fig 1



NUMBER 1,474,242—Acoustic Receiving Apparatus

ACOUSTIC RECEIVING APPARATUS, which consists in an electromagnet monotone system having an electromagnetically vibrated reed supported at one end in order to be fully responsive to vibrations of a single frequency. An electromagnet is mounted in a position to vibrate the reed from one side of the reed. A resonance chamber is located in a position on the other side of the reed and serves to amplify the intensity of sounds produced by the reed. The resonance chamber may be changed in period in order accurately to approach the period of the reed. Signals may be received by means of a listening tube connected with the resonance chamber.

1,474,293—F. Reynolds, filed November 10, 1921, issued November 13, 1923. Assigned one-half to the Silica Syndicate, Ltd., of London, England.

THERMIONIC VALVE, in which provision is made for the expansion and contraction of the electrodes under conditions of temperature change. The electrodes within the tube are telescopically supported in members which are secured to the tube. An arrangement of springs within the telescopic members is provided whereby the electrodes are free to expand or contract as the temperature within the tube may vary.

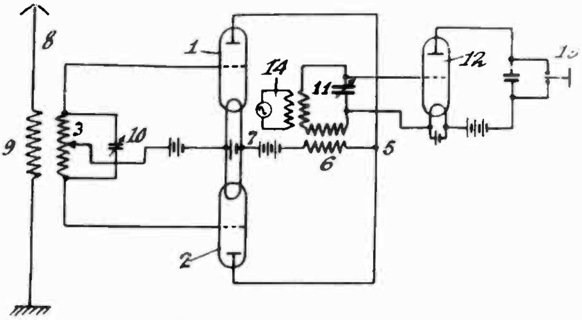
1,474,382—H. J. Round, filed March 31, 1920, issued November 20, 1923. Assigned to Radio Corporation of America.

APPARATUS FOR RADIO TELEGRAPHY AND TELEPHONY at the receiving station in which a coupled primary and secondary circuit is employed and a slotted metallic sheath positioned to surround the secondary winding. The metal sheath is connected with the filament circuit of the receiver. The metal sheath operates to eliminate the effect of short forced waves upon receiver.

1,474,486—B. MacPherson, filed June 3, 1919, issued November 20, 1923. Assigned to Wireless Specialty Apparatus Company.

ELECTRICAL CONDENSER of the stacked plate and sheet type, The stack is divided into sections, the sections being in series for high potential service. The invention resides in connecting the sections together by providing a metal sheet between adjacent sections, the sheets being connected at one end with the terminal of one section and at the opposite end with the terminal of the next succeeding section.

1,474,726—A. Meissner, filed August 8, 1922, issued November 20, 1923. Assigned to Gesellschaft, für Drahtlose Telegraphie m. b. h. of Berlin, Germany.

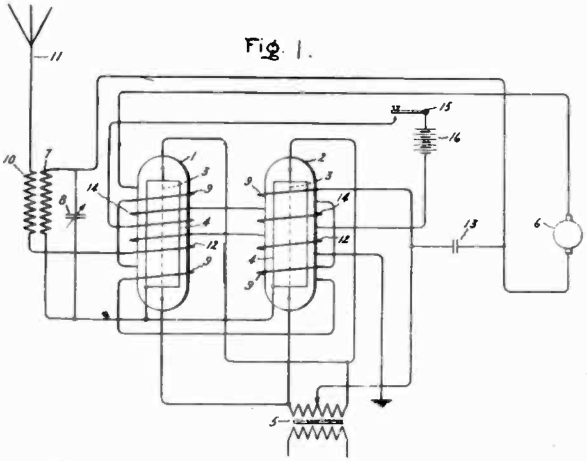


Number 1,474,726—Method of and Arrangement for Receiving Electrical Oscillations

Method of and Arrangement for Receiving Electrical Oscillations at a radio station, wherein the number of channels of communication simultaneously operable side by side may be quadrupled over the number of channels available with the usual heterodyne reception. In the present system the signals are received and then increased in frequency, before the heterodyne, and a beat frequency derived from the combination of the increased frequency and a local generator which is detected for observing the signals. The channels are separated by differentially increasing and thereby separating the frequency of the signals in the receiving station.

1,475,164—W. R. G. Baker, filed June 9, 1922, issued November 27, 1923. Assigned to General Electric Company.

Fig. 1.



Number 1,475,164—Signal Transmitting System

Signal Transmitting System, utilizing vacuum tubes for the generation of radio frequency currents in which an electron current is controlled by a magnetic field. The oscillatory circuit is connected with the electrodes of a magnetron, and a winding is provided surrounding the magnetron for producing a polarizing magnetic field. A third winding is provided surrounding the magnetron for producing a magnetizing field of sufficient value to interrupt the production of oscillations in accordance with telegraphic signals.

1,475,219—R. Bown, filed November 1, 1920, issued November 27, 1923. Assigned to American Telephone and Telegraph Company.

Radio Signaling System, arranged for multiplex operation with a plurality of transmission channels under centralized control and arranged to operate in co-operation with a corresponding number of secondary radio stations without interference. The transmitting frequency of a secondary station is controlled by transmitting from the primary station a modulated wave of fixed frequency. The received modulated wave is beaten at the secondary station with the unmodulated transmitted wave of the secondary station. The frequency of the unmodulated transmitted wave is adjusted until the difference in frequency between the received modulated wave and the unmodulated transmitted wave is of such modulation as to pass thru a selective circuit associated with the receiving circuit of the secondary station. In this manner interference between stations is prevented.

1,475,297—R. B. Goldschmidt, filed June 25, 1920, issued November 27, 1923.

Radio Selection System, which employs at the transmitting station a regulator which insures a uniform succession of trains of transmitted waves, and at the receiving station a regulator which causes the receiver to come into operation only during the time of transmission of such trains. The system is intended to eliminate interference from extraneous signals.

1,475,448—Harold Rowntree, filed May 16, 1921, issued November 27, 1923.

Electrical Transmission of Communications, consisting of a method in which a plurality of characteristics of a transmitted carrier current are continuously altered in a predetermined sequence of nature, type or degree of alteration. The carrier current is simultaneously modulated in accordance with the signal to be transmitted. The object of the invention is to secure greater selectivity for providing more channels of communication.

1,475,583—C. A. Hoxie, filed May 20, 1921, issued November 27, 1923. Assigned to General Electric Company.

VARIABLE CURRENT GENERATOR, wherein the amount of current or voltage produced at any instant is controlled by a screen placed in the path of light travelling from a suitable source to a photo-electric cell. This screen is provided with specially formed cut-away or transparent portions and is arranged to be moved so that the light which passes thru these portions and falls upon the photo-electric cell is caused to vary in a manner corresponding to the variation which it is desired to produce in the current or voltage. The photo-electric cell is connected to control an electron tube circuit.

1,475,632—H. B. Herty, filed February 10, 1922, issued November 27, 1923.

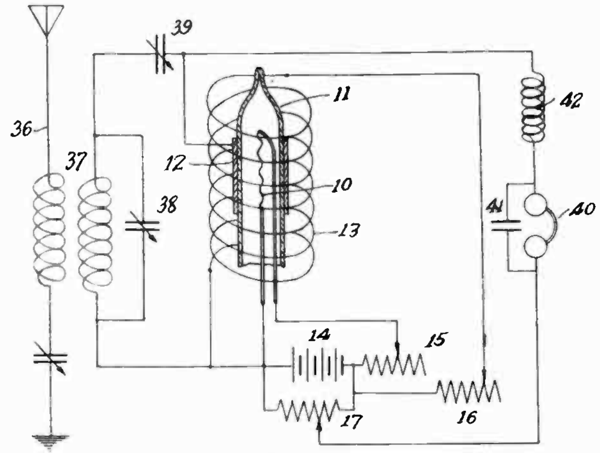
PROTECTIVE DEVICE FOR RADIO RECEIVING SYSTEMS, in which a thermal device is connected in the antenna system to control a relay circuit which operates on excess current for short-circuiting the element which couples the receiver to the antenna, thereby avoiding injury which might result to the receiver in case of excess energy in the antenna circuit.

1,476,003—De Loss K. Martin, filed August 18, 1922, issued December 4, 1923. Assigned to American Telephone and Telegraph Company.

RADIO SIGNALING CALL SYSTEM, in which any one of a number of remote stations may be called from a central radio station. The system includes a plurality of stations arranged for intercommunication, with calling means for establishing channels between one station and any other which comprises a given combination of voice frequencies on a plurality of different carrier frequencies.

1,476,156—H. P. Donle, filed April 7, 1921, issued December 4, 1923. Assigned to Connecticut Telephone and Electric Company, Incorporated.

RADIO FREQUENCY DEVICE which consists of a vacuum tube containing only a cathode within the evacuated space. The anode is placed in intimate contact with the outer surface of the tube and connected with the cathode. An adjustable magnetizing coil is provided which surrounds the anode outside of the tube.

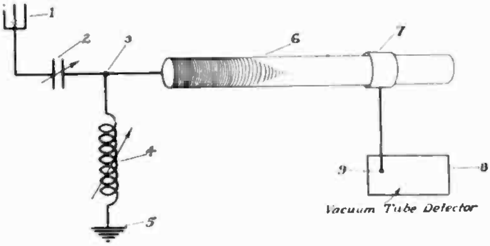


NUMBER 1,476,156—RADIO FREQUENCY DEVICE

1,475,027—E. F. Randall, filed June 7, 1923, issued November 20, 1923. Assigned to American Radio and Research Corporation.

DETECTOR FOR RADIO SIGNALS of the crystal type in which the connecting member held in contact with the rectifying crystal is maintained in position by a permanent magnet. The conducting contact member may be moved in different positions and held in such position by the magnetic attraction between the contact member and the permanent magnet.

1,476,691—L. Cohen and J. O. Mauborgne, filed January 26, 1921, issued December 11, 1923.



NUMBER 1,476,691—ELECTRICAL SIGNALING

Electrical Signaling, in which a "wave coil" is employed for eliminating static disturbances at the receiver. The receiving circuit may include an antenna tuned by a series condenser, a loop circuit, and a ground connection, constituting the antenna circuit. The wave coil is connected to a point on the antenna circuit with the receiving apparatus associated with the wave coil. The operation is as follows: The antenna circuit 1, 2, 3, 4, and 5, is tuned to the frequency of the signal which it is desired receive and if the capacity of the condenser 2 is small the inductance 4 large, the resonance potential across the condenser 2 may be made relatively very large, that is, many times the voltage induced in the antenna by the electromagnetic waves of the signal. Connecting the wave coil 6 to the point 3 on the antenna circuit, a high potential is impressed on the wave coil and part of the signal energy is transmitted over the wave coil effecting a wave development on the coil. Since the signal energy is transmitted at a high potential, the current in the wave coil is correspondingly small and the efficiency of transmission is accordingly large, comparatively little energy is lost in the transmission. By suitably adjusting the length of the coil in relation to wave length of the signals, one or more maximum potential points will occur on the coil. While good results may be obtained if the length of the wave coil is less than one-quarter of the wave length, it is preferable to have the coil of sufficient length to secure the development of at least a quarter wave length. By connecting the detector 8 to a maximum potential point on the wave coil, which is accomplished by sliding the ring 7 along the coil, a further increase in the receiving efficiency of the system is thus obtained. In using a three-electrode vacuum tube detector, the grid 9 is connected to the ring. When any other electrical disturbances act on the antenna, such as interfering signals or electrostatic disturbances, the effect on the detector is small, for the reason that the antenna circuit is not in resonance for the interference effects and hence the potential across the condenser 2 produced by these effects is relatively small. The effect is more in the nature of a rush of current flow thru the antenna circuit, part of which will necessarily be transmitted over the wave coil, but because of the large resistance of the wave coil the energy is quickly dissipated and the disturbance is very largely attenuated before it reaches the part of the wave coil which is connected to the detector, and therefore the effect on the detector is small.

1,477,316—F. Conrad, filed July 11, 1922, issued December 11, 1923. Assigned to Westinghouse Electric and Manufacturing Company.

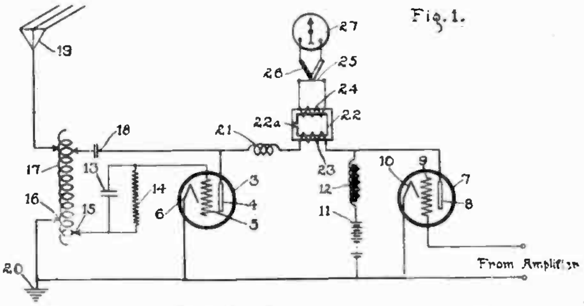


Fig. 1.

Number 1,477,316—Radio Modulating System

Radio Modulation System, in which a meter is provided for registering the alternating current component of the modulated current supplied to the oscillator tube at the transmitter. The meter is calibrated to indicate directly the ratio of the effective alternating current component to 0.7 times the steady direct current component. A current transformer is connected in circuit with the oscillator and may operate an oscillograph or meter to indicate the ratio of the actual modulated current to the minimum modulated current possible without undesirable distortion. The apparatus is described in connection with a broadcasting station where the characteristics of the transmitter are always observable by the operator in charge of the station controls.

1,476,721—D. Loss K. Martin, filed November 23, 1921, issued December 11, 1923. Assigned to American Telephone and Telegraph Company.

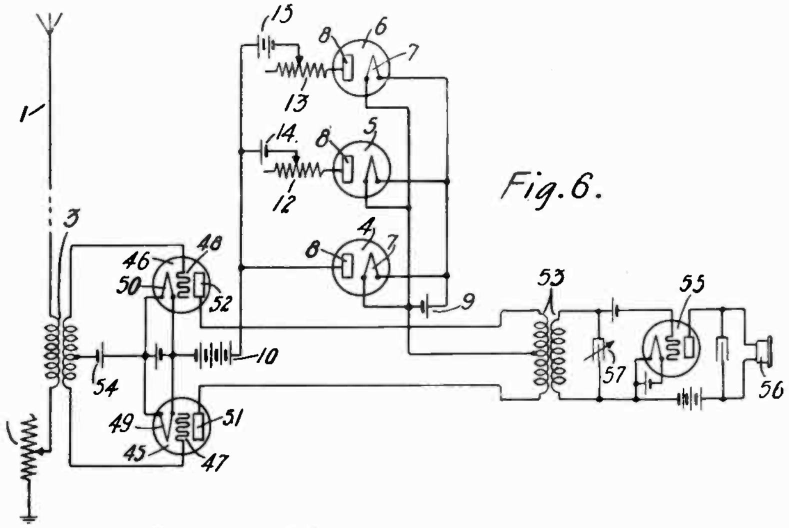


Fig. 6.

Number 1,476,721—Frequency Control System

FREQUENCY CONTROL SYSTEM for producing synchronism between a locally generated frequency and a controlling frequency transmitted from a distant point, which consist in adjusting an oscillator so that it will normally produce a frequency in the neighborhood of the controlling frequency, transmitting the controlling frequency thru a one-way device, and in impressing the controlling frequency thus passed upon the oscillator whereby the oscillator will oscillate in synchronism with the controlling frequency.

1,477,314—E. F. W. Alexanderson, filed June 24, 1921, issued December 11, 1923. Assigned to General Electric Company of New York.

RADIO RECEIVING SYSTEM having a circuit arrangement for preventing interference by signals from an undesired transmitting station. A multiple tuned circuit is connected to the antenna which is resonant to the frequency of the disturbing effect to be eliminated. A series tuned circuit is also connected to the antenna and it is also resonant to the frequency of the disturbing effect to be eliminated. The electromotive forces derived from both of the resonant circuits are impressed upon the same receiving circuit. By properly proportioning the circuits the voltage drops produced across these circuits by the desired signal may be made to be substantially opposite in phase, so that they will add in the receiving circuit. The magnitude of the voltage drop across the multiple tuned circuit will also be less than the voltage drop across the series tuned circuit. The signal which has a frequency only slightly different from that of the interfering wave may be received with practically full intensity at the same time that interfering wave is neutralized.

1,477,645—R. E. Hall, filed August 13, 1919, issued December 18, 1923. Assigned to Hall Research Corporation of Delaware.

SIGNAL RECEIVING SYSTEM AND METHOD, in which a plurality of independent receiving stations located at separate points are all tuned to the same transmitting station. The separate relays operate to synchronously respond to the received signal and operate a central recorder connected in a relay circuit with all of the receivers. Static disturbances which are local to one of the stations may not exist at one of the other stations. Such disturbances being unsynchronized will not affect the central recorder, while a desired signaling frequency will synchronously operate the several receivers and thereby control and operate the central recorder.

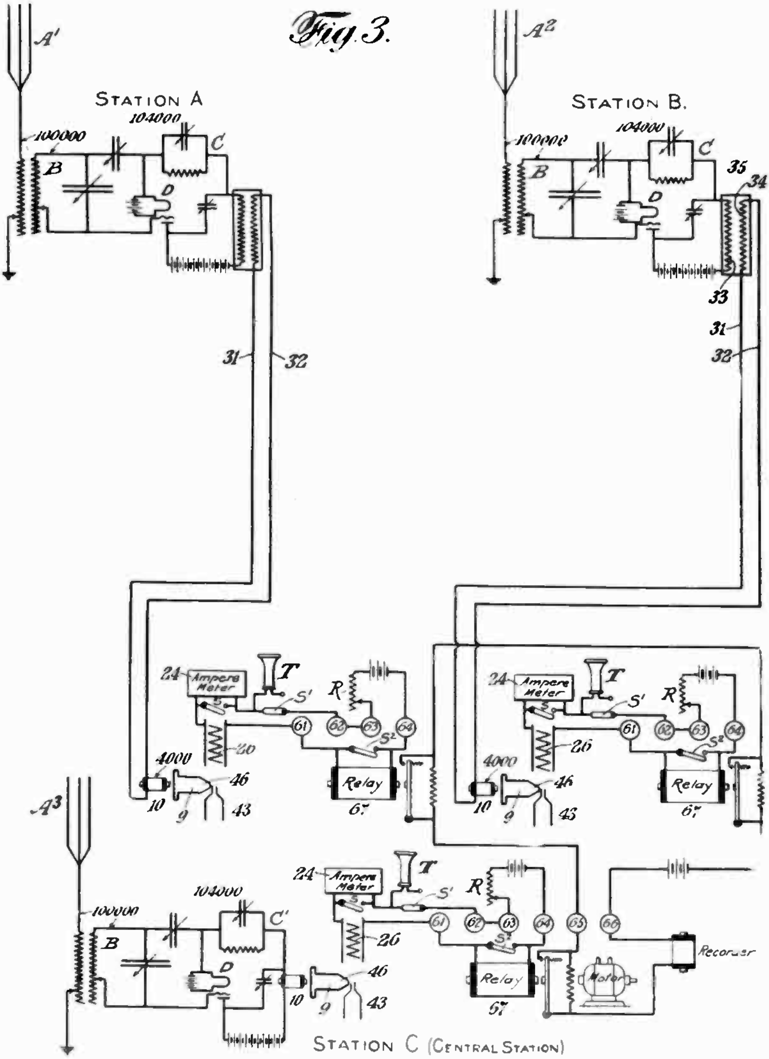


Fig. 3.

Number 1,477,645—Signaling Receiving System and Method

1,477,826—R. J. Heitzman, filed June 29, 1922, issued December 18, 1923.

Detector Stand of the crystal type in which a lever is pivoted upon a vertical standard and one end of the lever adjusted up and down by rotation of a cam against the action of a spring. A contact wire is attached to the opposite end of the lever and is capable of variable adjustment against the rectifying crystal.

1,477,868—H. P. Donle, filed May 9, 1919, issued December 18, 1923. Assigned to Connecticut Telephone and Electric Company.

METHOD AND APPARATUS FOR INCREASING ELECTRONIC EMISSION from an electrode within the glass bulb of a thermionic valve which consists in extracting a metallic element from the material of the glass bulb and depositing the same upon the cathode. The patent states that with this arrangement the electronic emissivity is greatly increased.

1,477,869—H P. Donle, filed February 3, 1923, issued December 18, 1923. Assigned to Connecticut Telephone and Electric Company, Incorporated.

ELECTRONIC EMISSION secured in increased proportions by attracting to the cathode of the tube electrically charged particles of sodium. The object of the invention is to provide metallic ions within the tube and thus, in addition to furnishing a basis for ionization effects, increase the electron emission of the cathode for a given temperature.

1,477,899—C. W. Rice, filed July 27, 1921, issued December 18, 1923. Assigned to General Electric Company.

HIGH FREQUENCY SIGNALING SYSTEM, in which the stray or static ratio is materially improved at the receiver. A circuit is provided at the receiver which includes an artificial transmission line having an effective length equal to a plurality of wave lengths of the signals to be received. The received signals are impressed on this transmission line and then the signaling currents derived from more than two points in the transmission line impressed upon the receiving apparatus.

1,478,029—Lee de Forest, filed July 2, 1920, issued December 18, 1923.

RADIO RECEIVING SYSTEM for receiving undamped wave trains in the form of a musical note without the intermediary of a tikker, tone wheel, or mechanical interrupter of any kind, and further, without using the principle of heterodyne or beat note reception. The patent describes a circuit in which the received radio frequency current is utilized to interrupt itself, thereby to produce current impulses of audio frequency.

1,478,047—J. Mills, filed December 22, 1920, issued December 18, 1923. Assigned to Western Electric Company, Incorporated.

RADIO RECEIVING SYSTEM for avoiding interference due to static or other atmoshperic conditions. A plurality of sets of incoming waves are separately received at different stations and caused to modulate separate carrier waves which are transmitted to the same receiving station, where they are combined to secure the signal with suppression of interference.

1,478,050—E. L. Nelson, filed April 26, 1922, issued December 18, 1923. Assigned to Western Electric Company, Incorporated.

MODULATION CIRCUITS AND MEASUREMENTS, in which a device is employed at the radio transmitter which has an indicator moving over a calibrated scale. This device is responsive to current intensities and is included in the modulation circuit to indicate the degree of modulation. The patent points out that this measuring device is to be preferred over the oscillograph for studying output at the broadcasting station.

1,478,072—H. J. Van Der Bijl, filed March 20, 1918, issued December 18, 1923. Assigned to Western Electric Company, Incorporated.

VACUUM TUBE construction in which the grid and plate are mechanically reinforced against distortion from their original shape by means of ridges on the plate and grid. These reinforcing means serve to always maintain the electrodes in the same spaced relation and at the same time they offer substantially no obstruction to the passage of electrons.

1,478,076—H. W. Weinhart, filed August 7, 1919, issued December 18, 1923. Assigned to Western Electric Company, Incorporated.

ELECTRON DISCHARGE DEVICE, in which an inwardly projecting portion is provided within the tube upon which the electrodes are supported by means of bands which are independently clamped to the inwardly projecting portion.

1,478,087—W. Wilson, filed November 21, 1919, issued December 18, 1923. Assigned to Western Electric Company, Incorporated.

VACUUM TUBE construction, in which the cathode is formed by a plurality of intertwined twisted ribbons of thermionically active material. The object of the invention is to provide a cathode which has the property of large electron emissivity at a minimum temperature.

1,478,342—R. C. Lewis, filed January 31, 1921, issued December 18, 1923. Assigned to Coto-Coil Company of Boston, Massachusetts.

ELECTRICAL AIR CONDENSER of the variable type in which the plates are supported in a single unitary mounting, consisting of a spider-member having an extended bearing hub at the center and three arms extending therefrom. The stationary plates are supported from the extremities of the arms and the movable plates are journalled in the bearing at the center of the spider.

LIST OF RADIO TRADE MARKS PUBLISHED BY PATENT OFFICE PRIOR TO REGISTRATION

(The numbers given are serial numbers of pending applications)

185,394—"RADIODYNE" in ornamental design for radio receiving sets. Western Coil and Electrical Co., Racine, Wisconsin. Claims use since August 19, 1923. Published November 13, 1923.

185,822—"GIANT" for crystal detectors. Foote Mineral Co., Philadelphia, Pennsylvania. Claims use since May 11, 1923. Published November 13, 1923.

185,823—"VARIO-TENSER" in ornamental design for cat whisker for detector. Foote Mineral Co., Philadelphia, Pennsylvania. Claims use since May 11, 1923. Published November 13, 1923.

184,252—"MARLE" in ornamental design for transformers. Marle Engineering Co., Orange, New Jersey. Claims use since May 19, 1922. Published November 13, 1923.

184,330—"MICRO-TUNE" for variable condensers. The Fett and Kimmel Co., Bluffton, Ohio. Claims use since May 14, 1923. Published November 13, 1923.

176,781—"RADIO ARGENTITE," a crystalline compound for detectors. J. Byrne Curry, doing business as Curry and

Coutellier, Los Angeles, California. Claims use since July 1, 1922. Published November 27, 1923. (Not subject to opposition.)

165,987—"DICTOGRAPH RADIO" in ornamental design for telephonic headsets. Dictograph Products Corporation, New York, New York. Claims use since May 1, 1922. Published November 27, 1923.

185,665—"MURAD" for radio receiving apparatus. Mu-Rad Laboratories, Inc., Asbury Park, New Jersey. Claims use since November 20, 1921. Published November 27, 1923.

186,856—"R. C. Co." for electrical condensers. Radio Condenser Company, Camden, New Jersey. Claims use since February 1, 1923. Published November 27, 1923.

187,109—"L-ANCO" in ornamental design for vario-couplers. Lanco Coupler Co., Lancaster, Pennsylvania. Claims use since October 15, 1923. Published November 27, 1923.

186,974—"BRADLEYLEAK" for grid leaks. Allen-Bradley Company, Milwaukee, Wisconsin. Claims use since September 1, 1923. Published November 27, 1923.

179,912—"FOOTE" for radio crystals. Foote Mineral Co., Philadelphia, Pennsylvania. Claims use since May 1, 1922. Published November 27, 1923. (Not subject to opposition.)

168,936—"THE NORTH AMERICAN RADIO & SUPPLY CORPORATION" in ornamental design for Radio apparatus. The North American Radio and Supply Co., New York, Claims use since June 21, 1922. Published December 18. 1923.

181,519—"EKKO" in ornamental design for radio phonograph apparatus. The Ekko Company, Chicago, Illinois. Claims use since July 1, 1922. Published December 18, 1923.

183,040—Triangular design for dry batteries. National Carbon Company, New York. Clains use since June 1, 1923. Published December 18, 1923.

184,108—"BASUB" in ornamental design for apparatus for adapting commercial alternating current for use in radio receiving circuits as a substitute for a storage battery.

Simplex Electrical Laboratories, New York and Brooklyn. Claims use since on or about July 1, 1923. Published December 18, 1923.

185,358—"CELERUNDUM—THE CRYSTAL WITH A SOUL" for radio detectors. The Ferris Radio Research Laboratory, Boston, Massachusetts. Claims use since July 1, 1923. Published December 18, 1923.

186,024—"EVEREADY-THREE" for dry batteries. National Carbon Company, Inc., New York, New Qork. Claims use since June 1, 1923. Published December 18, 1923.

177,606—"TRUTONE" in ornamental design for radio loud-speaking horns. Claims use since July 5, 1922. Published December 18, 1923. Sadler Mfg. Co., San Francisco, California. (This mark is nor subject to opposition.)

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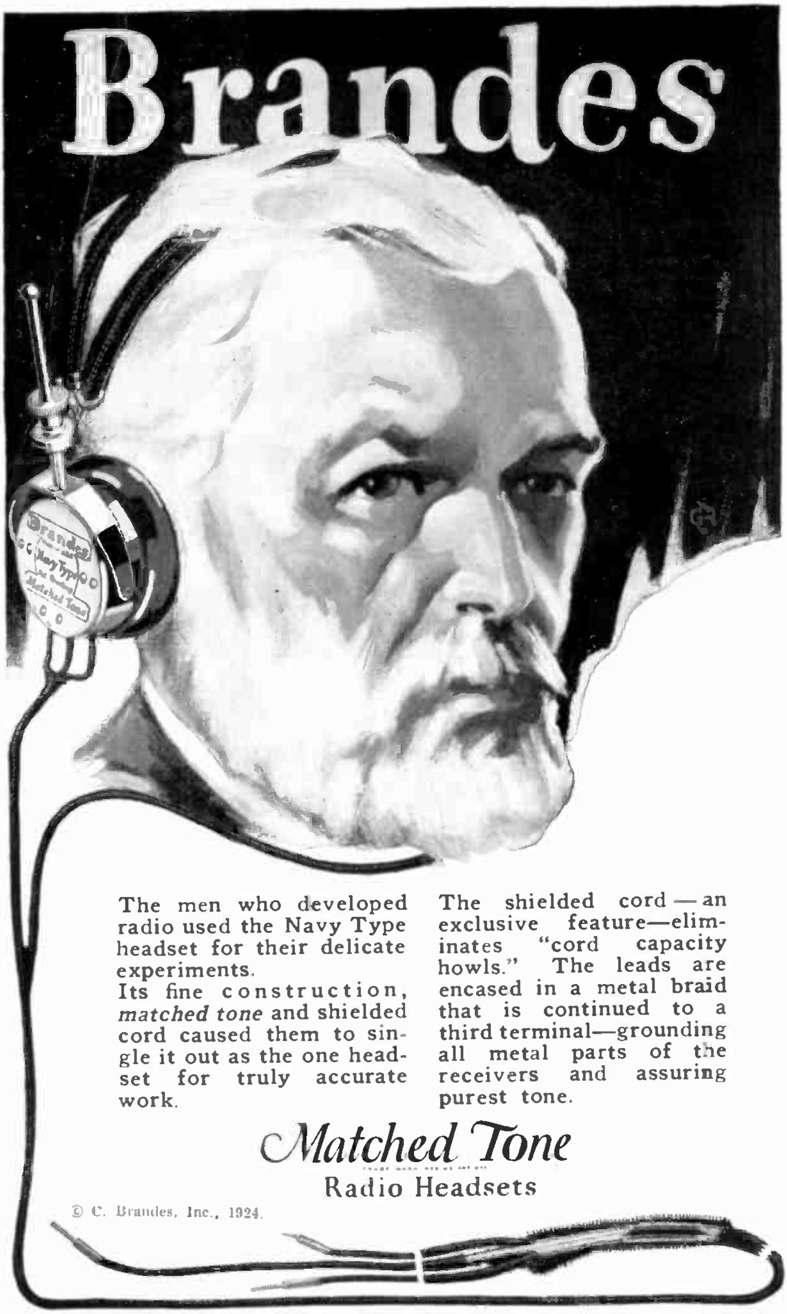
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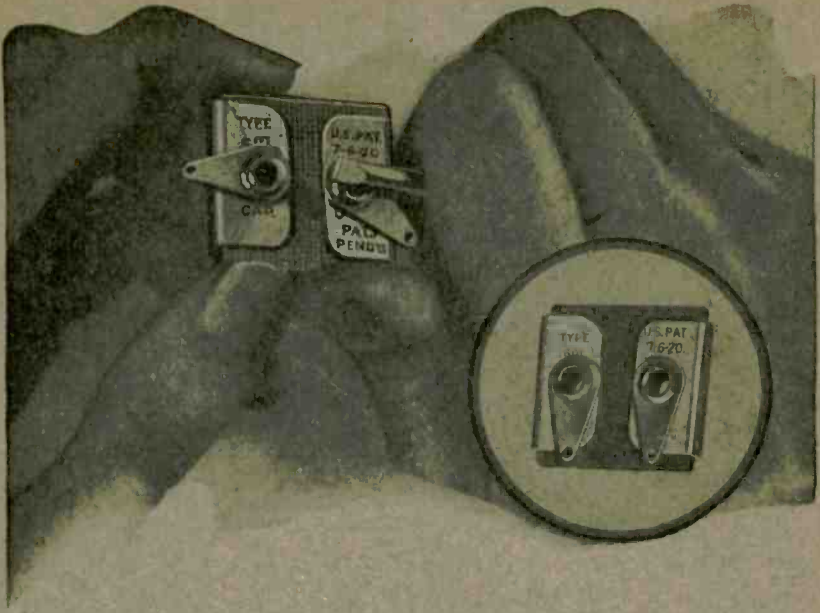

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