UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE

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LIGHTNING PROTECTION HANDBOOK-*

Forest Service Handbook

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UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE

* * * LIGHTNING PROTECTION HANDBOOK

Contents

CHAPTER I - INTRODUCTION

Extensive field studies of lightning have been made in recent years which have resulted in a much better understanding of the characteristics of lightning and therefore of the requirements for a good lightning protective system.

In the 1948 edition of the Encyclopaedia Britannica, in an article entitled Lightning and Lightning Protection, K. B. McEachron summarizes the present state of knowledge of the characteristics of lightning and of protection against it. These are described in part below.

Lightning strokes may vary in current magnitude from a few hundred amperes to over two-hundred thousand amperes. Measurements indicate that 50% of the strokes to ground have currents above 15,000 amperes.

Records also show that about one-half of all cloud to ground lightning strokes consist of two or more high current peaks. In many, if not all of these, relatively low continuing current flows during the time interval between the peaks. Each high current peak usually lasts only a few millionths of a second. Many peaks increase to their maximum and decay to half current within forty-millionths of a second. Infrequently, times of eighty-millionths of a second have been measured. The average time between peaks is about 0.03 second, with a range of 0.0005 second to 0.4 second. The time required for a complete stroke varies from less than 0.001 second to over 1.5 second.

A very large majority of the strokes discharge negative electricity to earth. Occasionally a stroke may start a negative discharge and change to positive when a positively charged region in the cloud is tapped.

The amount of electricity discharged from the beginning of a high current peak until it decays to half current is less than one coulomb in nearly all cases. In 50% of the cases measured the amount discharged was less than one-quarter coulomb. Complete strokes, however, average about 18 coulombs. A stroke of 165 coulombs has been measured. A large part of this charge is carried by the relatively low continuing current on which the high current peaks are superimposed.

The time required for a current peak to reach its maximum value is usually very short. It average from one to two and one-half millionths of a second. There is evidence that occasionally it may be less than one-half millionths of a second. Measurements indicate that the current increases at a rate of 8,000 or more amperes in a millionth of a second in 50% of the cases.

Due to the very brief period of discharge of these high current peaks the energy dissipated is small but the rate of energy dissipation is very great. It is this high rate which causes the explosive effects of lightning. These explosive effects are due to the very rapid transformation of the material in the path of the stroke into gas with a consequent large increase in volume and to the very rapid heating and therefore expansion of the gas and of the air.

The very rapid rate of current rise in the usual lightning stroke is one of the cause of sideflashing. For example, if a discharge of 25,000 amperes through a conductor reaches its crest in one-millionth of a second the inductive drop per foot of the conductor will amount to roughly 11,300 volts per foot. If the conductor is a 50-foot downlead from the cab at top of the tower to ground, the difference in voltage between the cab and ground as a result of this inductive drop will be fifty times 11,300 or 565,000 volts. If any metal object in the cab is independently grounded and not tied into the protective system at the cab level, these 565,000 volts may cause a sideflash from the protective system to it. Because of the very rapid rate of rise of this voltage and the short time during which it is applied, it will flash over only from 7 to 10 inches of air.

This inductive drop can be greatly reduced by increasing the number of downleads from the protective structure. Thus, four ground leads electrically connected at the upper terminal and a little below ground level will reduce the current per downlead to one-fourth and, consequently, the inductive drop along it to about one-fourth of the value for a single downlead.

Although the protective system rises to a high voltage above ground owing to the above-mentioned inductive voltage, it may rise to a still higher voltage owing to current passing through its ground connections. This voltage is equal to the product of the resistance of the protective system ground and the current passing through it. Thus, a 25,000-ampere discharge passing through a 50-ohm ground would raise the protective system to a potential above ground of 1,250,000 volts. This would be sufficient to sideflash a distance of 6 to 8 feet through the air. Therefore, the danger of trying to ground metal objects independently within or near protective systems is apparent.

The high voltages that appear between protective system and ground emphasize the hazard to which an individual subjects himself when he stands on or close to ground near such a protective system when a thunderstorm threatens. He is in grave danger of a sideflash through his body which may be fatal. However, neither the inductive drop nor the resistive drop produces any additional hazards within the cab of a lookout structure if there are no separate or independently grounded objects (such as a separately grounded telephone) within the cab.

At the instant of a discharge, high voltages can appear also along the ground surface near the buried downleads of the protective system. Current is passing into the soil all along these wires. This develops high voltages owing not only to the resistance of the soil path but also to the very rapid rate of current rise. Thus, the voltage across the ground spanned by a man's legs may be sufficient to stun or even kill him. This is the voltage that frequently kills animals even though lightning may not strike them directly. In their case, discharge passes near the heart and lungs. This fact, plus their much lower resistance, makes discharges more dangerous to them.

It is obvious therefore that personnel should be cautioned not to walk or stand near lightning protective grounding systems, or allow animals near such systems, when a storm is in the vicinity. It should be remembered that the first stroke is as dangerous as any other, and that it may occur to the lookout tower.

The functions which must be performed by a protective system are to:

1. Intercept and conduct harmlessly to earth all direct strokes to the structure protected.

2. Prevent sideflashes through the bodies of personnel or through equipment.

3. Minimize induced voltages on personnel and objects within the protective system.

The first function is accomplished by use of heavy air terminals and multiple paths to ground by at least two down conductors located in as direct a route to earth as possible with no breaks or sharp bends in the conductors. Experiments have indicated that a lightning rod will usually be struck by all strokes that otherwise would have struck within a cone-shaped space the apex of which is the upper end of the rod and the base of which is a circle having a radius of from one to two times the height of the rod.

To accomplish the second function, the ideal arrangement would be a complete metal enclosure electrically bonded throughout. This is not practical, so the present method is to approach the objective as far as economically possible with a metal cage around the structure and with all sizable metal objects securely bonded to the cage.

Sideflashes are caused by a difference in potential between two bodies. Hence, if all metal objects in a building are bonded together the relative voltage between objects cannot be great, even though the cage itself may be several hundred thousand volts above the ground potential. This leads to the question of ground resistance which has come up occasionally. The National Bureau of Standards states, "Low resistance is, of course, desirable but not essential." For a building located on bare, solid rock, the Bureau further states that "the most effective means would be an extensive wire network laid on the surface of the rock surrounding the building, after the manner of a counterpoise to a radio antenna to which the down conductor could be connected. Resistance to earth at some distant point of such an arrangement would be high but at the same time potential distribution about the building would be substantially the same as though it were resting on conductive soil, and the resulting protective effect also substantially the same."

Many details of instructions and drawings in this handbook may appear trivial, but are actually very important and should be rigidly adhered to. For example, grounding a stove through the leg rather than through the main body of the stove would be dangerous if the leg were not solidly fastened. In case of a direct stroke down the flue and in a small cabin a sideflash would very likely occur, with possible injury to any individual in the vicinity. Another point is that bends in lightning conductors such as around eaves or at connections with tower bolts, etc., should have a radius of at least 8 inches.

Individual drawings to accompany the plans for each type of tower may be prepared from these specifications; however, the erector should be thoroughly familiar with this handbook and have a copy available for reference, since not all details that may arise can be included on a single drawing.

CHAPTER II - GENERAL INSTRUCTIONS

Standard protective systems for several types of structures are illustrated by figures 12-23. To answer questions that may arise, the following sections discuss rules which apply in all cases.

A. Ground Systems. Ground connections are a very important part of the system. One must be provided for each down conductor. Because the soil on lookout points is usually rocky, it is difficult to bury a ground to the preferred depth of at least 10 feet; therefore, the practice will be to use the trench-type ground connection. This calls for a narrow trench dug diagonally away from each corner of the structure, with the lower end of each conductor laid straight in it to a length of 12 feet and buried 3 feet deep. If rock is encountered, less depth and greater length are called for. If the location is on bare surface rock only, conductors each 80 to 100 feet long laid on the surface and weighted down with stones will be sufficient. If, in addition, about 200 square feet of spreadout chicken-wire netting, interwoven telephone wire, or other similar material is connected to the end of each ground wire and weighted down with rocks, additional protection will be provided. The more extensive the underground metal available, the more effective the protection. All the ground conductors should be joined together by a conductor buried in the trench surrounding the building or tower. Four grounds at opposite points of the structure will be provided except in the case of the observation mast.

Water-system pipes are excellent for grounding purposes if they pass through extensive regions of moist soil. If so used, however, they are also sources of danger to anyone who may be in contact with the ground and with the pipe at the instant of a stroke to a connected tower. The person's body might then serve as one of the discharge points from pipe to ground. A safe rule, therefore, is to avoid the use of water pipes as lightning protective system grounds unless the connection between protective system and pipe can be made at least several hundred feet from the nearest building where the pipes come to the surface of the ground.

The use of charcoal, salt, or other chemical treatment of buried ground conductors is generally unnecessary and is not recommended.

B. Conductors. Conductors will be of copper with a weight of not less than 187.5 pounds per thousand feet. The form of the material is of no consequence except that copper cables should not include wires smaller than No. 17 AWG. When conductors already installed are of heavy galvanized steel weighing not less than 320 pounds per thousand feet with wires not smaller than No. 14 steel wire gage in cables, no change need be made. No. 2 B&S gage copper wire

weighs 201 pounds per thousand feet, 000 SWG iron galvanized wire weights 354 pounds per thousand feet. Soft drawn-copper wire is more easily worked into place than are the stiffer forms. This should be borne in mind when ordering material.

C. Bends. The conductor shall run as directly as possible to the ground. When bends are absolutely unavoidable, they should have a radius of at least 8 inches and no angle in excess of 90°.

D. Connections. Corrosion resistance of lightning conductor materials should be emphasized at this point. Corrosion, either soil or atmospheric, should be forestalled whenever possible because it leads to deterioration and consequent impairment of the initial degree of reliability of a protective system. Certain combinations of metals and alloys of metals are not susceptible to marked corrosion when exposed to moisture. Experience with metal structures and telephone construction should be used as a guide in the selection of appropriate materials that have greatest corrosion resistance.

Do not join metals of different kinds when this can reasonably be avoided, as electrolytic action may corrode or destroy the connections. When such connections are necessary, they should be soldered or kept protected with aluminum paint. All fasteners should be of the same material as the conductor or of such nature that there will be no electrolytic corrosion. Copper staples on copper fasteners for attaching conductors to steel frames should be used if practicable. Fastenings must be tight and not more than 3 feet apart. Do not attempt to insulate lightning conductors where they come in contact with a structure.

E. Splices. Splices shall be permitted in the vertical down conductors provided they are made with a compression-type sleeve splice such as the Nicopress. Compression-type splices are also recommended for use in splicing continuous horizontal conductors around a structure. However, the use of U connectors in the horizontal conductors is permissible. Compression-type splices are to be preferred for any splicing or conductor-joining requirement when the two wire to be joined are of sizes and configurations that will permit using standard sleeves. The U, V, and W connectors are primarily for use in bonding or otherwise joining irregular-shaped or -sized metal objects to the lightning conductor cage when the sizes and configurations of objects or conductors are such that standards sleeves cannot be used.

F. Chimneys

1. Metal. Each metal chimney, such as a stovepipe or flue, shall be connected above the roof to the nearest lightning conductor by means of a connector band or ribbon connector.

2. Nonmetal. Brick or tile chimneys shall be provided with a T-7 air terminal securely fastened to the nearest lightning conductor.

G. Metal Objects. To prevent sideflashes, all large metal parts within, adjacent to, or part of a structure will be solidly connected to the protective system conductors at their point of nearest approach. Nevertheless, at the instant of a stroke it is possible for considerable potential difference to appear between objects connected to different parts of the protective system. This circumstance can result in shock to a person who happens to be touching two such objects when a stroke occurs.

An approach can be made toward equalizing these potentials by connecting all objects to a central point of the protective system. Where there is access to the under side of the floor, this central point can be located by running No. 2 B&S or larger copper conductors or equivalent under the floor between each diagonally opposite downlead of the protective system. These two wires should be solidly connected with a substantial connector at the point where they cross. Often this will occur directly under the fire finder. All metal objects should then be connected to this central point by No. 6 B&S or larger copper conductors. These conductors should pass through the floor, then under it by the shortest possible path to the central point. All objects also should be connected to the nearest conductor of the protective system at its point of nearest approach as mentioned above. Where possible, this interconnecting conductor should be continuous from protective system to object to central point.

If metal cots or wooden-frame cots having metal springs are used, the metal parts should be connected to the protective system at both ends of the cot, preferably at the level of the springs. It is desirable to use a single conductor for these two connections, running the conductor from the nearest protective system wire direct to the bed, thence along the frame of the bed and to the nearest protective wire at the other end of the bed. This conductor should also be connected to the central interconnecting point described above.

A stove is a source of considerable danger, since its chimney may pass through the roof of the structure and is connected to the protective system above the roof. The body of the stove, therefore,

must be connected to the nearest downlead, preferably at the level of the working surface of the stove.

In the case of a building resting on the ground, a ground rod should be driven beneath the floor and connected to the stove. However, the stove should never be grounded to a ground rod unless it is also connected to the nearest conductor of the lightning protective system.

Stoves with chimneys should not be used while there appears to be danger of a nearby lightning stroke. The use of coal-oil stoves during thunderstorm weather is recommended, as they have no chimneys to serve as terminals for the stroke.

Methods of connecting metal objects within the cab and of making the conductor crossties beneath the floor are illustrated by figures 1-6.

H. Fire Finders. Metal fire-finder stands or pedestals are not recommended. However, when used, they should be securely bonded at their base to the center point of the under-floor diagonal conductors.

When metal fire finders are mounted on wood stands, grounding of the finder depends entirely upon whether there is any other grounded object immediately adjacent to, on, or within the stand.

If there are no other grounded objects on the stand (such as radio or telephone), do not ground the finder.

If the stand contains or carries other grounded objects, such as a telephone or radio, the fire-finder track or frame (any nonmovable part) should be securely bonded to the under-floor diagonals. This bonding lead should be common to all metal objects on the stand, that is, separate ground leads should not be used for each object.

I. Floors. All exposed cabins will have wood floors. Electrical connections between metal objects and the central point of the diagonal ties under the floor shall be made beneath the floor. These conductors shall be kept at least 6 inches below the actual inside floor surface. This can usually be automatically accomplished by attaching such conductors to the under side of the floor joist.

J. Adjacent Poles. The telephone pole nearest to each cabin and station will be provided with a lightning ground wire (FSH2 5622.1, Telephones, chapter on Lightning Protection).

Placing of flagpoles on exposed points or towers should be avoided. When used, wooden poles must have a T-7 air terminal and one ground conductor. Metal poles do not require an air terminal or down conductor, but the pole must be grounded by means of a substantial ground clamp. When pipe is used, it must be either copper or galvanized iron and 1 inch shall be the minimum inside diameter. Anemometers or other instruments on exposed points should be located within the protective cone of the closest air terminal; that is, the horizontal distance to the air terminal should not be greater than twice the vertical distance from the top of the anemometer to the top of the air terminal.

K. Other Wires. Telephone, radio, and similar wires should enter the building at or below floor level. Near this level the lead-in wire or wires shall be brought close to the protective system and a reliable arrester shall be connected between each line wire and the protective system. Drawings of representative installations for such telephone wires and broadcast receiver antennas are shown in figure 1.

L. Radio Antennas. Antennas for communication equipment in lookouts should be installed to comply with the general cable routing pattern shown by figures 1 and 6. The principal points to be observed are:

1. Regardless of actual mounting location of the antenna, bring coaxial transmission lines into the cab under the floor and follow the diagonal crosstie to a point directly, or as nearly so as possible, below the location of the radio equipment.

2. Do not drape control cables across the cab on the inside. Follow the illustrated practice of running cables under the floor and lashing them to the under-floor crosstie conductors.

3. Whenever possible, keep the radio equipment and controls concentrated in the corner of the cab nearest the antenna and the point of grounding of the equipment case.

Antennas for broadcast receivers should be kept within the cone of protection offered by the tower. This can best be done by attaching the antenna wire at the floor level near the corner of the cab or catwalk by means of a common antenna strain insulator. The wire is then slanted toward the ground at such an angle that, when it is continued to the ground level, the horizontal distance from the base to the tower will not exceed the height of the tower.

The upper end of the broadcast receiver wire should be run to a standard sawtooth or other low-voltage standard telephone arrester which has been bonded as closely as possible to the corner downlead of the lightning cage at a point directly below the floor level. From here the wire must be insulated and carried along the diagonal under-floor conductors to a point directly under the location of the broadcast receiver.

As in the case of the communication equipment installation, avoid crossing the cab with the antenna wire by installing the antenna at the corner nearest the location of the receiver.

M. Lookout Telephone. See the Telephone Handbook for information on proper methods of installing telephone lightning protective devices.

N. Miscellaneous. If a balcony or catwalk is not more than 3 feet wide and has floors, floor supports, and rail entirely of wood, a conductor on the balcony rail is not required. All occupants should, however, be instructed to remain off the balcony while lightning is occurring or is probable within 5 miles. Window shutters on cabins or towers need no special protection, but shutter should not be raised above the horizontal. Support rods should be of wood or other nonconducting material.

CHAPTER III - SAFETY RULES

A. General. The following set of rules shall be posted in each lookout point:

1. Do not go outdoors or remain out during thunderstorms unless it is necessary. Stay inside the building where is is dry, preferably away from fireplaces and from stoves or other metal objects.

2. If there is any choice of shelter, choose in the following order:

a. Large metal or metal-frame buildings.

b. Dwelling or other building which is protected against lightning.

c. Large unprotected building.

d. Small unprotected building.

3. If remaining outdoors is unavoidable, stay away from:

a. Small sheds and shelters, if in exposed location.

b. Isolated trees.

c. Wire fences.

d. Hilltops and wide-open spaces.

4. Instead: seek shelter in dense woods, a grove of trees, a cave, a depression in the ground, a deep valley or canyon, or at the foot of a steep or overhanging cliff. Stay as far as possible from walls and ceilings of caves and cliffs. Avoid very moist spots therein and do not stand or sit near or against tall trees.

B. Telephone Operation. The following instructions shall be posted near all telephones in exposed structures:

1. When the storm is a mile or more away, and it is necessary to use the telephone:

a. Always stand on insulated stool.

b. Do not hold receiver tightly against ear.

c. Do not touch any metal part of telephone or building.

2. When the storm is less than a mile away:

a. Throw disconnect-grounding switch.

b. Stay away from the telephone; remain in the building, as far as possible from a window, door, other large metal object or lightning conductor.

C. Radio Operation. The following instructions shall be posted near all radio equipment located in exposed structures.

1. When the storm is more than 1 mile but less than 5 miles away:

The radio receiver may be left operating, but touching the controls of the equipment should be avoided until the storm has passed.

2. When the storm is less than 1 mile away:

It is desirable, although not essential, to shut off the master switch on the equipment.

Caution: Since shutting off the equipment involves touching the instrument panel, this should be done immediately following a local flash and the equipment thereafter avoided until the storm has passed.

These simple but desirable precautions must be rigidly adhered to by all persons occupying Forest Service lookout houses and towers. To disregard them invites possible injury to the person.

D. Typical Layouts of Grounding

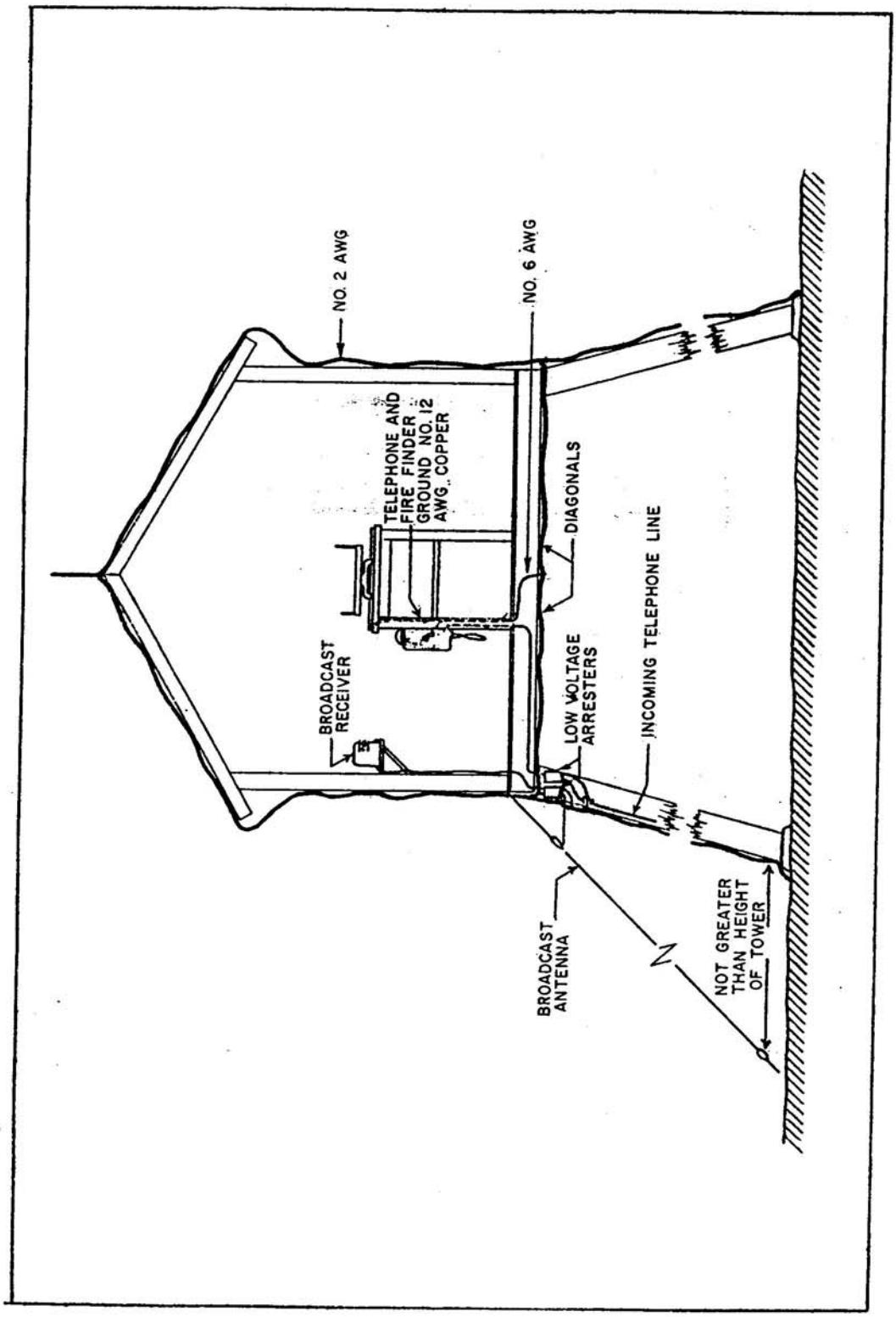


Figure 1.--Typical layout of grounding for fire finder, Forest Service telephone, and employee broadcast radio.

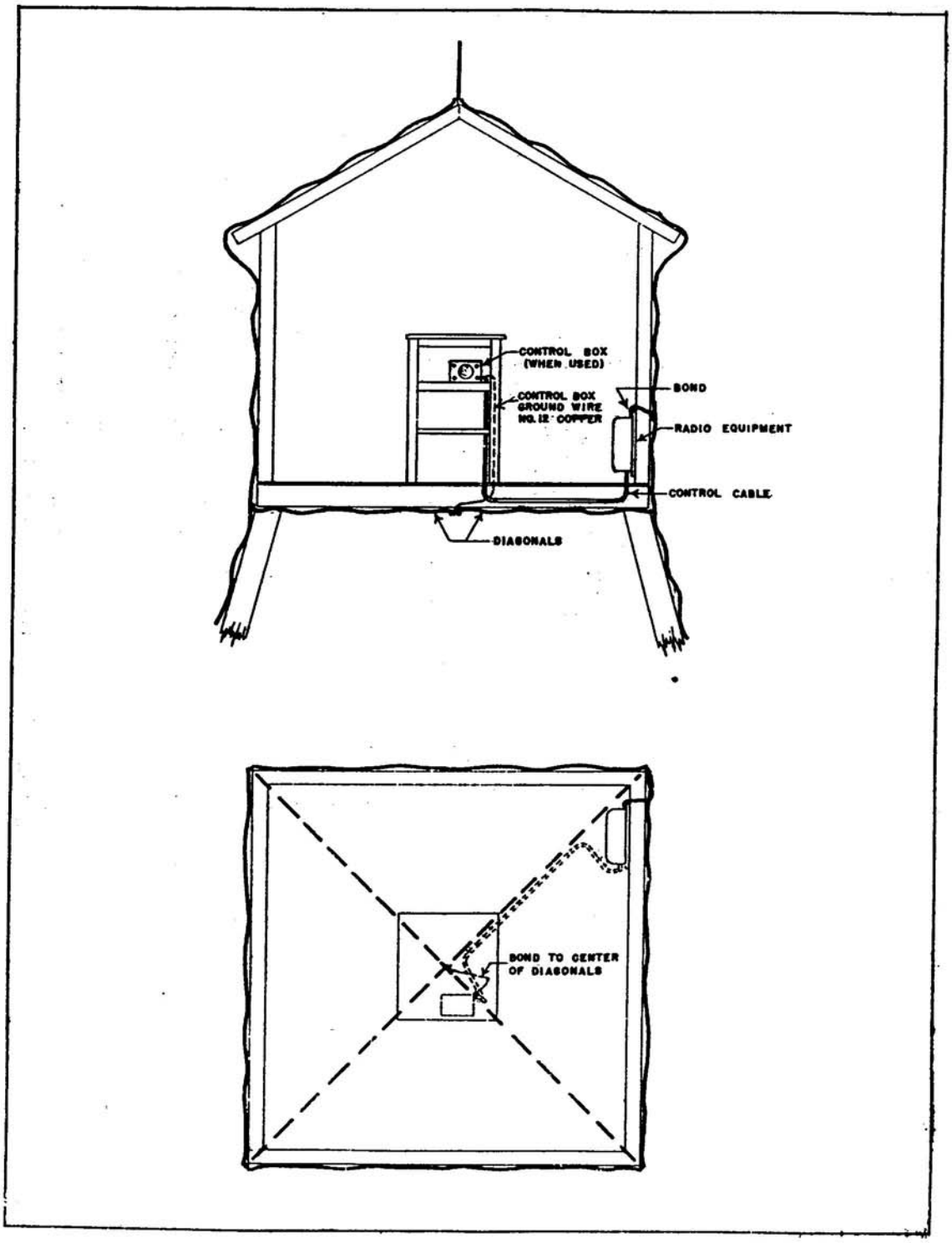


Figure 2. --Typical layout of grounding for forest radio equipment.

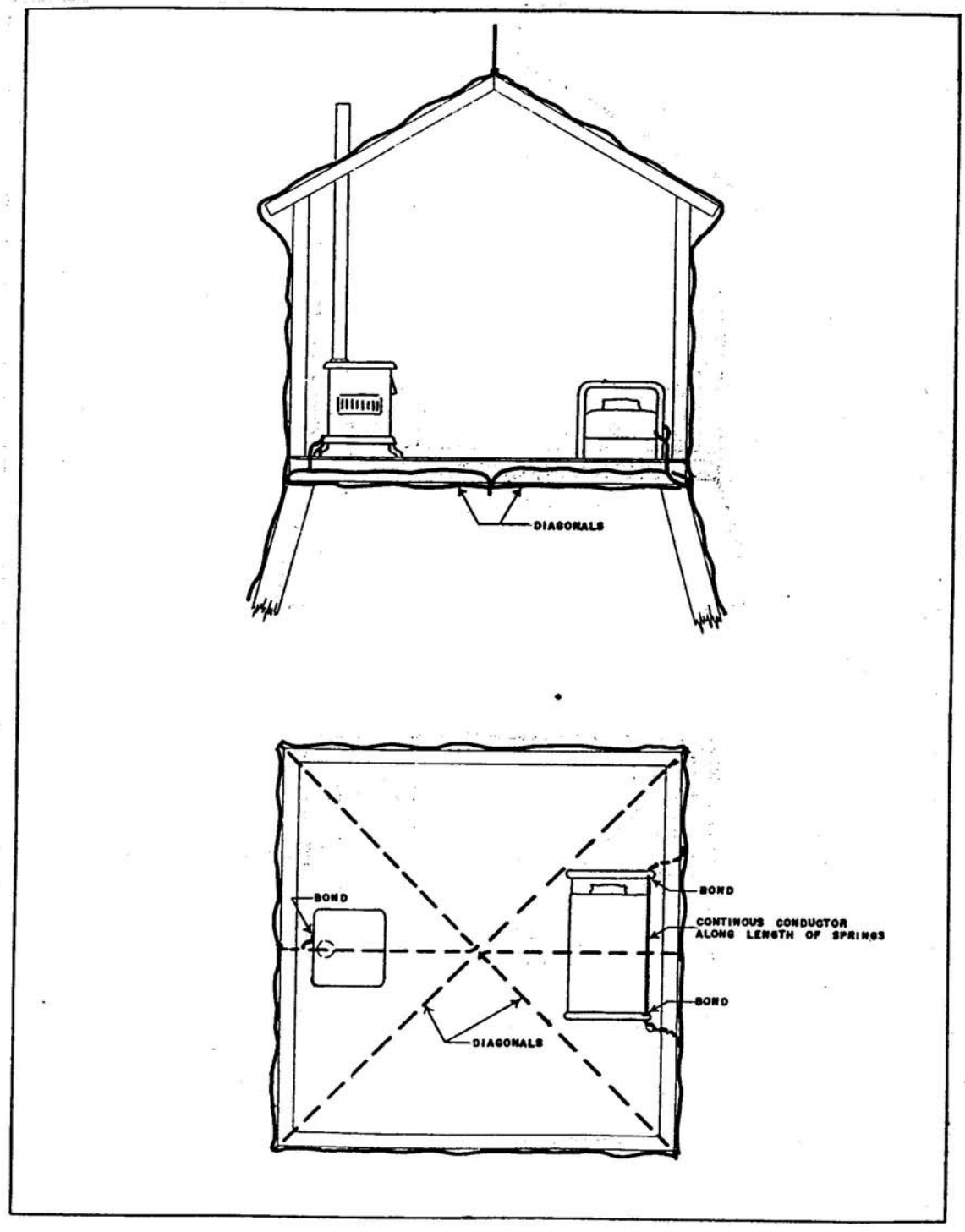


Figure 3. --Typical layout of grounding for bed and stove (center line location).

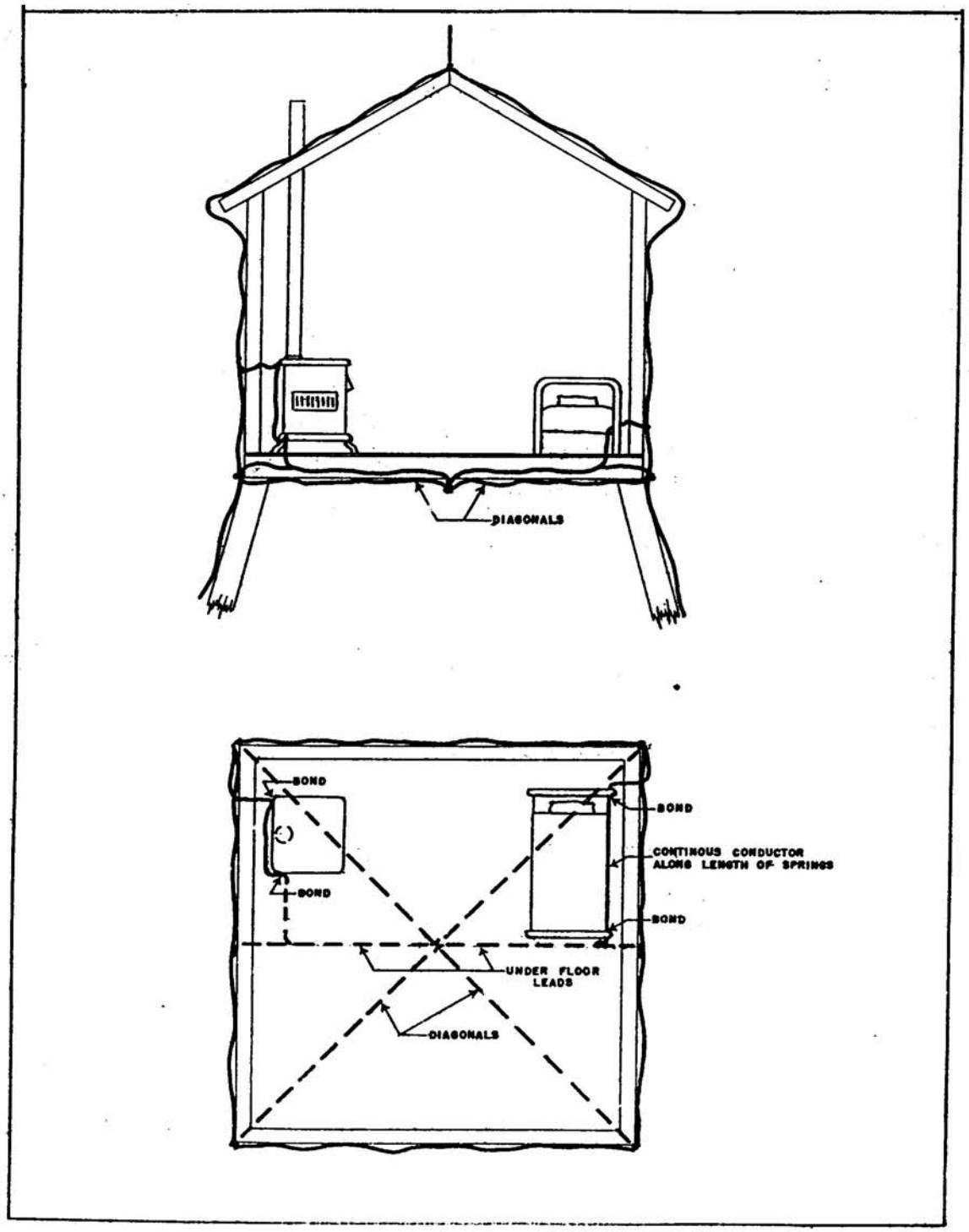
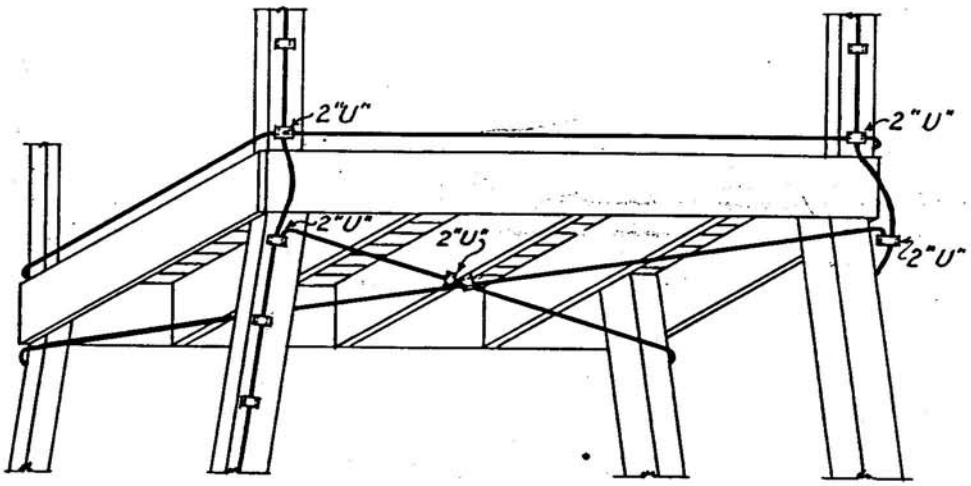


Figure 4. --Typical layout of grounding for bed and stove (corner location).



Use on all wood cabs on towers with wood floor joists. If diagonal lead must be detoured to clear trap door it should be bent in such manner as to increase its total length as little as possible.

Figure 5. --Typical layout of diagonal conductors under cab floor.

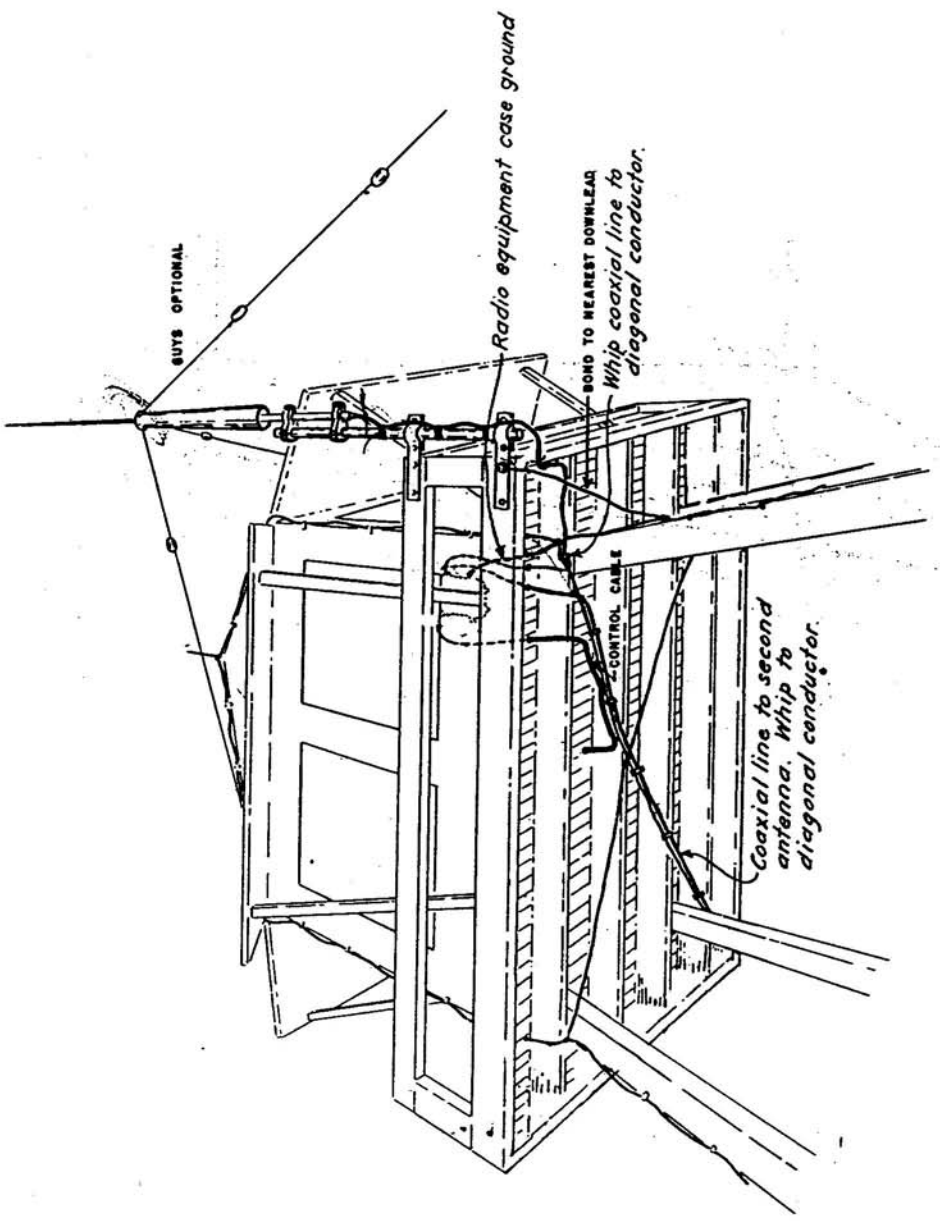


Figure 6.--Typical layout of radio antenna installation and lightning protection.

CHAPTER IV - INSTALLATION

A. Table of Material Weights. In preparing the approximate weight for each installation, the following figures were used:

Item	Weight
Type T-5 air terminal	5-1/4 No.
Type T-7 air terminal	3-1/4 No.
Type U connectors	4-1/2 oz.
Type V connectors	5 oz.
Type W connectors	6 oz.
Conductor straps	1 oz.
Connector bands	8 oz.
Ribbon connector	1 No. 10 oz. per 8 ft.
1" x 5/16" copper-plated stove bolts with nuts and copper-plated 1/8" x 1/16" spring washers	25 per lb.
2" x 5/16" copper-plated stove bolts with nuts and copper-plated 1/8" x 1/16" spring washers	14 per lb.
1" x No. 8 RH brass wood screws	7 per oz.
No. 12 coppered market wire	33 ft. per lb.
No. 2 B&S gage SD bare solid copper wire	5 ft. per lb.

B. Connectors, Terminals, and Typical Applications

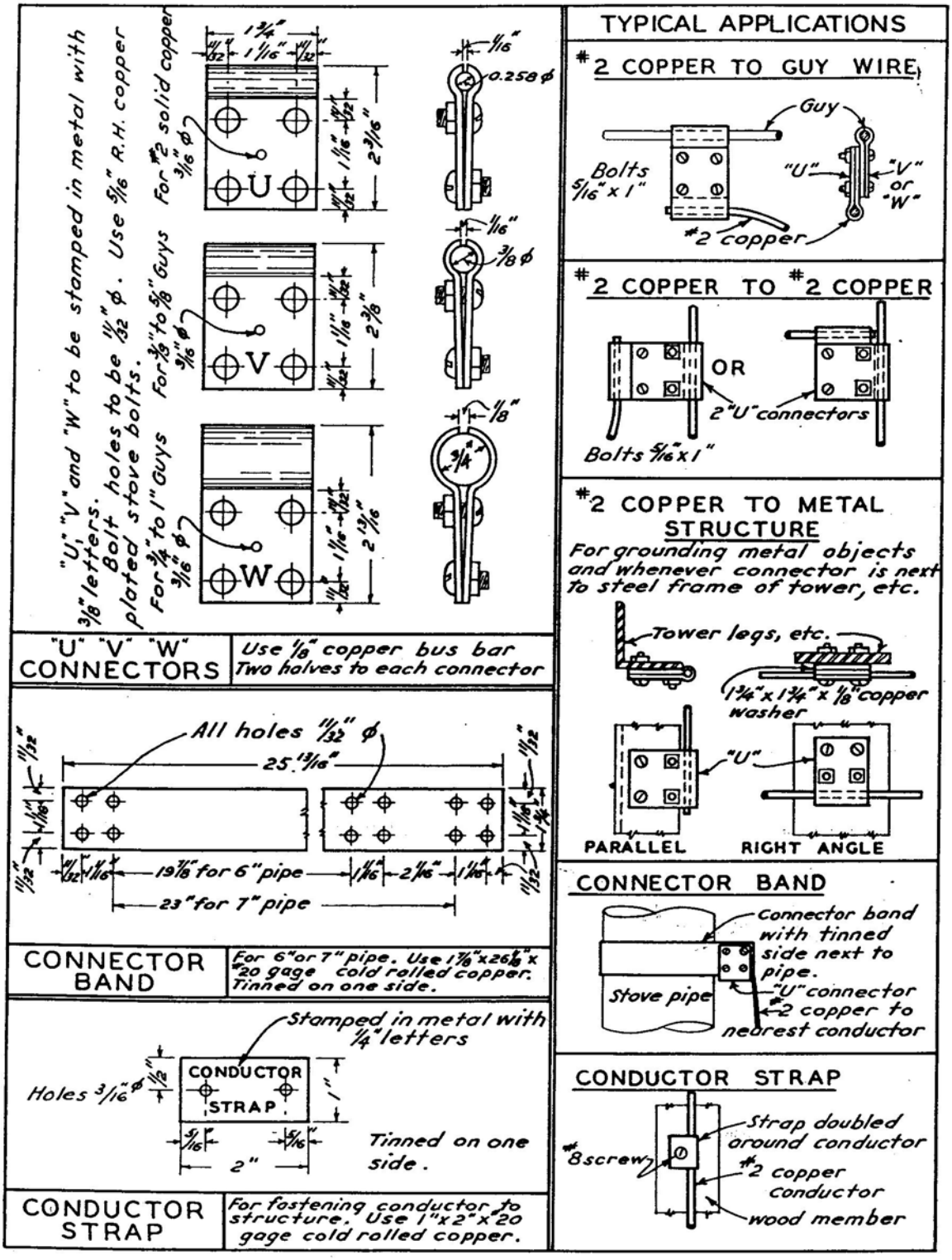


Figure 7. --Connectors.

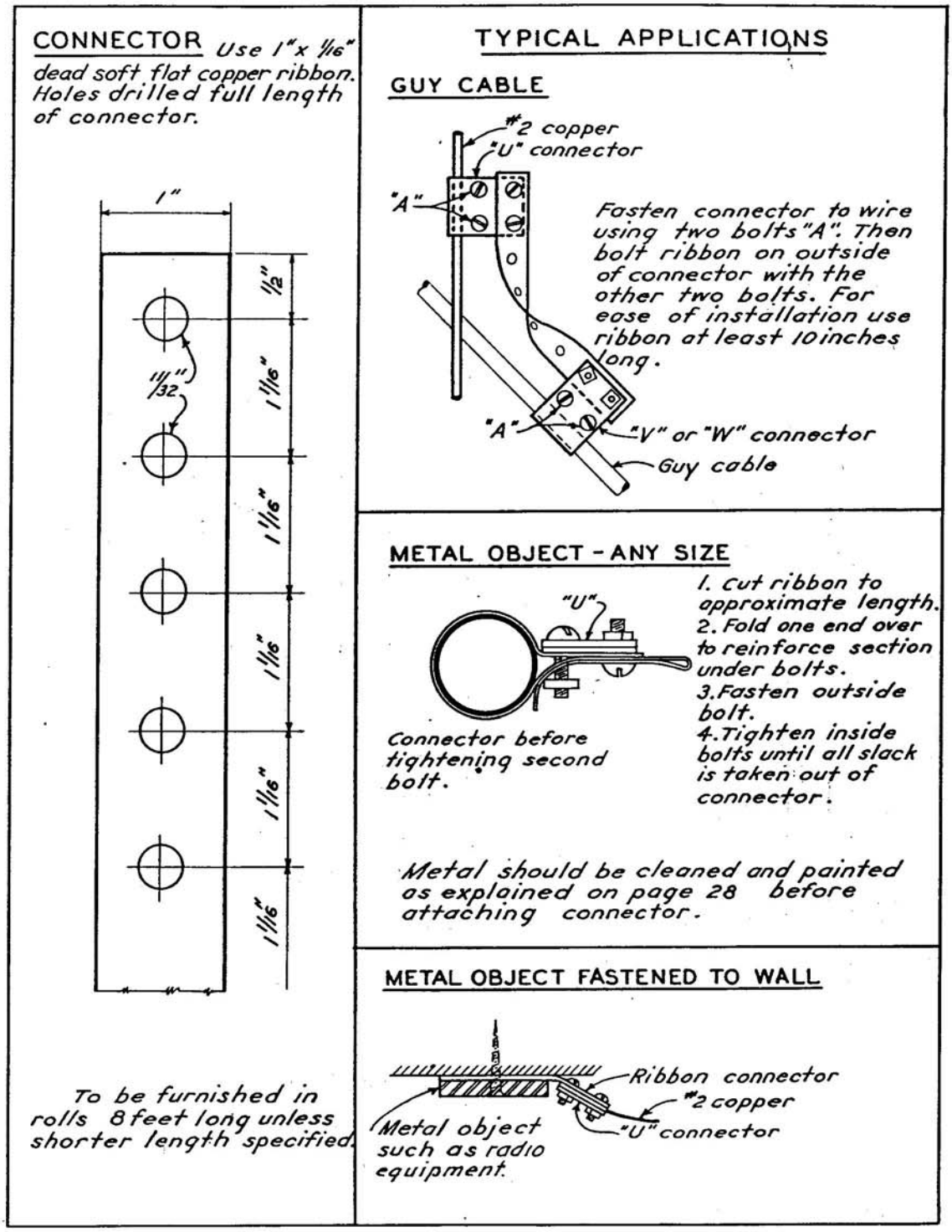


Figure 8. --Ribbon connector.

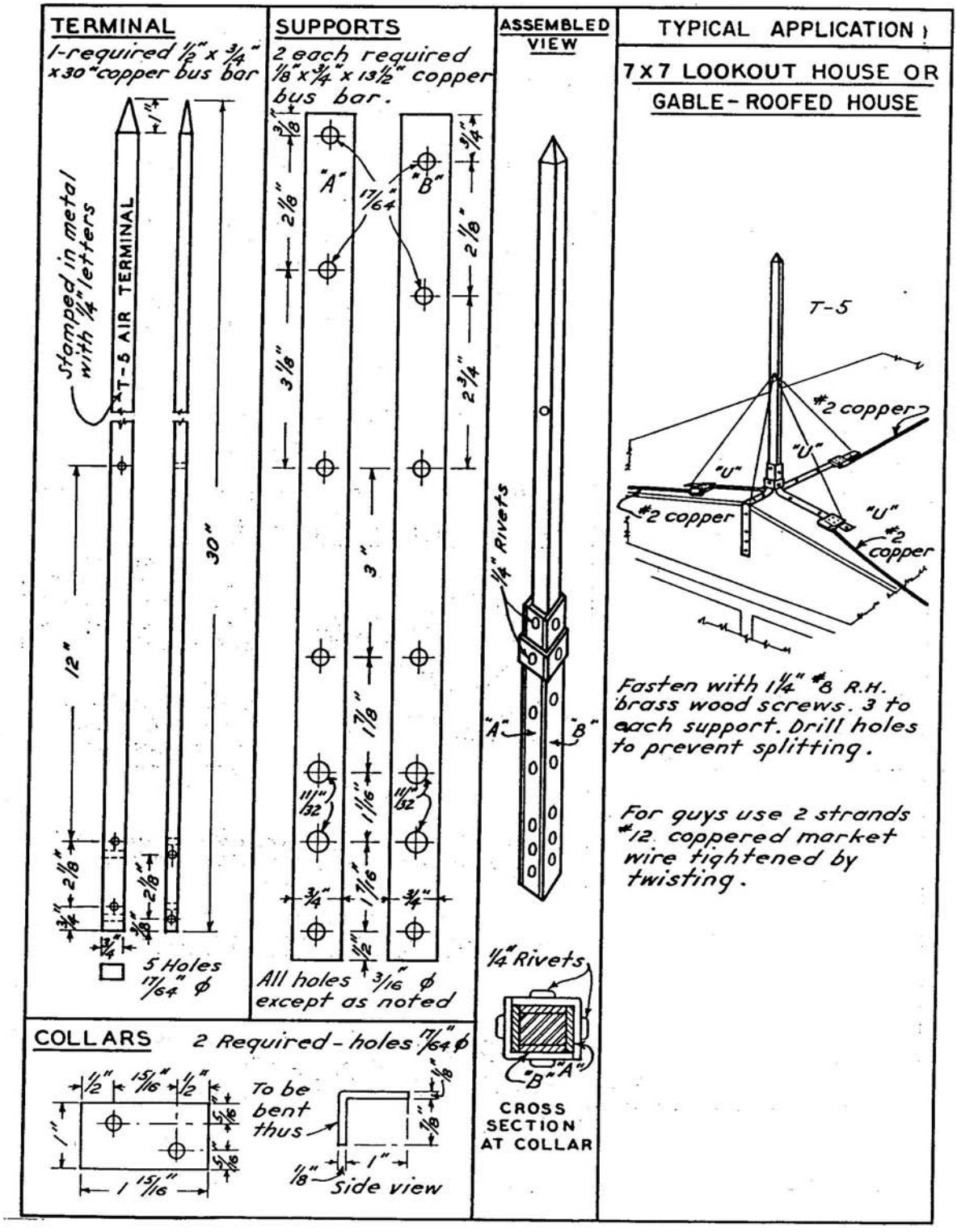


Figure 9. --T-5 Air Terminal.

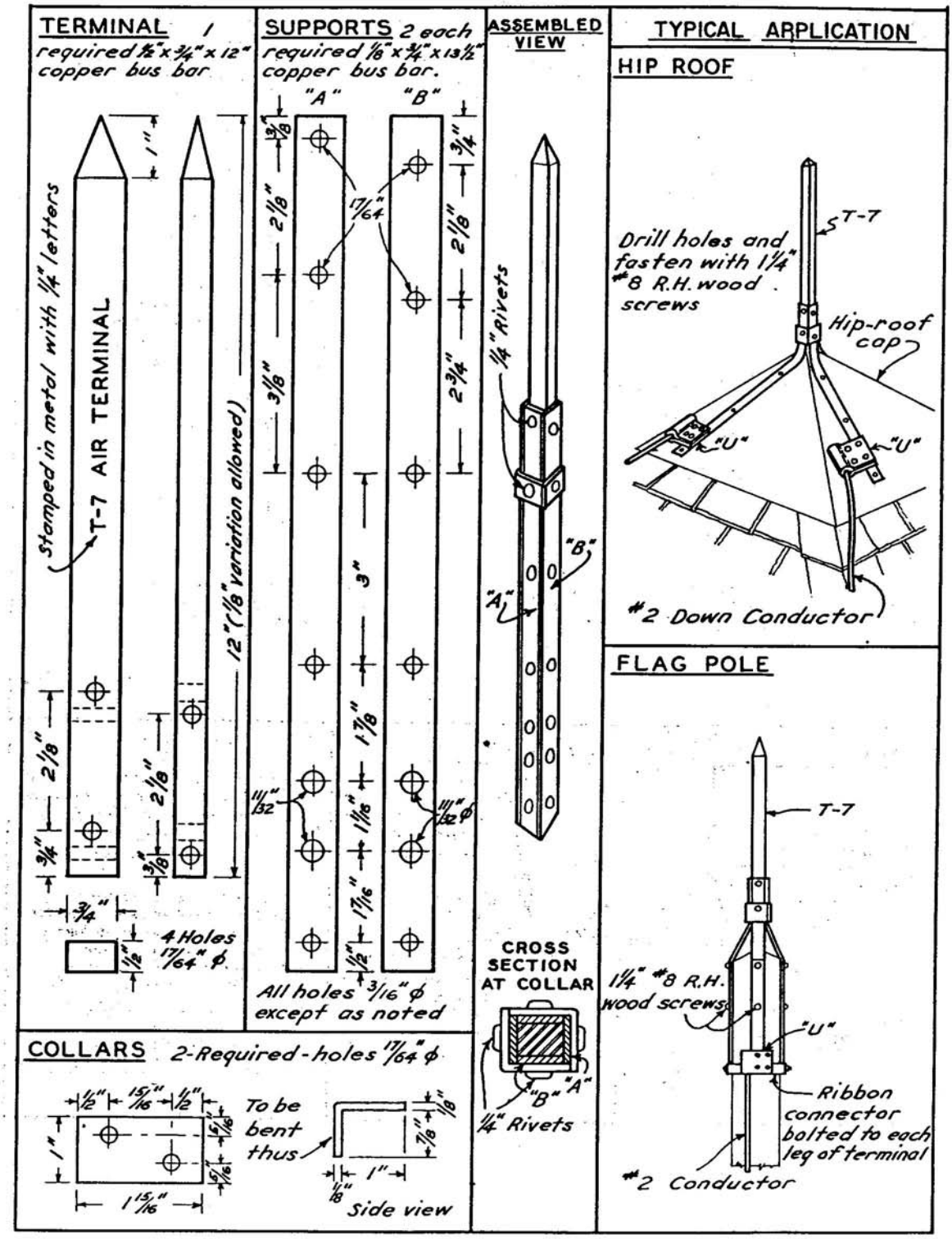


Figure 10. --T-7 Air Terminal.

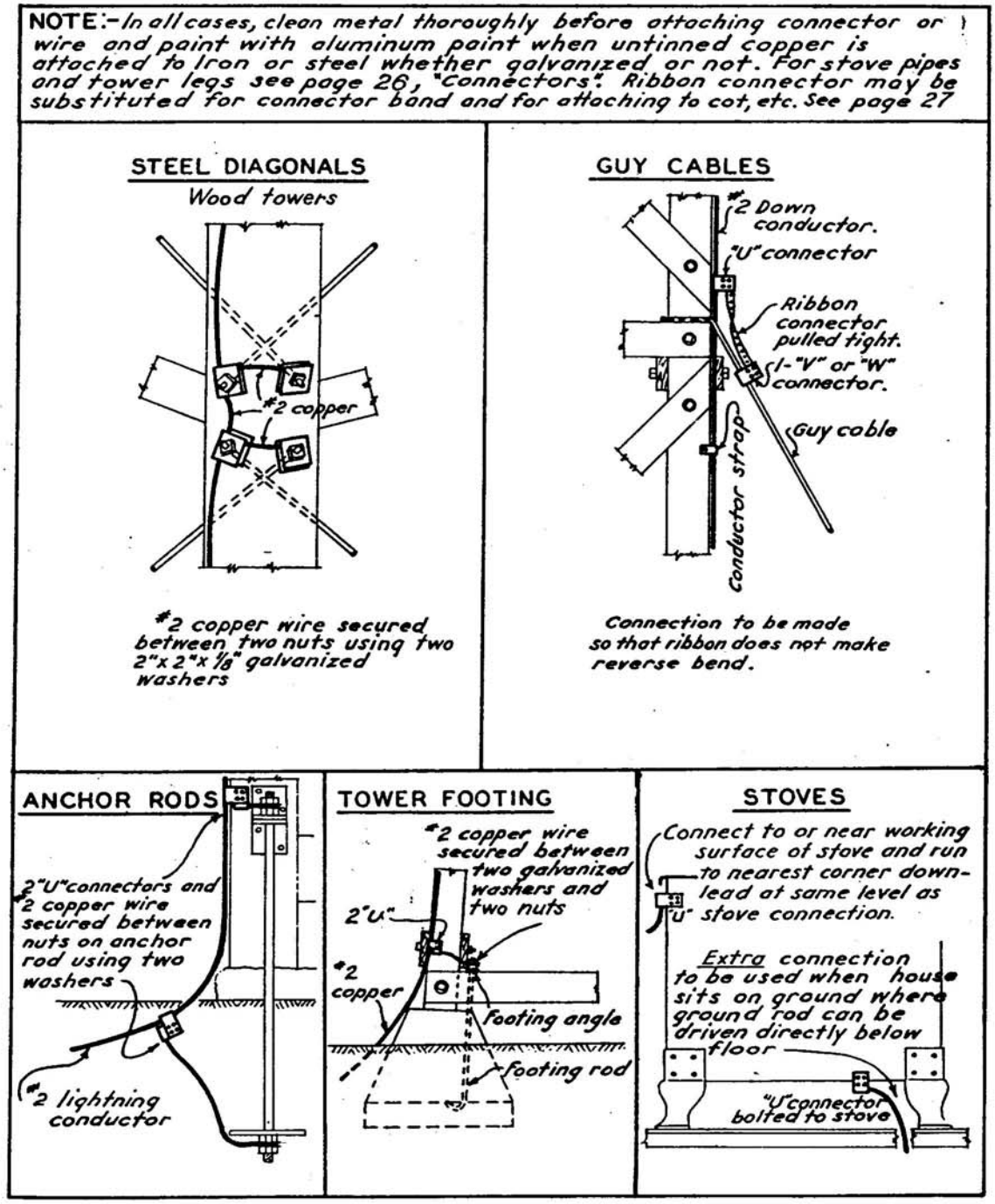


Figure 11. --Grounding metal objects.

C. Detail Drawings and Material Lists

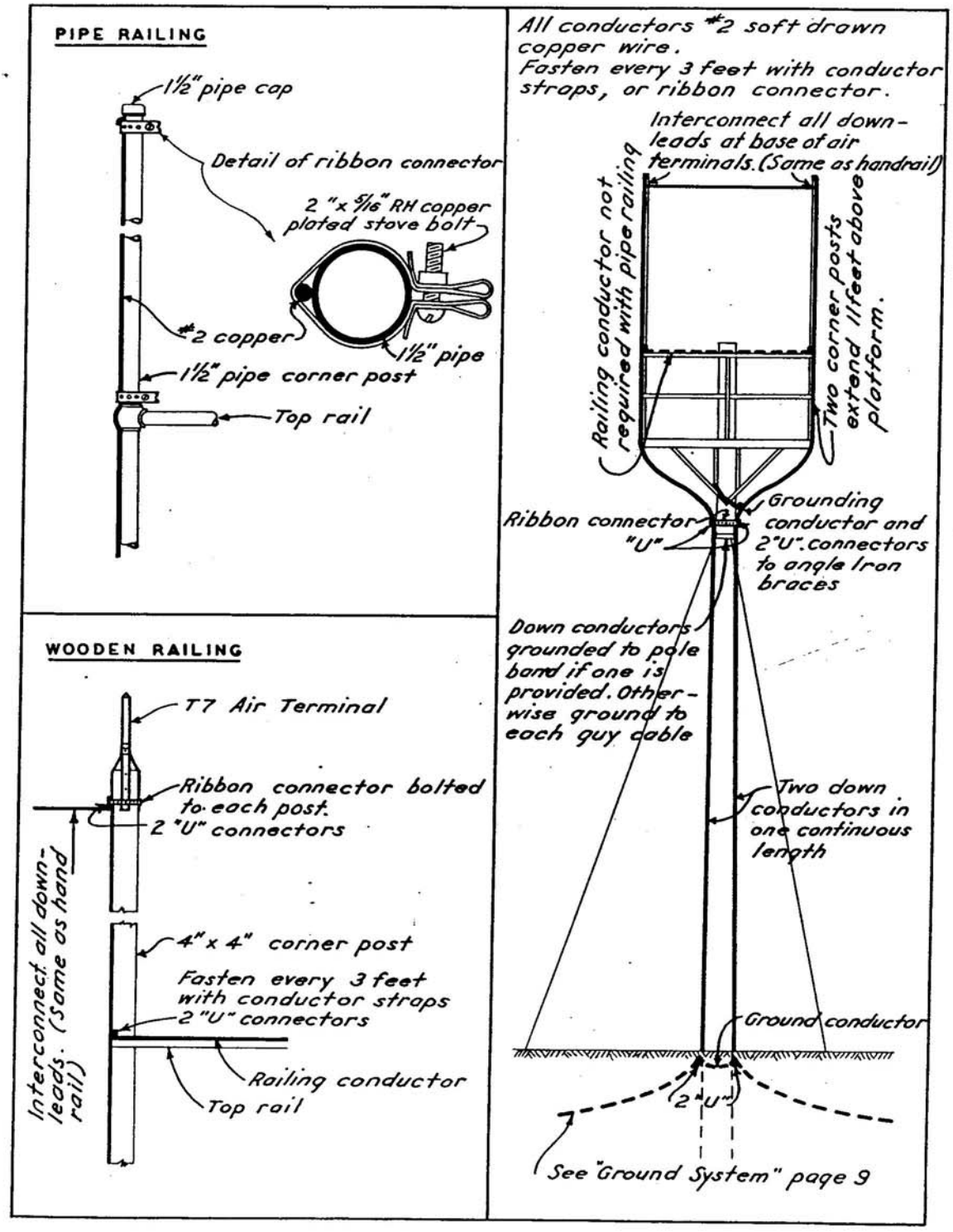


Figure 12. --Observation mast.

MATERIAL LIST

OBSERVATION MAST

Quantity wood railing	Item
2	Type T-7 air terminals (assembled)
18	Type U connectors
3	Type V connectors
8 ft.	Ribbon connector
60	1" x 5/16" copper-plated stove bolts with nuts and 1/8" x 1/16" copper-plated spring washers
45	Conductor straps
80	1" x No. 8 RH brass wood screws
65 lbs.	No. 2 B&S gage SD bare solid copper wire

Approximate total weight, 85 lbs.

Pipe railing	Item
12	Type U connectors
3	Type V connectors
16 ft.	Ribbon connector
30	1" x 5/16" copper-plated stove bolts with nuts and 1/8" x 1/16" copper-plated spring washers
10	2" x 5/16" copper-plated stove bolts with nuts and 1/8" x 1/16" copper-plated spring washers
35	Conductor straps
40	1" x No. 8 RH brass wood screws
55 lbs.	No. 2 B&S gage SD bare solid copper wire
1/4 pt.	Aluminum paint with small brush for same

Approximate total weight, 68 lbs.

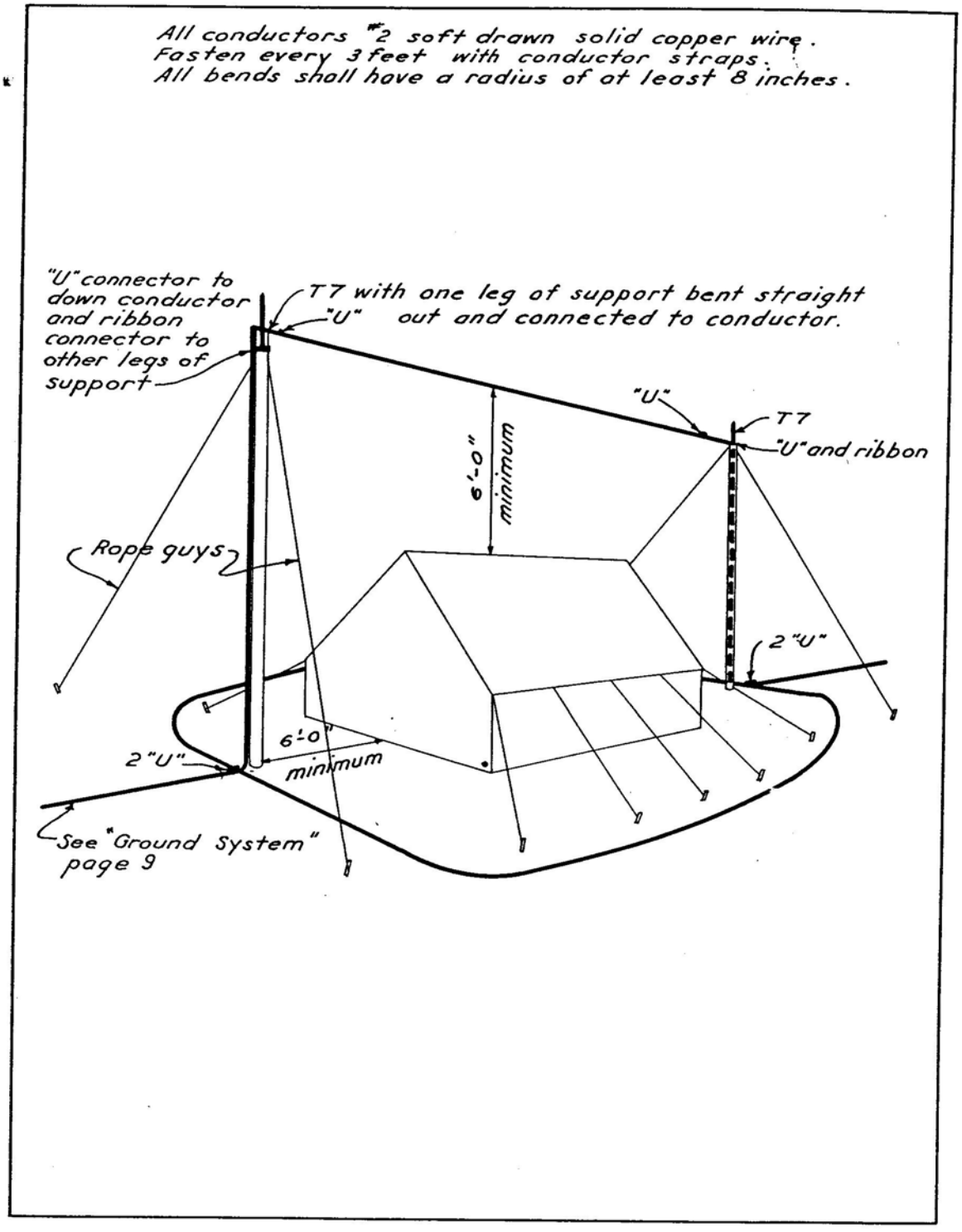


Figure 13. --Tent on exposed point.

MATERIAL LIST

TENT ON EXPOSED POINT

Quantity	Item
2	Type T-7 air terminals (assembled)
8	Type U connectors
26	1" x 5/16" copper-plated stove bolts with nuts and 1/8" x 1/16" copper-plated spring washers
30	1" x No. 8 RH brass wood screws
4 ft.	Ribbon connector
15	Conductor straps
70 lbs.	No. 2 B&S gage SD bare solid copper wire

Approximate total weight, 82 lbs.

Types of Tower

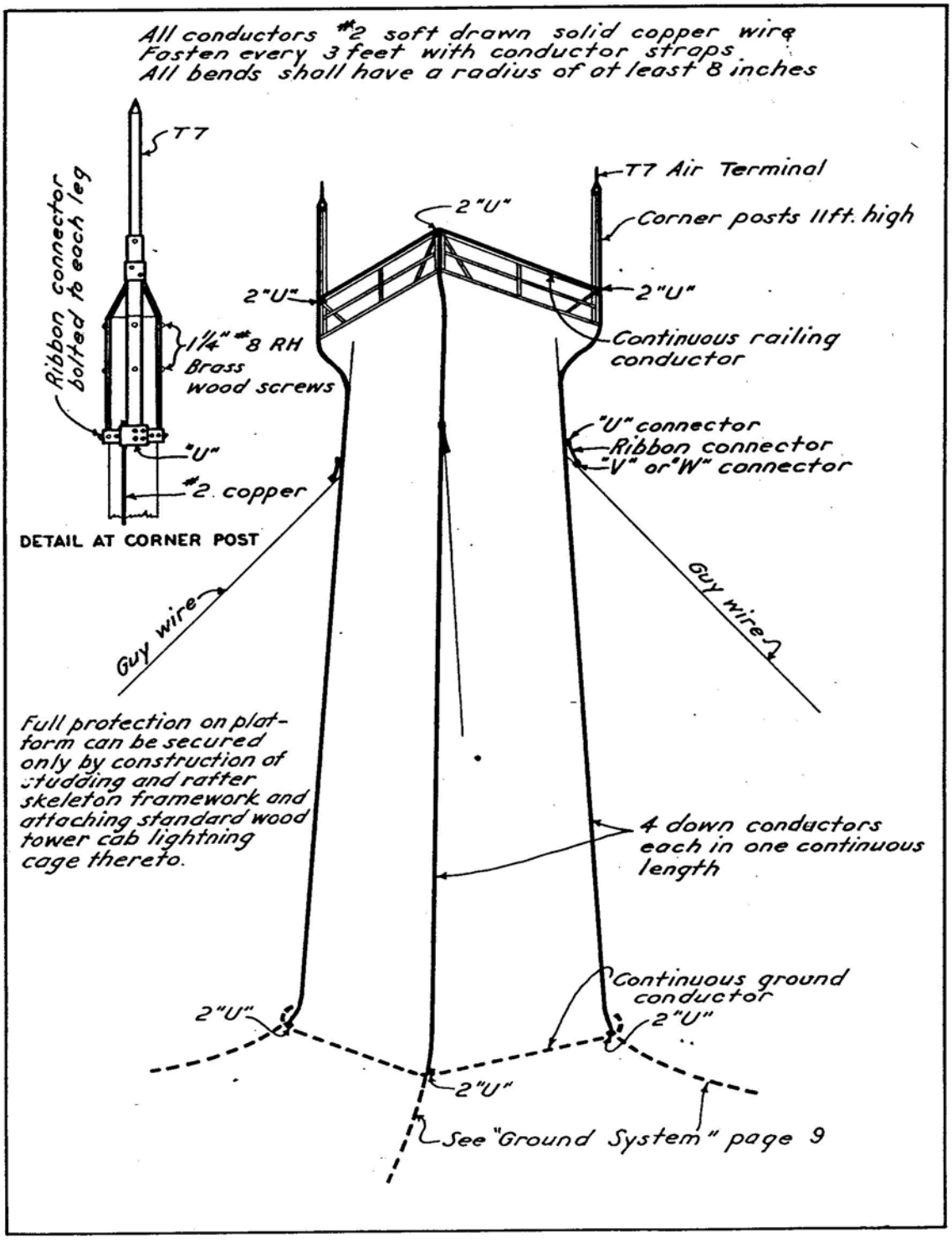


Figure 14.--Wood tower with open platform.

MATERIAL LIST

WOOD TOWER WITH OPEN PLATFORM

Quantity	Item
2	Type T-7 air terminals (assembled)
28	Type U connectors
84	1" x 5/16" copper-plated stove bolts with nuts and 1/8" x 1/16" copper-plated spring washers
110	12" x No. 8 RH brass wood screws
8 ft.	Ribbon connector
70	Conductor straps
110 lbs.	No. 2 B&S gage SD bare solid copper wire
4	Type V or W connectors (type dependent on size of guy wire)

Approximate total weight, 136 lbs.

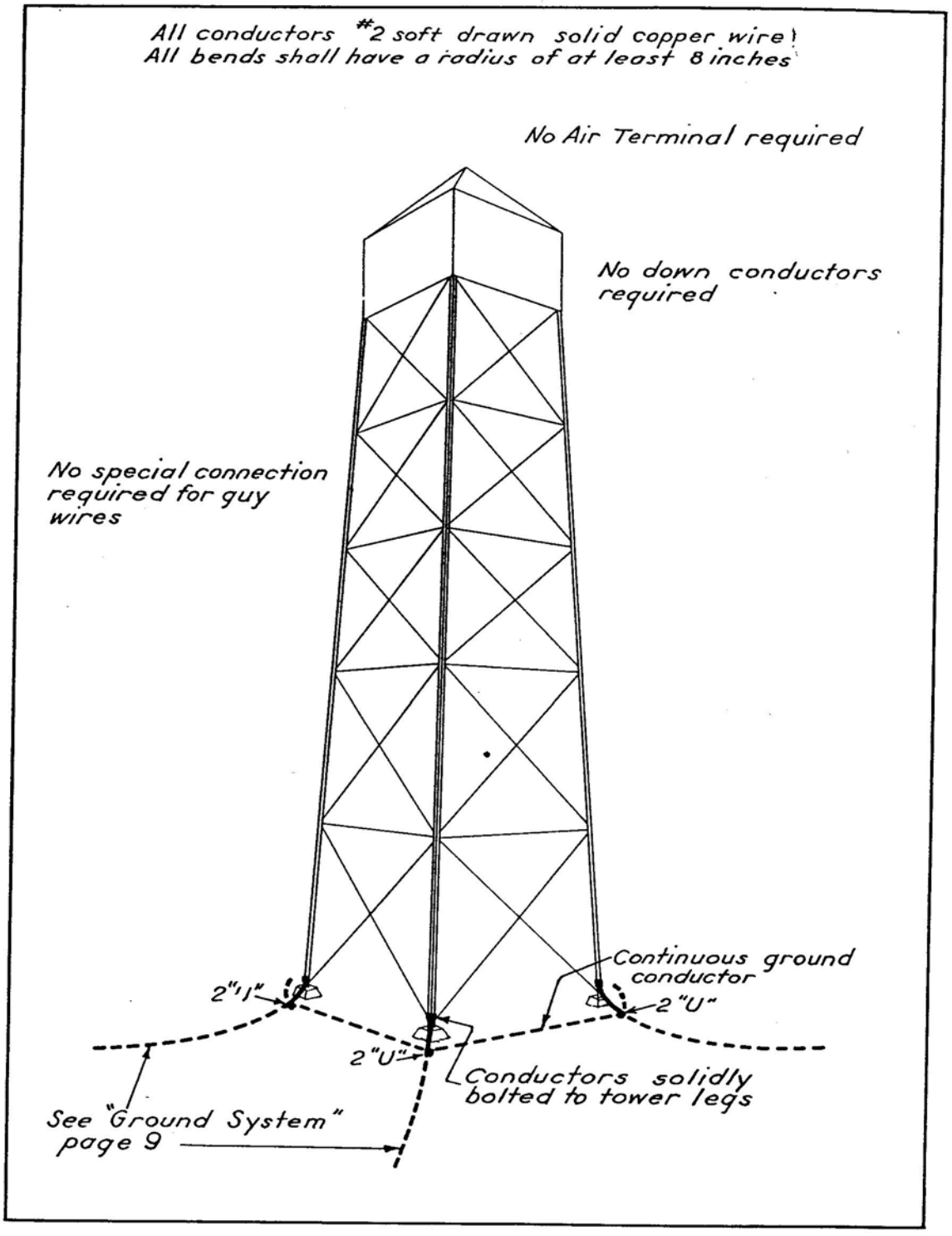


Figure 15. --Steel tower with steel cab.

MATERIAL LIST

STEEL TOWER WITH STEEL CAB

(All heights with or without guys)

Quantity	Item
12	Type U connectors
32	1" x 5/16" RH copper-plated stove bolts with nuts and 1/8" x 1/16" copper-plated spring washers
75 lbs.	No. 2 B&S gage SD bare solid copper wire

Approximate total weight, 80 lbs.

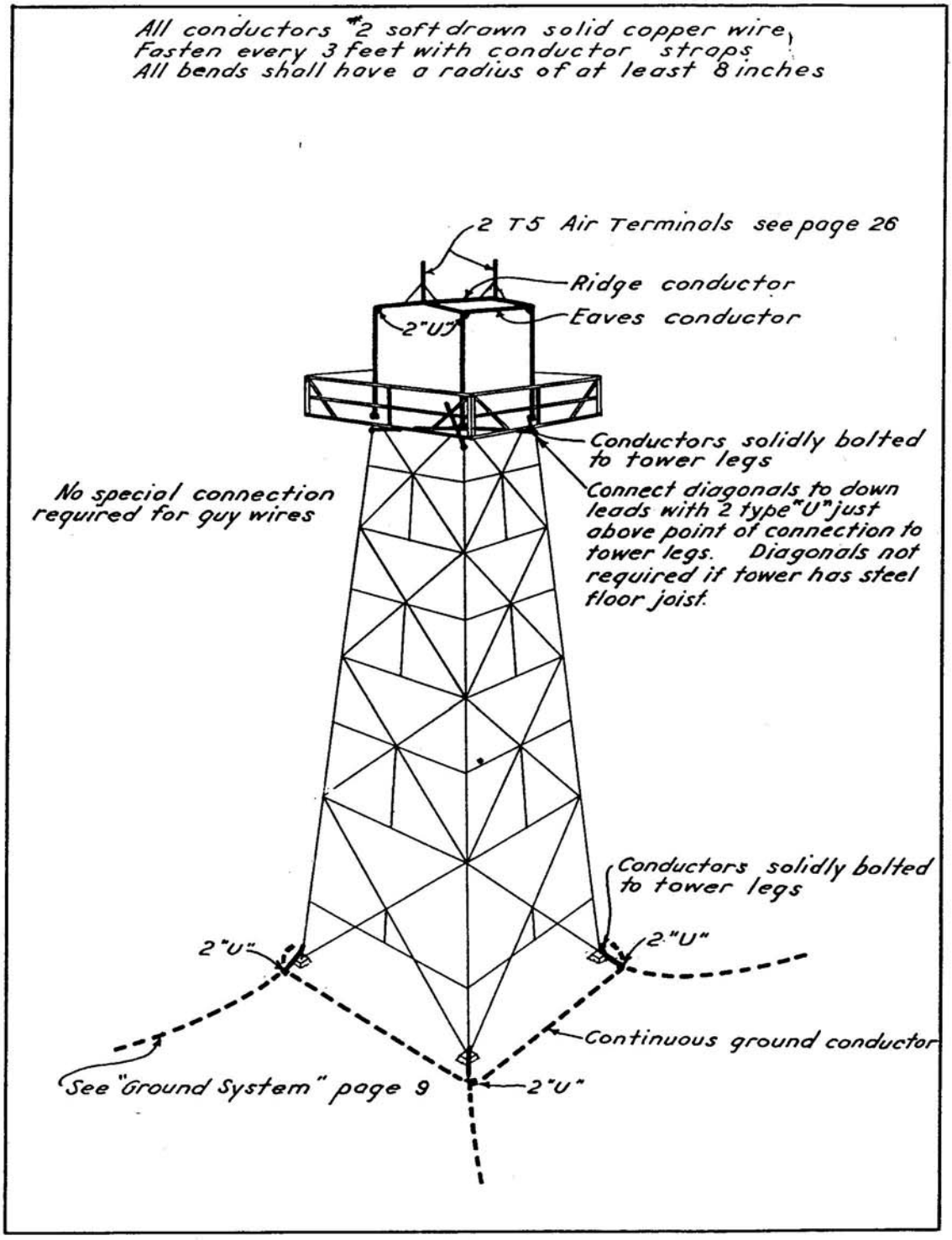


Figure 16. --Steel tower with 7- by 7-foot or flat-roofed wood cab.

MATERIAL LIST

STEEL TOWER WITH 7-BY 7-FOOT OR FLAT-ROOFED WOOD CAB

(All heights with or without guys)

Quantity	Item
2	Type T-5 air terminals (assembled)
34	Type U connectors
70	1" x 5/16" copper-plated stove bolts with nuts and 1/8" x 1/16" copper-plated spring washers
50	1" x No. 8 RH brass wood screws
25 ft.	No. 12 coppered market wire
22	Conductor straps
90 lbs.	No. 2 B&S gage SD bare solid copper wire
1/4 pt.	Aluminum paint with small brush for same

Approximate total weight, 117 lbs.

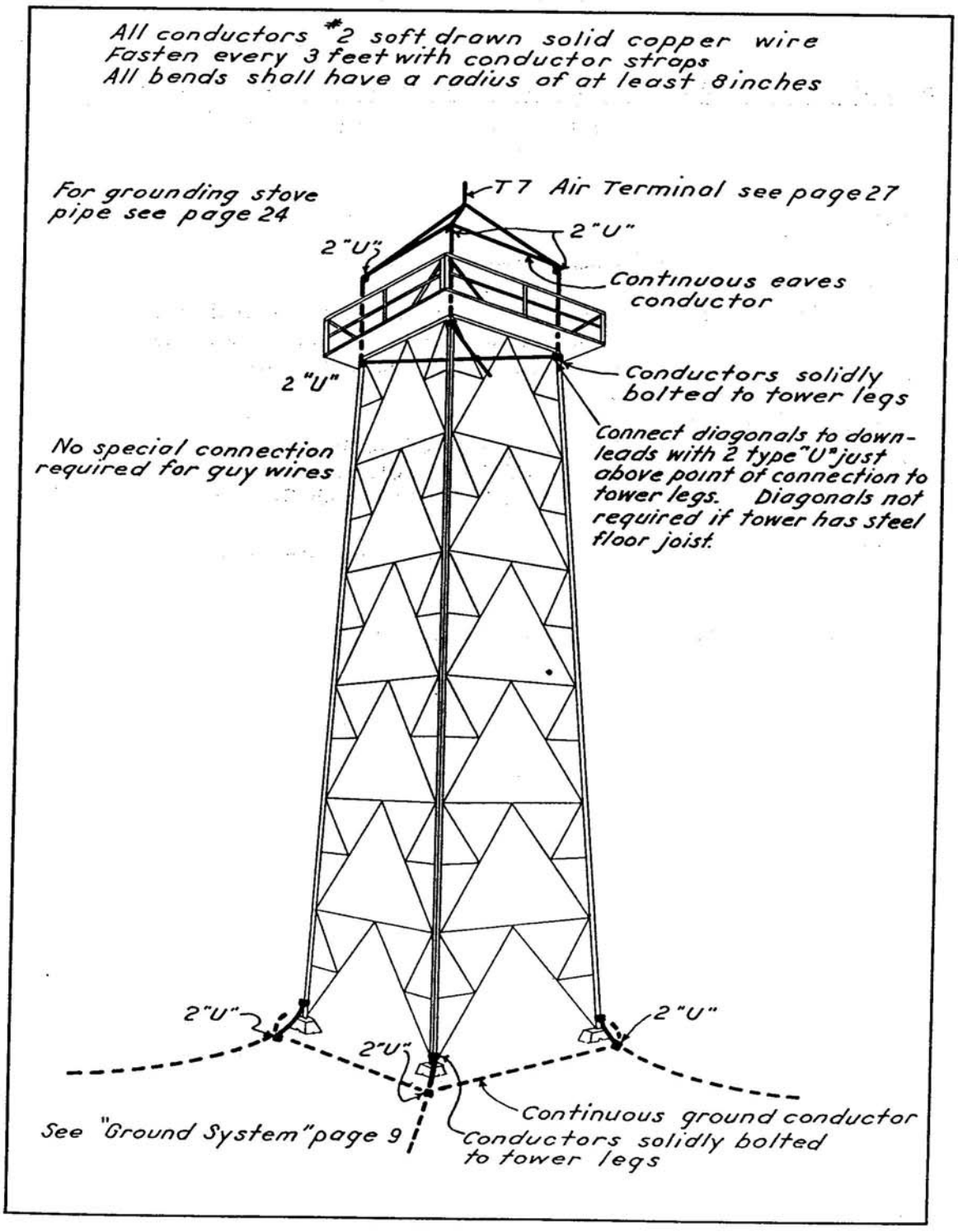


Figure 17. --Steel tower with 14- by 14-foot or hip-roofed wood cab.

MATERIAL LIST

STEEL TOWER WITH 14- BY 14-FOOT OR HIP-ROOFED WOOD CAB

(All heights with or without guys)

Quantity	Item
1	Type T-7 air terminal
50	Type U connectors
130	1" x 5/16" copper-plated stove bolts with nuts and 1/8" x 1/16" copper-plated spring washers
16	1-1/4" x No. 8 RH brass wood screws
8 ft.	Ribbon connector
45	Conductor straps
50	1" x No. 8 RH brass wood screws
90 lbs.	No. 2 B&S gage SD bare solid copper wire
1/4 pt.	Aluminum paint with small brush for same

Approximate total weight, 119 lbs.

Materials included for grounding chimney, cot, and stove.

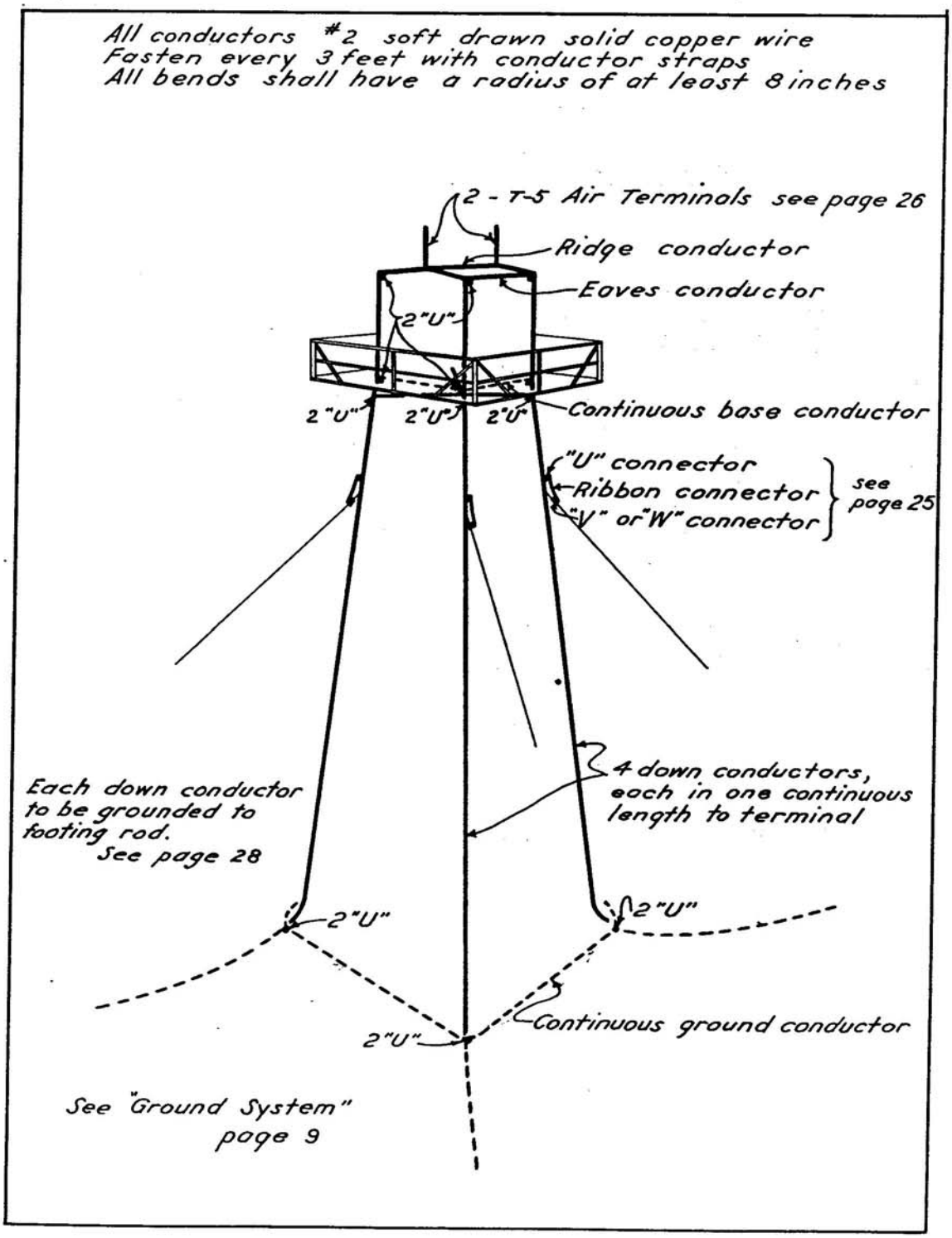


Figure 18. --Guyed timber tower with 7- by 7-foot or flat-roofed cab.

MATERIAL LIST

CT-1 TOWERS

Following materials required for all heights:

Quantity	Item
2	Type T-5 air terminals (assembled)
42	Type U connectors
120	1" x 5/16" copper-plated stove bolts with nuts and 1/8" x 1/16" copper-plated spring washers
12	2" x 5/16" copper-plated stove bolts with nuts and 1/8" x 1/16" copper-plated spring washers
24 ft.	No. 12 coppered market wire
4 ft.	Ribbon connector
8	3/4" cut washers, galvanized
4	Square nuts for 3/4" bolts, galvanized
1/4 pt.	Aluminum paint with small brush for same

For CT-1 52-ft. height add:

133 lbs.	No. 2 B&S gage SD bare solid copper wire
100	Conductor straps
134	1" x No. 8 RH brass wood screws
4	Type V connectors

Approximate total weight, 174 lbs.

For CT-1 66-ft. height add:

144 lbs.	No. 2 B&S gage SD bare solid copper wire
120	Conductor straps
154	1" x No. 8 RH brass wood screws
4	Type V connectors

Approximate total weight, 185 lbs.

For CT-1 82-ft. height add:

158 lbs.	No. 2 B&S gage SD bare solid copper wire
135	Conductor straps
170	1" x No. 8 RH brass wood screws
4	Type W connectors

Approximate total weight, 199 lbs.

MATERIAL LIST

CT-1 TOWERS (Contd.)

Quantity	Item
	For CT-1 99-ft. height add:
170 lbs.	No. 2 B&S gage SD bare solid copper wire
160	Conductor straps
195	1" x No. 8 RH brass wood screws
4	Type W connectors
	Approximate total weight, 215 lbs.
	For CT-1 119-ft. height add:
186 lbs.	No. 2 B&S gage SD bare solid copper wire
186	Conductor straps
226	1" x No. 8 RH brass wood screws
4	Type W connectors
	Approximate total weight, 232 lbs.

MATERIAL LIST

CT-5 TOWERS

Following materials required for all heights:

Quantity	Item
2	Type T-5 air terminals (assembled)
42	Type U connectors
120	1" x 5/16" copper-plated stove bolts with nuts and 1/8" x 1/16" copper-plated spring washers
12	2" x 5/16" copper-plated stove bolts with nuts and 1/8" x 1/16" copper-plated spring washers
24 ft.	No. 12 coppered market wire
4 ft.	Ribbon connector
8	3/4" cut washers, galvanized
4	Square nuts for 3/4" bolts, galvanized
1/4 pt.	Aluminum paint with small brush for same

For CT-5 31-ft. height add:

116 lbs.	No. 2 B&S gage SD bare solid copper wire
68	Conductor straps
96	1" x No. 8 RH brass wood screws
4	Type V connectors

Approximate total weight, 153 lbs.

For CT-5 41-ft. height add:

124 lbs.	No. 2 B&S gage SD bare solid copper wire
82	Conductor straps
112	1" x No. 8 RH brass wood screws
4	Type V connectors

Approximate total weight, 162 lbs.

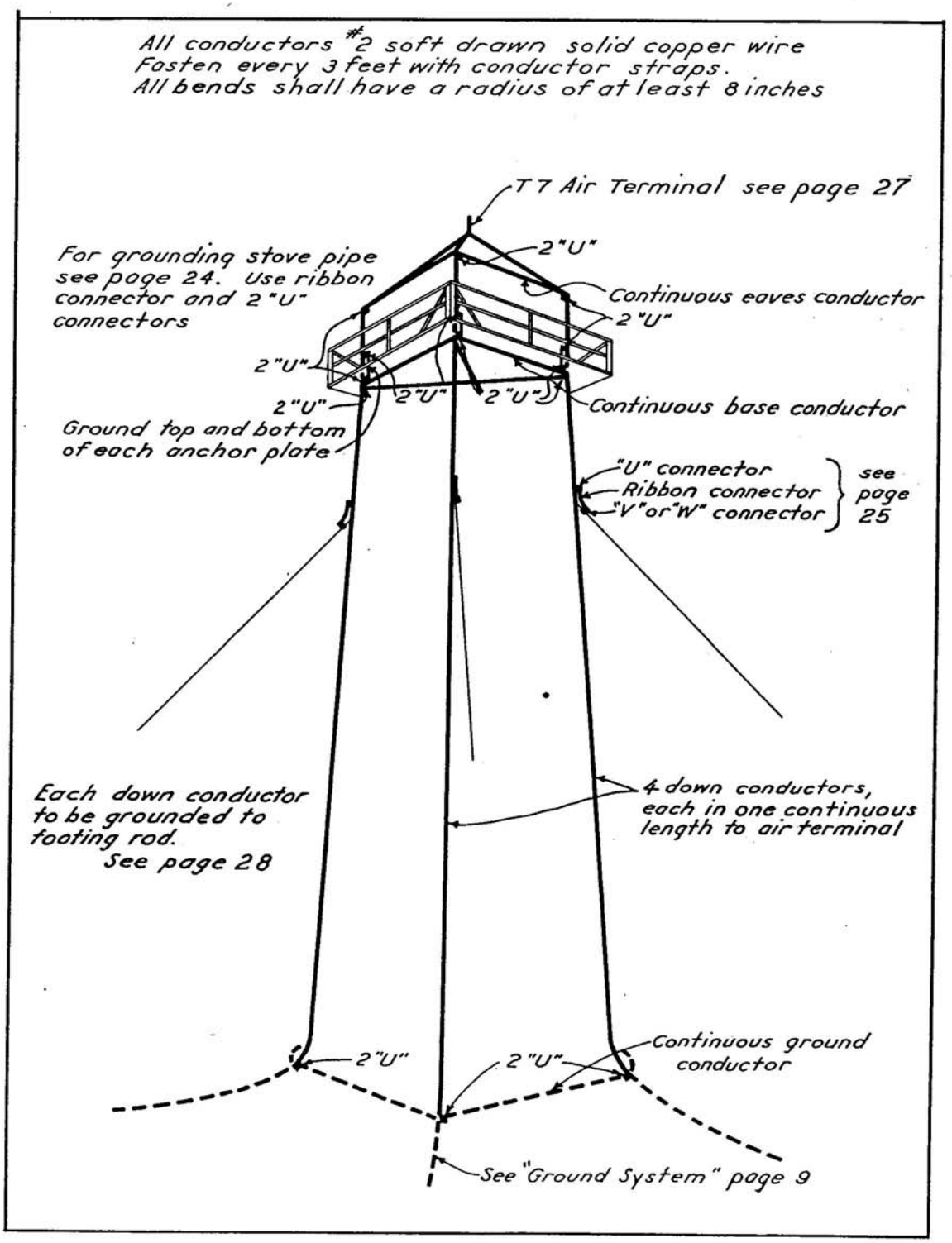


Figure 19. --Guyed timber tower with 14- by 14-foot or hip-roofed cab.

MATERIAL LIST

RT-1 TOWERS

Materials included for ground chimney, stove, and cot.

Following materials required for all heights:

Quantity	Item
1	Type T-7 air terminal (assembled)
50	Type U connector
116	1" x 5/16" copper-plated stove bolts with nuts and 1/8" x 1/16" copper-plated spring washers
12	2" x 5/16" copper-plated stove bolts with nuts and 1/8" x 1/16" copper-plated spring washers
12	1-1/4" x No. 8 RH brass wood screws
8 ft.	Ribbon connector
16	1/2" cut washers, galvanized
8	Galvanized hexagonal nuts for 1/2" machine bolts
1/4 pt.	Aluminum paint with small brush for same

For RT-1 24-ft. type add:

118 lbs.	No. 2 B&S gage SD bare solid copper wire
83	Conductor straps
94	1" x No. 8 RH brass wood screws
4	Type V connectors

Approximate total weight, 153 lbs.

For RT-1 40-ft. type add:

130 lbs.	No. 2 B&S gage SD bare solid copper wire
105	Conductor straps
115	1" x No. 8 RH brass wood screws
4	Type V connectors

Approximate total weight, 167 lbs.

MATERIAL LIST

CT-2 TOWERS

Materials included for grounding chimney, stove, and cot.

Following materials required for all heights:

Quantity	Item
1	Type T-7 air terminal (assembled)
50	Type U connector
116	1" x 5/16" copper-plated stove bolts with nuts and 1/8" x 1/16" copper-plated spring washers
12	2" x 5/16" copper-plated stove bolts with nuts and 1/8" x 1/16" copper-plated spring washers
12	1-1/4" x No. 8 RH brass wood screws
8 ft.	Ribbon connnector
16	1/2" cut washers, galvanized
8	Galvanized hexagonal nuts for 1/2" machine bolts
8	3/4" cut washers, galvanized
4	Square nuts for 3/4" bolts, galvanized
1/4 pt.	Aluminum paint with small brush for same

For CT-2 28-ft. type add:

122 lbs.	No. 2 B&S gage SD bare solid copper wire
88	Conductor straps
96	1" x No. 8 RH brass wood screws
4	Type V connectors

Approximate total weight, 159 lbs.

For CT-2 41-ft. type add:

130 lbs.	No. 2 B&S gage SD bare solid copper wire
105	Conductor straps
115	1" x No. 8 RH brass wood screws
4	Type V connectors

Approximate total weight, 168 lbs.

For CT-2 53-ft. type add:

140 lbs.	No. 2 B&S gage SD bare solid copper wire
125	Conductor straps
137	1" x No. 8 RH brass wood screws
4	Type W connectors

Approximate total weight, 179 lbs.

MATERIAL LIST

CT-3 TOWERS

Materials included for grounding chimney, stove, and cot.

Following materials required for all heights:

Quantity	Item
1	Type T-7 air terminal (assembled)
50	Type U connector
116	1" x 5/16" copper-plated stove bolts with nuts and 1/8" x 1/16" copper-plated spring washers
12	2" x 5/16" copper-plated stove bolts with nuts and 1/8" x 1/16" copper-plated spring washers
12	1-1/4" x No. 8 RH brass wood screws
8 ft.	Ribbon connector
16	1/2" cut washers, galvanized
8	Galvanized hexagonal nuts for 1/2" machine bolts
8	3/4" cut washers, galvanized
4	Square nuts for 3/4" bolts, galvanized
1/4 pt.	Aluminum paint with small brush for same

For CT-3 20-ft. type add:

114 lbs.	No. 2 B&S gage SD bare solid copper wire
80	Conductor straps
88	1" x No. 8 RH brass wood screws
4	Type V connectors

Approximate total weight, 150 lbs.

For CT-3 30-ft. type add:

122 lbs.	No. 2 B&S gage SD bare solid copper wire
88	Conductor straps
96	1" x No. 8 RH brass wood screws
4	Type V connectors

Approximate total weight, 158 lbs.

For CT-3 40-ft. type add:

130 lbs.	No. 2 B&S gage SD bare solid copper wire
105	Conductor straps
115	1" x No. 8 RH brass wood screws
4	Type V connectors

Approximate total weight, 168 lbs.

MATERIAL LIST

CT-4 TOWERS

Materials included for grounding chimney, stove, and cot.

Following materials required for all heights:

Quantity	Item
1	Type T-7 air terminal (assembled)
50	Type U connector
116	1" x 5/16" copper-plated stove bolts with nuts and 1/8" x 1/16" copper-plated spring washers
12	2" x 5/16" copper-plated stove bolts with nuts and 1/8" x 1/16" copper-plated spring washers
12	1-1/4" x No. 8 RH brass wood screws
8 ft.	Ribbon connector
16	1/2" cut washers, galvanized
8	Galvanized hexagonal nuts for 1/2" machine bolts
8	3/4" cut washers, galvanized
4	Square nuts for 3/4" bolts, galvanized
1/4 pt.	Aluminum paint with small brush for same

For CT-4 65-ft. height add:

150 lbs.	No. 2 B&S gage SD bare solid copper wire
148	Conductor straps
160	1" x No. 8 RH brass wood screws
4	Type W connectors

Approximate total weight, 191 lbs.

For CT-4 83-ft. height add:

164 lbs.	No. 2 B&S gage SD bare solid copper wire
172	Conductor straps
188	1" x No. 8 RH brass wood screws
4	Type W connectors

Approximate total weight, 207 lbs.

For CT-4 100-ft. height add:

178 lbs.	No. 2 B&S gage SD bare solid copper wire
195	Conductor straps
210	1" x No. 8 RH brass wood screws
4	Type W connectors

Approximate total weight, 219 lbs.

MATERIAL LIST

CT-4 TOWERS (Contd.)

Quantity	Item
	For CT-4 117-ft. height add:
192 lbs.	No. 2 B&S gage SD bare solid copper wire
220	Conductor straps
240	1" x No. 8 RH brass wood screws
4	Type W connectors

Approximate total weight, 238 lbs.

Types of Ground House

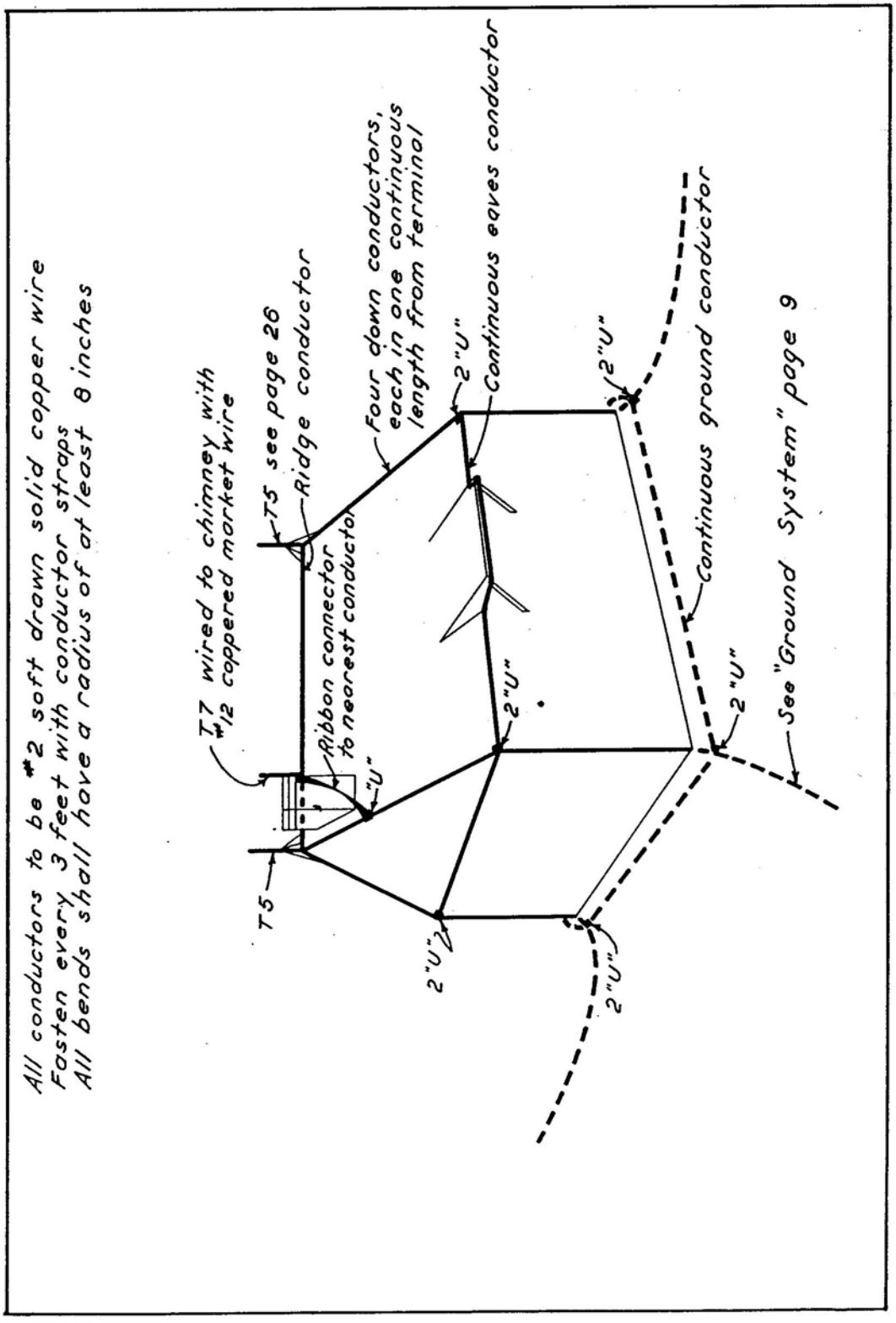


Figure 20.--Gable-roofed ground house.

MATERIAL LIST

GABLE-ROOFED GROUND HOUSE

Quantity	Item
2	Type T-5 air terminals (assembled)
1	Type T-7 air terminal (assembled)
28	Type U connectors
78	1" x 5/16" copper-plated stove bolts with nuts and 1/8" x 1/16" copper-plated spring washers
85	1" x No. 8 RH brass wood screws
70 ft.	No. 12 coppered market wire
8 ft.	Ribbon connector
50	Conductor straps
100 lbs.	No. 2 B&S gage SD bare solid copper wire
1/4 pt.	Aluminum paint with brush for same

Approximate total weight, 133 lbs.

If metal chimney is used, eliminate T-7 air terminal and add 4-foot ribbon connector.

Materials included for grounding cot and stove.

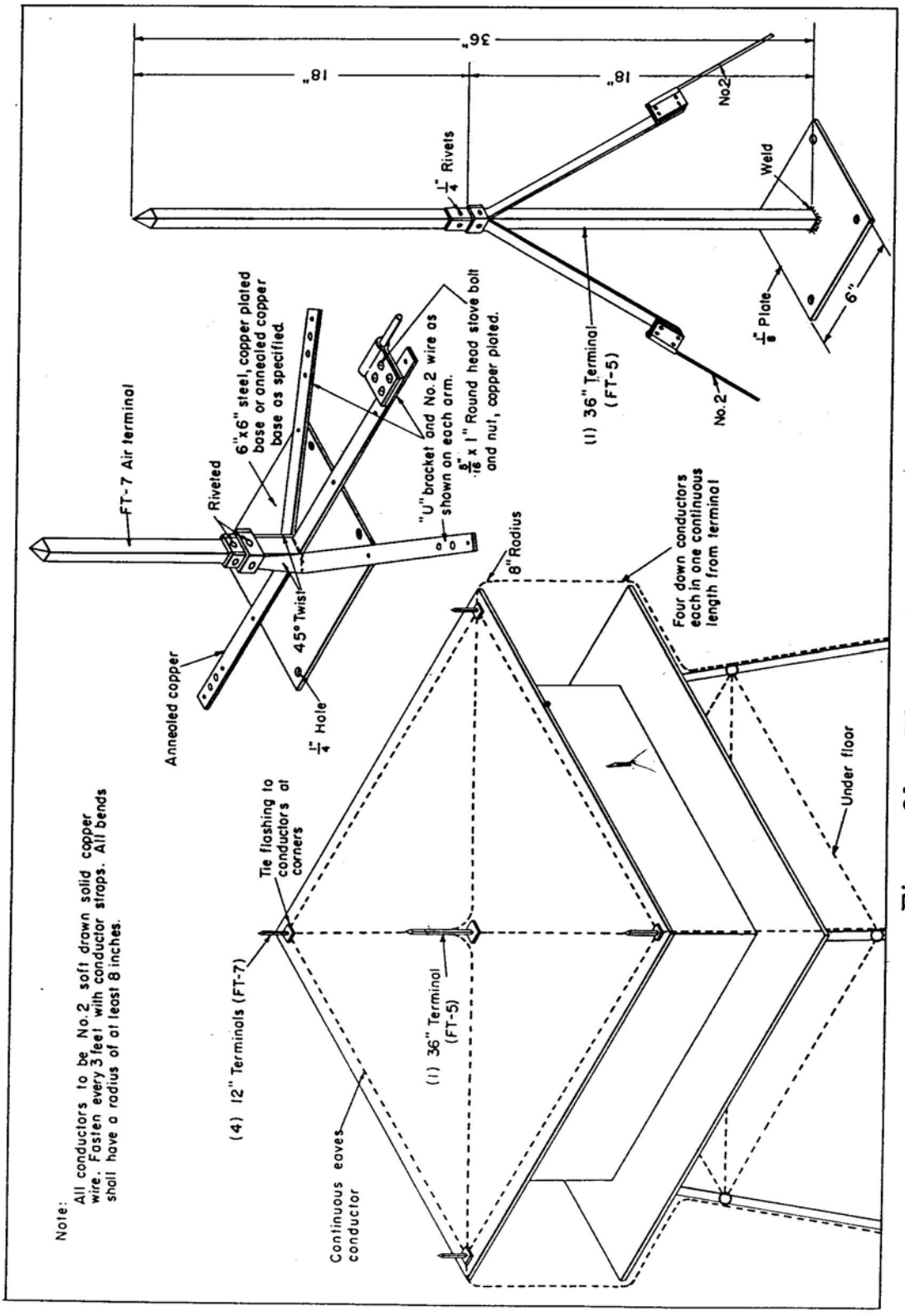


Figure 21. --Flat-top lookout house.

MATERIAL LIST

FLAT-TOP LOOKOUT HOUSE

Quantity	Item
4	FT-7 air terminals (attached to base plate)
1	FT-5 air terminals (attached to base plate)
60	Type U connectors
180	1" x 5/16" copper-plated stove bolts with nuts
36	1-1/4" x No. 8 x 1/16" brass wood screws
16 ft.	Ribbon connector
90 lbs.	No. 2 B&S gage SD bare copper wire

Note: For ground configuration materials, see page 9. Ground system not normally supplied as kit.

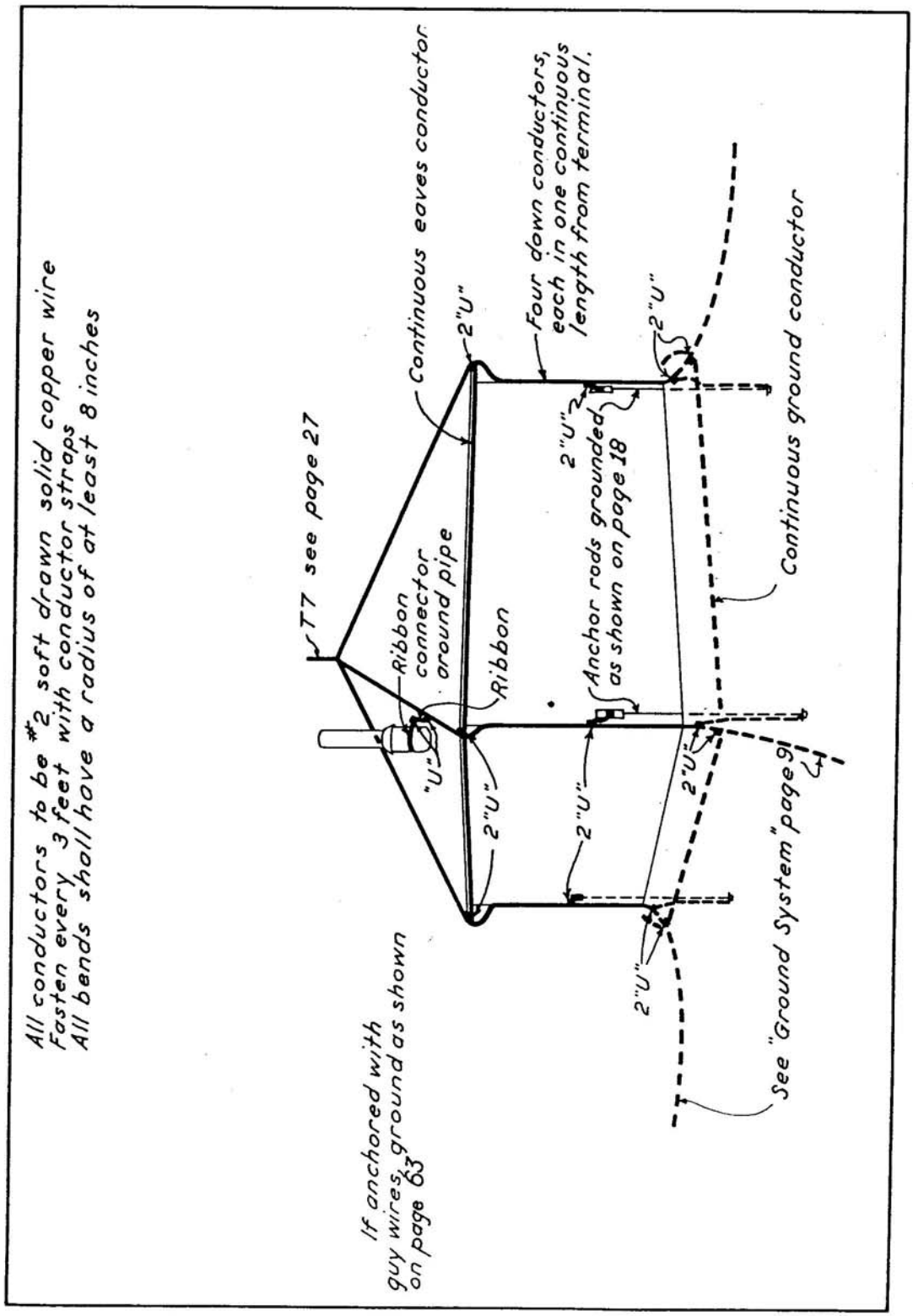


Figure 22. --14- by 14-foot or hip-roofed ground house.

MATERIAL LIST

14- BY 14-FOOT OR HIP-ROOFED GROUND HOUSE

Quantity	Item
1	Type T-7 air terminal (assembled)
45	Type U connectors
90	1" x 5/16" copper-plated stove bolts with nuts and 1/8" x 1/16" copper-plated spring washers
6	2" x 5/16" copper-plated stove bolts with nuts and 1/8" x 1/16" copper-plated spring washers
50	1" x No. 8 RH brass wood screws
12	1-1/4" x No. 8 RH brass wood screws
45	Conductor straps
8 ft.	Ribbon connector
88 lbs.	No. 2 B&S gage SD bare solid copper wire
1/4 pt.	Aluminum paint with small brush for same

Approximate total weight, 114 lbs.

For anchor rods add:

16	3/4" cut washers

For guy wires add:

4	Type V connectors

Materials included for grounding chimney, stove, and cot.

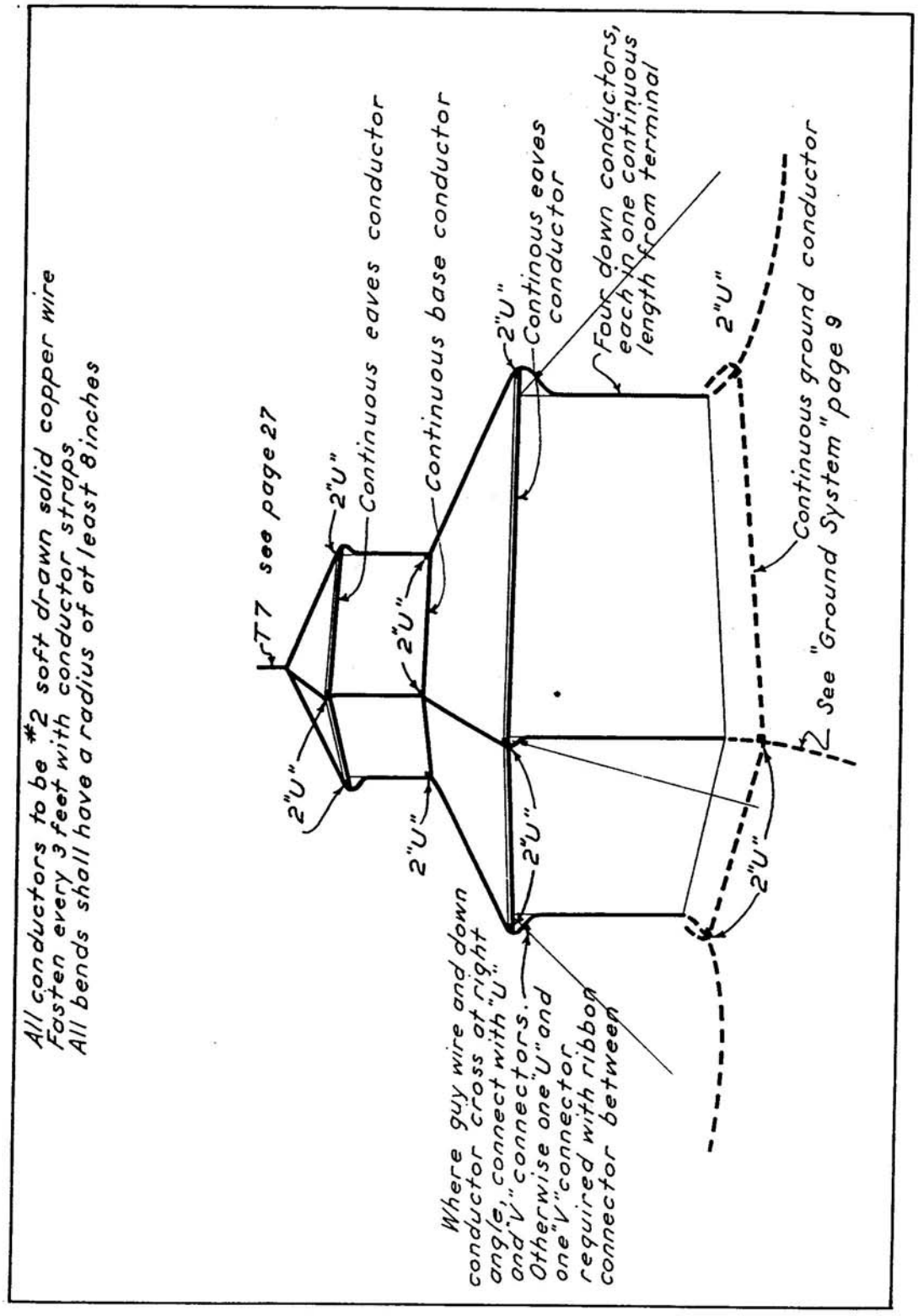


Figure 23. --Hip-roofed ground house with cupola.

LIGHTNING PROTECTION HANDBOOK

MATERIAL LIST

HIP-ROOFED GROUND HOUSE WITH CUPOLA

Structure obsolete so no material list prepared.