Bilby Steel Tower for Triangulation

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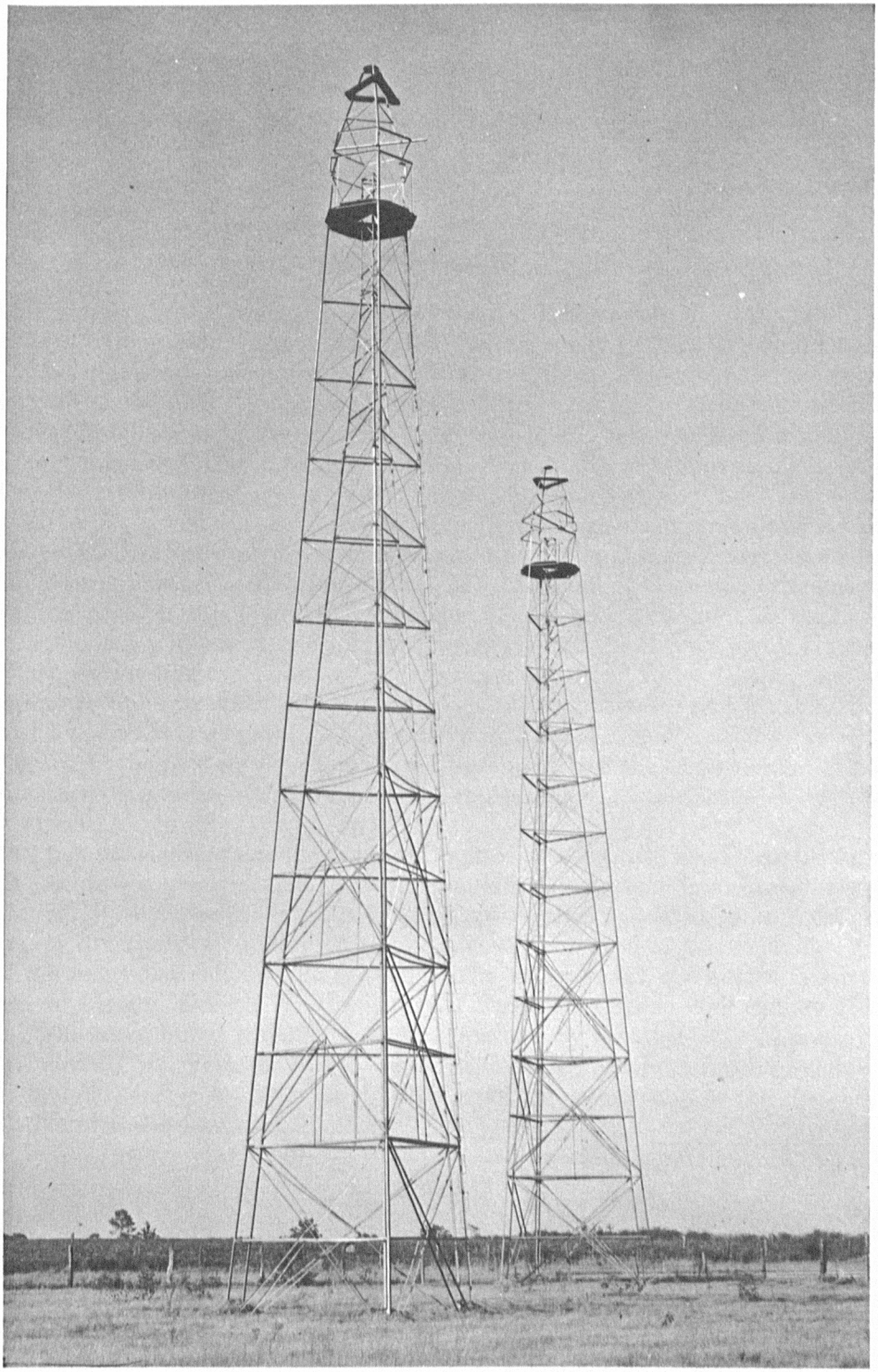

Two Complete Bilby Towers on Transcontinental Geodimeter Traverse.

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PREFACE

This manual is the second revision of Special Publication No. 158, "Bilby Steel Tower for Triangulation," which was published originally in 1929 and first revised in 1940. This publication contains many additional details regarding the construction and dismantlement of Bilby towers that were not covered in the 1940 edition; in addition, considerable space in this manual is devoted to the safety precautions and regulations that must be followed in this hazardous work. Recent innovations in building and teardown procedures are incorporated in this publication. Two subjects that were treated in the old manual—specifications for triangulation marks and a description of the vertical collimator—are purposely omitted in this manual; these subjects are well covered in Special Publication No. 247, "Manual of Geodetic Triangulation."

The purposes of this manual are twofold: (1) to serve as a guide to the new employee, acquainting him with the general procedures and the chronology of events that take place during the construction and dismantlement of Bilby towers, and introducing him to the important safety precautions relating thereto; and (2) to serve as a standard for steel-tower operations, especially with respect to the safety precautions. With regard to the new employee, it should be emphasized that this manual is not intended as a replacement of, but only as a supplement to, the on-the-job instruction that is so essential in this type of work.

This manual incorporates the practices applied by the Coast and Geodetic Survey's various steel-tower triangulation parties. Occasionally, specific procedures vary from party to party; in these cases, only those practices that appeared to be most widely accepted or consistent with adopted safety policies were used in this manual.

Of the many individuals who contributed to this manual, the author is especially indebted to Messrs. Russell W. Humphrey, Charles H. Greene, and Sidney Henderson, Jr., who contributed extensively to the preliminary manuscript. Appreciation is also extended to Mr. Verle B. Miller, whose manuscript provided much valuable data for this manual, and to Lt. Charles A. Burroughs for preparation of the sketches and compilation of the appendixes.

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INTRODUCTION TO THE BILBY TOWER

FUNCTIONS OF TRIANGULATION TOWERS

In many areas it is not possible to select station sites for a scheme of triangulation and have the stations intervisible from the ground, as trees, buildings, or other objects obstruct the lines of sight between adjacent points. Therefore, towers are necessary to elevate the observing instruments and the targets above intervening obstructions.

A complete triangulation tower is a combination of an inner and an outer structure, so designed that the two structures do not touch at any point. The requirements of a tower are: (1) that the outer structure must support an observer, a recorder, a lightkeeper, a tent that protects the personnel and the instrument from the elements, and the signal lights upon which the other observers are sighting; and (2) that the inner structure must support the observing instrument with such stability that, except in very strong winds, its motion in azimuth will never be so rapid nor so great as to affect seriously the accuracy of the measured angles, and that its disturbance in level will never be so irregular as to inconvenience the observer by making frequent adjustments necessary.

HISTORY OF THE BILBY STEEL TOWER

Prior to 1927, wooden structures were used exclusively for triangulation towers. These structures often required several days to erect and were normally used only once. Because of the time and expense involved in the use of high wooden towers, traverses were often used to extend horizontal control in flat and timbered regions. However, with the advent, in 1927, of the portable steel tower, designed by Jasper Sherman Bilby, a Coast and Geodetic Survey employee, it was possible to extend triangulation economically and efficiently into areas heretofore considered impractical for this type of control.

Three essential requirements had to be satisfied to make the steel tower a success. First, the tower had to have great rigidity and stability against vibration and against twist in azimuth; second, the tower had to be so constructed that it could be readily erected and taken down; and third, the complete tower had to be light enough that a single moderate-sized truck could transport it from station to station.

After the first tower had been completed and erected at the factory, a final test was made which showed clearly the degree of rigidity and elasticity that could be expected in the towers. This test demonstrated that the steel tower would satisfy every requirement. Final plans, specifications, and instructions to bidders were drawn up and forwarded to the Director of the U.S. Coast and Geodetic Survey, who gave the structure the official designation of Bilby steel tower.

Fourteen Bilby steel towers were purchased for use in Minnesota during the season of 1927. By the end of the 1928 season, each of the towers had been erected, taken down, moved forward, and reerected an average of 20 times. The cost of these operations per station represented a saving of about 75 percent of the amount required to construct one of the former wooden towers of comparable size.

The Bilby steel tower has been used by various countries throughout the world. It remains today as a vital tool in the efficient performance of triangulation.

A glossary of terms associated with the Bilby steel tower, tests to be met by the completed tower, specifications for the manufacture of the Bilby steel tower, and details of the observer's platform, the lightkeeper's platform, and the construction platform are given as appendixes A, B, C, and D, respectively.

Chapter II

DUTIES OF THE PERSONNEL

DUTIES AND RESPONSIBILITIES OF THE CHIEF OF PARTY AND THE FIELD FOREMAN

Chief of Party

The chief of party is responsible for the overall efficiency and economy of operation of the party, for compliance with Bureau regulations, and for rigid adherence to technical specifications and official instructions.

The party chief should make sure that the steel-tower building and teardown operations are progressing safely and smoothly. He should make a personal inspection, on station, of each building and teardown party at least once per month, remaining with each unit for an entire day's work. He must ascertain that the work is being performed in accordance with approved procedures, that adequate safety precautions are being taken, and that public or private property where the work is progressing is not unnecessarily disturbed or destroyed. He should be alert to correct any improper or unsafe procedures and to suggest improvements in the operations.

When hiring new men for steel-tower work, the chief of party must use discretion and select only those men who are physically qualified. He is responsible for seeing that an adequate training program is carried out (see page 65).

By means of safety meetings, discussions, and posted memoranda, he should strive to maintain safety consciousness throughout the party.

Field Foreman

The field foreman supervises the activities of the building and teardown parties and the steelhaulers, and coordinates the construction and dismantlement of towers with the schedules of the observing units. He makes out the daily work schedules and posts a copy on the party bulletin board each morning.

The duties of the field foreman include visiting each station site in advance of the building party for the purpose of checking and verifying the reconnaissance descriptions and sketches. He must make any adjustments in the reconnaissance data that may be required because of natural or man-made changes since the date of reconnaissance. He may have to change the proposed locations of stations and/or the proposed heights of towers, taking into account the intervisibility of stations, strength of figures, accessibility of the stations to trucks and personnel, availability of the stations for future use, the desires of the property owners, and the safety of the building crews. He must visit all property owners or other authorities to obtain permission for the establishment of marks and the erection, use, and dismantlement of steel towers. In some cases, he selects appropriate locations for the reference and azimuth marks,

or he may leave this task to the building foreman. If the station is an old (previously-established) station, the field foreman recovers all marks and checks on their condition. If any of the marks have to be moved or reinforced, he so instructs the building party.

The field foreman issues instructions on the methods to be used in the transportation of towers and building materials to the station sites, and on the precautions to be taken to avoid damage to property. These instructions, which are written in the daily work schedules, are supplemented by the field foreman's revised reconnaissance descriptions and verbal orders, if necessary.

The field foreman is responsible for the proper maintenance of the steel towers, for the storage or shipping of towers between projects, and for requisitioning tower parts and building materials. He is also responsible for the maintenance of all party vehicles.

On-site inspections of the building and teardown units are included in the duties of the field foreman.

DUTIES OF THE BUILDING PERSONNEL

A steel tower building party is ordinarily composed of five men:

(1) building foreman;
(2) ladder-leg man (No. 1 leg);
(3) back-leg man (No. 2 leg);
(4) back-leg man (No. 3 leg); and
(5) marksetter/takeoff man.

A sixth man (usually the steelhauler) is required on all 103-ft. and 116-ft. towers; this man is needed to help construct the heavy bases and assist in passing steel up to the leg men.

Under normal conditions, the building party erects one tower and establishes a complete set of marks (i.e., surface and underground station marks, two reference marks, and an azimuth mark) in a day's time.

Building Foreman

The building foreman has direct supervision over the builders; he is responsible for seeing that correct, safe building procedures are practiced by his men.

The building foreman operates in accordance with orders and instructions from the field foreman. At the beginning of each day, he consults the daily work schedule, the field foreman's notes, and the reconnaissance data in order to find out which station is to be built, the location of the station, the height of tower required, and any other pertinent information. He tells the marksetter how much building material is required, and makes sure that all necessary equipment is in the trucks.

Upon arrival at the station site, the building foreman locates the exact positions of the triangulation station mark, reference marks, and azimuth mark from the reconnaissance description and the field foreman's notes. He issues the necessary instruc-

tions for the marksetter to establish the reference and azimuth marks, **and makes sure that the disks are correctly stamped.**

The building foreman lays out the anchor holes for the tower and tells the builders the desired width and depth of holes. He determines the position of the ladder leg and parks the winch truck in the proper position for hoisting the steel. While the builders dig the anchor holes, the foreman lays out the steel on the ground around the station in order that it will be convenient during construction.

After the anchor holes are dug to the proper depth, the foreman sets up the level, obtains the differences in elevation at the bottom of the three anchor holes, and determines the places on the anchor posts where the base legs must be bolted in order to make the tower level.

As the builders assemble the lower sections, the foreman assists in handing the component members to the men on the tower. After the base is completed, he supervises the final leveling of the inner and outer towers, and makes sure they are in perfect alignment. If the tower is at an old station, he ascertains that the inner tower is properly centered over the mark.

In preparation for the hoisting operations, the foreman checks the winch truck to see that it is safely chocked and jacked and that the winch is bolted securely. He ties the component steel members in bundles for hoisting and operates the winch. He maintains constant surveillance over the work as it progresses for the purpose of issuing necessary instructions and making sure that required safety precautions are being followed.

Assisted by the marksetter, he carries the built-up and welded sections inside the tower and bolts the two sections together.

Upon completion of the building operations, and by the use of a vertical collimator, the foreman ascertains that the welded section and the lightplate are centered directly over the station mark (if the tower is at an old station); when the tower is at a new station, he uses the collimator to determine the exact position of the station, and instructs the marksetter to establish the station marks. He orients the reconnaissance sketch on the tower to verify that all lines to other stations are clear, and, if not, he issues instructions for the clearing of lines or for the installation of a vertical extension.

He supervises the placing of protective fencing, warning signs, lights, or any other special safeguards necessary for the protection of the public.

Before leaving the station, the building foreman checks to see that all equipment is in the trucks and that the site of the work is left in a clean and orderly condition. He completes the "Daily Report of Building Foreman," Form 749. (See Special Publication No. 247, "Manual of Geodetic Triangulation," pp. 75 and 79.)

It is impractical to formulate precise rules for all conditions — especially weather conditions — that could possibly make tower work hazardous. Consequently, certain decisions on safety must often be made by the building foreman. Keeping in mind that the safety of his crew is one of his primary responsibilities, he must exercise good judgment when making these decisions.

The building foreman is responsible for supervising the training of new employees and seeing that they are adequately indoctrinated in the building procedures and safety precautions.

Ladder-leg Man

Other than the foreman, the ladder-leg man is the most experienced builder on the crew. When necessary, he guides the less experienced men on the tower. Moreover, he may be given the job of training a new employee. He should be capable of performing the duties of the building foreman in the event of the foreman's absence.

He digs the anchor hole for the ladder leg. He erects the ladder legs of the inner and outer towers, and bolts all ties, diagonals, and rods at the ladder legs. He bolts the diagonals at their crossing points between the ladder (No. 1) leg and the No. 2 leg. He assists in plumbing the base of the tower, and helps align the inner and outer towers. He handles the block for hoisting steel, receives the component members from the takeoff man, and passes the members to the other leg men or lays them out on the ties for the other men to use. After the tower is assembled, he remains aloft and assists the foreman in the collimating operations. He inspects the ladder steps to make sure they are tight, and, if necessary, replaces defective steps.

As dictated by the building foreman, the ladder-leg man may assist in setting the station marks, clearing lines, and doing other routine jobs.

Back-leg Men

The No. 2 and No. 3 leg men dig their respective anchor holes; erect the No. 2 and No. 3 legs; and bolt the ties, diagonals, and rods in their respective corners of the tower. The No. 2 man bolts the diagonals at their crossing points between the No. 2 and No. 3 legs; the No. 3 man bolts the diagonals between the No. 3 and No. 1 legs. They assist in plumbing and aligning the inner and outer towers. They may help set the station marks and witness post, clear lines, and perform miscellaneous tasks as required by the building foreman.

Marksetter/Takeoff Man

The marksetter obtains the sand, gravel, and cement for the marks, and sees that the necessary equipment is in the marksetting truck. Upon arrival at the station site, he establishes the reference and azimuth marks (which includes digging the holes, mixing concrete, and setting the brass disks). The building foreman instructs him as to the exact location of these marks, and may occasionally help him set the marks. After the tower is constructed, the marksetter establishes the underground and surface station marks, aided by one of the builders.

If the tower is located at an old station where no marks are to be established, the marksetter assists the building foreman in preparing for construction by helping lay out the steel around the station, jacking and chocking the winch truck, bolting the winch to the right-rear wheel, clearing lines to reference and azimuth marks, or by performing other duties as ordered by the foreman.

During construction of the lower sections of the tower, the marksetter assists the foreman in passing the component steel members up to the leg men. He helps the rest of the crew plumb and align the inner and outer towers.

While the hoisting operations are being carried out, he acts as takeoff man (the fourth man on the tower). Standing one-half section below the ladder-leg man, he

removes the steel from the hoisting line and hands the members up to the leg men. Depending on his speed and ability, he may help the ladder-leg man fasten the blue rods, and may tighten the nuts on the blue legs. After construction of the cage has commenced, the takeoff man descends the tower and helps the foreman prepare the built-up and welded sections for hoisting.

DUTIES OF THE TEARDOWN PERSONNEL

A steel-tower teardown party ordinarily consists of four men:

(1) teardown foreman;
(2) ladder-leg man (No. 1 leg);
(3) back-leg man (No. 2 leg); and
(4) back-leg man (No. 3 leg).

An additional ground man (usually the steelhauler) is used when 103-ft. and 116-ft. towers are dismantled.

The teardown party, under normal conditions, dismantles two towers per day.

Teardown Foreman

The foreman supervises the teardown operations, making sure that the men on the tower perform their work safely and correctly. He operates in accordance with orders and instructions from the field foreman. At the beginning of the day, he consults the daily work schedule to find out which towers are to be dismantled.

The teardown foreman usually remains on the ground during the operations, although he may occasionally work the ladder leg while the ladder-leg man carries out the ground duties. When performing the ground duties, the foreman lowers the built-up and welded sections to the ground on the rope. He also lowers by rope, all cage steel, rods, and platform boards; and, in some cases, he may have to lower legs, ties, and diagonals to the ground. He keeps a constant surveillance over the work as it progresses, making sure that safety precautions — especially those that concern dropping steel from the tower — are being maintained.

The foreman picks up the dismantled members, sorts them, and either stacks them in neat piles or, if the steelhauler is present, helps the steelhauler load the pieces directly on the truck. He wires the rods and diagonals in groups with respect to color, length, and type.

Before leaving the station, the foreman checks to see that all equipment is in the truck and that the site is left in a clean and orderly condition.

The teardown foreman is responsible for training new employees in teardown procedures and the attendant safety regulations.

Ladder-leg Man

The ladder-leg man unfastens the tops of the connecting steps and loosens the nuts in the cage members. He handles the block and the rope on the tower, and ties all steel that is to be lowered by rope. He dismantles the ladder leg and all ties, rods,

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and diagonals at the ladder leg. He digs out the ladder-leg anchor and packs the soil back into the anchor hole.

Because the ladder-leg man is usually the most experienced man on the tower, he may be required to instruct and guide new employees. He should be capable of performing as teardown foreman.

Back-leg Men

The No. 2 and No. 3 leg men loosen the nuts on the red tower and remove the bolts from the bottom of the built-up section. They dismantle the cage and hand the cage steel to the ladder-leg man for tying and lowering. They dismantle all members in their respective corners of the tower, and lay the steel that is to be lowered by rope on the ties where the ladder-leg man can reach it. They dig out the No. 2 and No. 3 anchors and fill in their respective anchor holes.

Chapter III

STEELHAULING

DUTIES OF THE STEELHAULER

The primary duties of the steelhauler are: (1) to deliver steel to stations where towers are to be erected, and (2) to pick up and transport steel after teardown operations. The steelhauler should be an experienced builder; he must exercise a thorough knowledge of the various parts of the tower.

On a large (30–40 men) triangulation party, there are usually two building parties, one teardown party, and two steelhaulers. The steelhaulers' daily work schedules are posted on the party bulletin board by the field foreman. Ordinarily, each steelhauler is instructed to deliver a load of steel to a station where a tower is scheduled for construction that day. At those stations where 103-ft. towers or 116-ft. towers are to be built, the steelhaulers, after delivery of the steel, remain at the sites and help the building parties erect the bases of the towers. Each steelhauler then drives to one of the stations scheduled for teardown, picks up the steel, and returns to camp with his loaded truck at the end of the day.

A schedule such as the above is advantageous because: (1) the steelhaulers arrive at the stations when the building parties do, hence the building foremen can tell the steelhaulers exactly where they want the steel placed; (2) the steelhaulers are available to help the building parties erect the bases of the towers, if necessary; and (3) the steelhauler who picks up the second teardown can load the parts as they are dismantled, thus saving extra handling of steel.

Occasionally other steelhauling schedules are used. Sometimes one steel truck will be loaded and the other truck will be empty at the beginning of the day. The steelhauler with the empty truck accompanies the teardown party, picks up the first tower that is dismantled, delivers the steel to another station, and returns to camp with the empty truck; the steelhauler with the loaded truck accompanies the building party, lays out the steel at the station, picks up the second tower that is dismantled, and returns to camp with his loaded truck. This schedule has the advantage that the steelhaulers are present during both teardown operations.

At the beginning of a project, when building is predominant, the steelhaulers will be transporting steel from the storage area to the construction sites, whereas, at the end of the project, the steelhaulers will be primarily involved in picking up dismantled towers and delivering them to the storage yard or to a loading area for shipment. Assuming the capacity of the truck is not exceeded, two towers are loaded on each truck during these operations.

On some parties, the building crews often haul their own steel to the stations; in other words, the steelhaulers are regular members of the building crews.

LOADING THE STEEL TRUCK

When one tower is loaded on the truck, a procedure similar to the following is used:

1. All legs except the ladder legs are stacked according to tower sections in the center of the truck bed, about five deep.
2. The red and blue ties are placed alongside the corresponding red and blue legs, and stacked about six deep.
3. The red and blue rods are separated and placed on top of the legs and ties.
4. The red and blue diagonals are separated and placed, respectively, on the left and right sides of the truck bed. (Since the blue diagonals are longer than the red diagonals, they should be placed on the off-traffic side of the truck.
5. The vertical stays ("follies") and all cage steel except the wishbones are loaded in the front of the truck bed near the center.
6. The wishbones are placed on top and across the ladder legs, usually near the front of the truck.
7. The connecting steps are removed from the ladder legs. The ladder legs are placed on top of the steel that is already in the truck, filling in the lowest parts of the load.
8. The platform boards and the triangle board are spread out over the load.
9. The built-up section is placed on one side of the truck, and the welded section is placed on the other side.
10. The anchors and lockboards are interlocked in the built-up and welded sections. The load is now complete. (See fig. 1.)

When two towers are loaded on a truck, the steel for the second tower is placed on top of the first tower. The steel for each tower has an arrangement similar to the one just described. The two towers are separated with platform boards. The anchors, lockboards, welded sections, and built-up sections (if not dismantled) for both towers are placed on top of the total load. (See fig. 2.)

The outer end of the longest diagonal should be flagged with red or orange cloth before the truck is driven on the highways.

UNLOADING STEEL AT THE STATION SITE

If the tower is delivered on the day of construction, the building foreman will be present to supervise and assist the steelhauler in laying out the steel around the station site. The steel is laid out as described on page 19.

Occasionally, the steelhauler will deliver a tower one or two days before it is to be built. In this case, he must use his own judgment as to the most suitable position of the ladder leg for hoisting operations, taking into consideration the best location for the winch truck. He places the welded section on the ground about 20 feet out from the ladder-leg position (see page 19), and lays the ends of the members to be hoisted

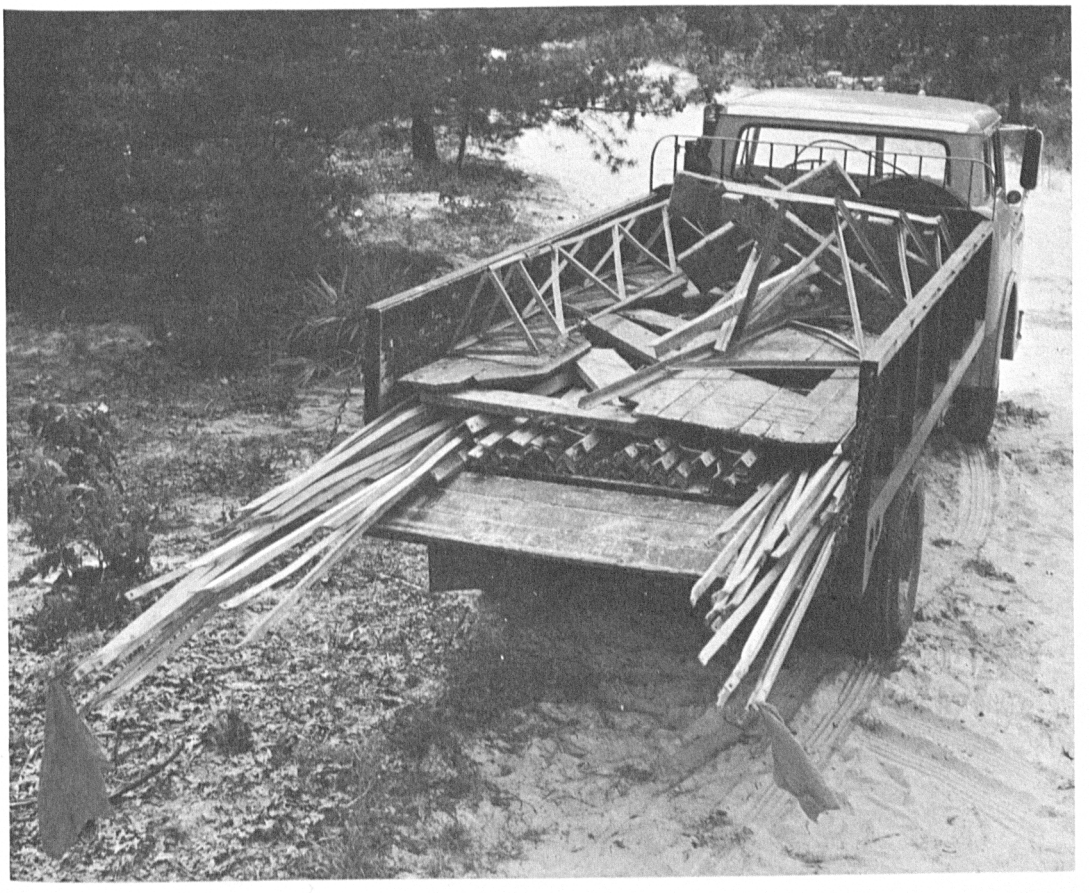

FIGURE 1.—Steel truck carrying one 90-ft. tower.

FIGURE 2.—Steel truck carrying two 90-ft. towers.

on the welded section. The built-up section and the platform boards are placed near the welded section. The members for the base sections, separated by color and use, are laid out in neat piles far enough from the station site that they will not hinder the digging of the anchor holes.

When unloading steel from the truck, care must be taken not to weaken a tie in the welded section and not to split a platform board or mudsill. If defective pieces are discovered, they must be brought into camp for repair or replacement.

PICKING UP STEEL AFTER TEARDOWN OPERATIONS

It is preferable that the steelhauler be present during teardown operations, in order to avoid extra handling of the steel. All members of the tower should be inspected by the teardown foreman and the steelhauler while the tower is being dismantled. (Inspection of tower parts is covered in detail on page 62.) Bent pieces are straightened before loading. Defective pieces are brought into camp by the steelhauler and either repaired or replaced. The field foreman should be notified when towers are found to be defective.

If the steelhauler is not present during the teardown operations, the teardown foreman should bring any defective pieces into camp himself, if possible. Otherwise, he should lay them to one side and notify the field foreman and the steelhauler after returning to camp.

THE STEEL TRUCK

The modern steel truck is a commercial 2-ton, cab-over-engine truck with a long wheel base. This type of vehicle is less costly and more maneuverable than the semi-trailer type. (See figs. 1 and 2.)

For reasons of economy, steel trucks are purchased without beds. The beds are constructed by the individual field parties. Normally, a steel-truck bed is about 14 feet in length and about 7 feet in width, with sides 25 inches high. The diagram given as appendix E contains the plans for a typical steel-truck bed.

In general, steel trucks have a rated gross vehicle weight of at least 16,000 lbs. Consequently, two towers (but certainly no more) of 103-ft. heights or less may be transported at one time. When 116-ft. towers are hauled, only one tower should be carried at a time.

STEELHAULING SAFETY PRECAUTIONS

Steelhaulers must adhere to the safety regulations for truckdrivers that are outlined on page 59. The steelhauler is responsible for keeping his truck neat and in good mechanical condition.

Important rules to remember when loading steel on the truck are: (1) the weight of the load must be evenly distributed, and (2) the capacity of the truck should not be exceeded.

The steelhauler must guard against back injuries as some of the steel members are quite heavy. The correct way to lift a heavy object off the ground is to pick up the

object from a crouching position and then stand, allowing the leg and arm muscles — not the back muscles — to do the work.

The steelhauler should wear gloves when loading or unloading steel.

While transporting steel, the steelhauler should check the load periodically to ensure that it is riding as it should and that no members are lost en route. This is especially important when proceeding "cross-country" or over rough roads.

Chapter IV

SELECTION OF TOWER SITES

INTRODUCTION

It has been stated that the field foreman must visit each proposed station site in advance of the building party for the purpose of checking the reconnaissance sketch and obtaining permission from the property owner to enter the property, establish the marks, and erect a tower. An important duty of the field foreman while he is inspecting the site is to check the area for any obstructions or conditions that could render the building and teardown operations unsafe. This section deals, in particular, with safety features associated with the selection of tower sites. It will be assumed that the primary requirements such as strength of figure, accessibility, etc., have been satisfied.

POWER LINES

Overhead power lines — particularly high-tension lines — may be especially dangerous if they are near a tower. The tower must be so situated that there is no possibility of a steel member coming in contact with the electrical wires during building and teardown operations. An attempt should be made to locate the station at a distance from the power line equal to at least the height of the tower. If this can not be accomplished, the tower site may be located nearer the power line, provided that the ladder leg is oriented in a direction away from the power line and that the legs on the side of the station opposite the power line are guyed. Under no conditions, however, should a tower be erected less than 30 feet from a power line.

At previously-established stations, it is occasionally found that a power line has been constructed over the station mark since the date of establishment. In this case, a new reference mark with a subsurface mark should be established at a safe distance from the station and the tower erected over the reference mark. (All computations will be carried through the occupied reference mark.)

TELEPHONE LINES

In the past, steel towers have occasionally been erected through telephone wires, but this practice is hazardous and should be avoided. Not only will it disrupt telephone connections should the wires come in contact with the tower, but the builders might trip on the wires or get steel members entangled in them. Furthermore, if a builder accidentally touches a wire while the line is in use, the electric shock could possibly cause him to lose his balance and fall from the tower.

UNDERGROUND UTILITIES

In populated areas, consideration should be given to the possible presence of underground electrical cables, water pipes, gas lines, etc. An investigation should be

carried out if there is any possibility that underground utilities would interfere with the digging of the anchor holes.

TREES

Building and dismantling steel towers among trees can be hazardous. Trees may obstruct the view between the ground man and the men on the tower. There is a chance that the hauling line will become entangled in the branches or that the steel will get hung up in the branches while it is being hoisted. Branches and limbs near the tower may make it difficult for the builders to handle the long pieces of steel; a builder striking a limb with a piece of steel could lose his balance or drop the steel. During teardown operations, the steel may get caught in branches while it is being lowered and fall loose from the rope. It is dangerous to drop steel when trees are nearby as a member could hit a limb and glance off in any direction.

Because of the above hazards, towers in forested areas must be so positioned that *no tree limbs or branches project through or into the towers* and that *ample clearance is provided for the hoisting operations.* In many cases, it will be necessary to cut tree limbs — or possibly entire trees — that are adjacent to the station. Permission must always be obtained from the property owner before trimming or cutting trees.

The amount of clearing required may be a primary factor in the final selection of a tower site.

TOPOGRAPHY

The ground in the immediate vicinity of the station should be as level as possible. It is difficult to plumb the tower on a hillside where one anchor is much lower than the other anchors. Furthermore, the leg and diagonals on the downhill side of the station would probably have to be bolted to the anchor post above the ground; this condition would tend to decrease stability and increase the possibility of the leg buckling.

It may also be difficult to position the building truck for hoisting operations when the ground is not level.

SOIL CONDITIONS

Extremely hard or rocky ground may prevent the anchor holes from being dug to the required depths, in which case it would be necessary to guy the tower and sandbag the anchors. The efficiency of the building operations is dependent to a large degree upon the time consumed in digging the anchor holes; this should be kept in mind when selecting a tower site.

PROTECTION OF THE PUBLIC

For the safety of the public, a steel tower should be located at a distance equal to at least the tower's height from: (1) the edge of a well-traveled road or highway, (2) railroad tracks, and (3) occupied buildings or residences. When this cannot be done, the tower should be guyed in order to reduce the risk of structural failure should severe storms develop.

Chapter V

PROCEDURE FOR ERECTING A BILBY TOWER

LAYING OUT THE ANCHOR HOLES

When the building party arrives at the site of a new station, the building foreman determines the exact positions of the station, reference, and azimuth marks from the reconnaissance description and the field foreman's notes. The foreman drives a small stake in the ground to temporarily mark the location of the station.

If the tower site is a previously-established station, the field foreman recovers the various marks.

With the property owner's permission, members of the building crew set to work clearing any brush or trees that could obstruct the building operations. The foreman, meanwhile, lays out the positions of the anchor holes.

The anchor holes must be so placed that the legs of the tower will not obstruct measurements to the reference marks. In addition, the tower should be so oriented that lines of sight to other stations are not blocked by the legs of the outer tower, although this condition could be rectified, if necessary, by rotating the swivel sections. The approximate direction of each line can be determined with the aid of the reconnaissance sketch and a magnetic compass.

Either a transit or a tripod may be used to obtain the necessary 120-degree angles that define the directions of the anchor holes from the station mark. A tripod, with the head placed on the ground over the station mark and the legs laid out flat on the ground, works very well and is convenient.

The building foreman selects one of the three anchor-hole locations for the ladder leg, taking into consideration the position of the winch truck that would be most suitable for hoisting steel.

After the directions to the anchor holes have been determined, the foreman measures the proper distance from the station mark to the inner edge of each hole. (The inner edge of an anchor hole will be regarded as that edge nearest the station.) This distance will vary according to the height of the tower, as shown in table 1.

It is convenient to use the bottom edges of the mudsills as guides for digging the anchor holes. With a tripod spread out on the ground as previously described, three anchors are so placed that each anchor post lies on top of, and in line with, a tripod leg. (See fig. 3.) The anchors are then moved along the tripod legs, either toward or away from the station mark, until the outside edges of the mudsills are located at the proper distances from the station.

When 37-ft. towers are built, the distances to the anchor holes are often obtained by placing the top 50-ft.-section red ties in a triangle around, and equidistant from, the station. The anchors are laid on the ground as before, with the outside edges of the mudsills about 2 to 5 inches inside the vertices of the triangle. This procedure may also be used to lay out the anchor holes for a 50-ft. tower; in this case, the top 64-ft.-section red ties would be used.

Table 1

Anchor Hole Dimensions

Height of tower (feet)	Distance from station to inner edge of hole*	Width of hole (inches)	Length of hole** (inches)	Minimum depth of hole† (feet)
37	(††)	46–48	54	3
50	4′10″– 5′0″	40–42	54	3–3½
64	6′ 2″– 6′4″	32–34	54	3½
77	7′ 6″– 7′8″	30–32	54	3½–4
90	9′ 0″– 9′2″	30–32	54	4–4½
103	10′ 3″–10′5″	30–32	54	4½–5
116	11′ 6″–12′0″	30–32	54	4½–5

*These distances may vary several inches one way or the other, depending on how the builder digs his anchor hole.

**This length is required for 4-ft. mudsills. If 3½-ft. mudsills are used, hole lengths should be about 48 in.

†These are minimum depths in moist soil, clay, or sand, where the ground is not extremely hard or rocky. Depths should be increased if dry clay, humus, or dry sand is encountered.

††Distances for 37-ft. (and sometimes 50-ft.) towers are usually obtained by placing ties around the station mark, as described on page 17.

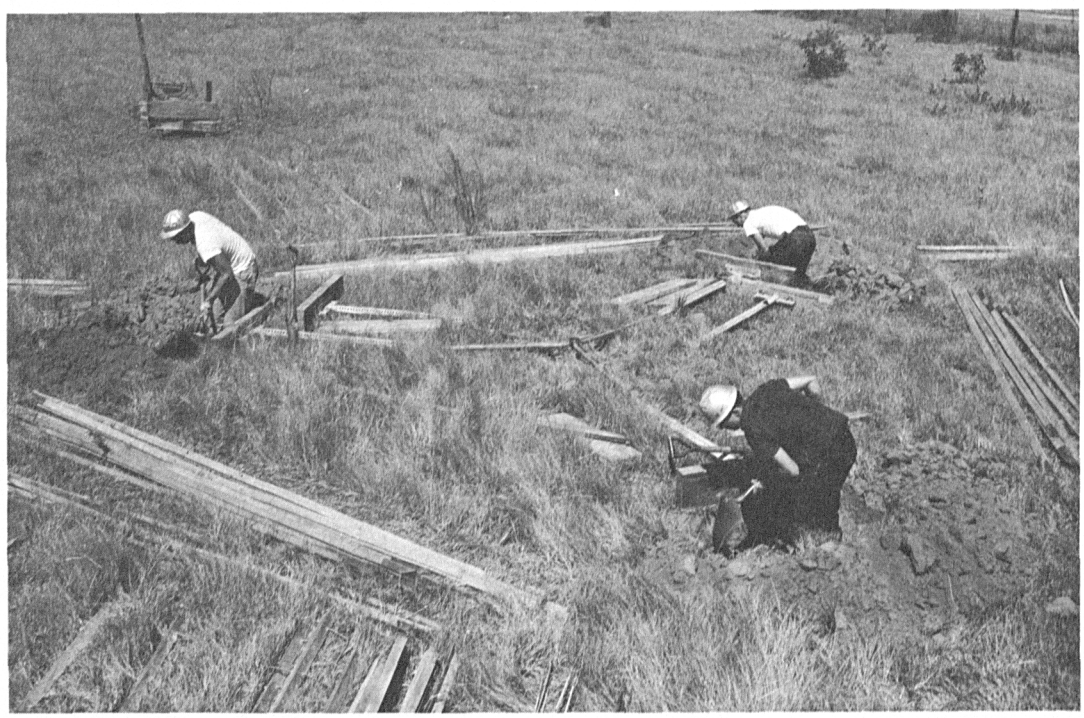

FIGURE 3.—Digging the anchor holes. Note that the anchor posts are placed over the tripod legs for proper placement of the anchor holes.

The building foreman measures off the correct width and length of each anchor hole. For towers between 37 feet and 77 feet in height, the width of the anchor hole varies with the size of the tower. The length of the hole is independent of the tower height; each hole should be about 6 inches longer than the mudsills. Anchor-hole dimensions are listed in table 1.

DIGGING THE ANCHOR HOLES

After the anchor holes have been laid out, the three leg men begin digging their respective holes. (See fig. 4.) The building foreman ascertains that the anchor holes are dug to the proper dimensions.

The depth of the anchor holes depends not only upon the height of the tower, but also upon the type and condition of the soil. In general, moist soil anchors a tower better than dry soil. The anchor-hole depths given in table 1 are minimum depths when moist sand or clay is encountered and the digging is not unusually difficult. In areas where dry loose sand, humus, or dry hard clay is prevalent, the hole depths should be increased. In rocky ground where difficult digging is encountered, it may be impracticable to dig the anchor holes to the specified depth; consequently, the anchors must be weighted down with sandbags or boulders, and guy wires must be attached to the tower.

After the anchor holes have been dug to the required depth, the holes for the lockboards are excavated. (The lockboards are 2″ x 10″ x 42″ boards which are placed perpendicular to, and over, the anchor mudsills.) Two lockboard holes are tunneled horizontally into the outer side of each anchor hole, one on each side of the anchor posts. (See figs. 5 and 6.) The bottom of each lockboard hole should be about 5 inches above the bottom of the anchor hole. For towers of 64-ft. height and over, the lockboard holes must be tunneled to such depths (approximately 10 inches) that the lockboards will fit tightly against the back of the lockboard holes and the front (inner side) of the anchor hole. Because of the increased anchor-hole width for 37-ft. and 50-ft. towers, the lockboards will not extend to the front of the anchor holes; however, the boards should at least cover the red mudsill.

The purpose of the lockboards is to make the tower more secure. With one end of each lockboard firmly embedded under solid undisturbed earth, the boards tend to "lock" the anchors into place. Should strong winds occur, the lockboards provide a factor of safety against the possibility of the anchors being uprooted.

LAYING OUT THE STEEL

While the anchor holes are being dug, the building foreman and the steelhauler (if present) lay out the steel around the station so that it will be readily available during the tower construction. The exact layout of the steel will depend upon the preferences of the particular foreman and, to some extent, upon the characteristics of the site. In general, the steel is arranged as described below.

The welded section is placed on the ground about 20 feet from the ladder-leg hole, in the direction from which the steel is to be hoisted. The steel members that will be hoisted are laid perpendicular to the welded section, with the top ends away from the

tower and resting on the welded section. (See fig. 7.) With this arrangement, the steel for hoisting is just behind the winch truck, in a location where the foreman can conveniently attach the bundles of steel to the hauling line.

The platform boards are placed adjacent to the welded section.

The steel that will be passed up by hand (i.e., the steel for the base sections) is laid out as follows (fig. 8). The ties and diagonals for the first section are placed parallel to the respective sides of the tower, far enough back from the station that they will not become covered with soil from the anchor holes. The ties for the other base sections are placed behind the ties and diagonals for the first section, parallel to the sides of the tower; the diagonals for the other base sections are then laid behind, and perpendicular to, the ties. The No. 2 and No. 3 legs are placed perpendicular to the sides of the tower, with the bottom ends of the legs near their respective anchor holes. The ladder legs are usually left near the welded section. When the steel for the base sections is laid out, it should be kept in mind that the top ends of the legs and diagonals and the painted ends of the ties will be handed up first.

If the built-up section had been dismantled for shipping, the building foreman assembles it and places it to one side where it will not interfere with the hoisting operations. (The built-up section is ordinarily kept bolted together while the party remains on one project, and is dismantled only for moves between projects.)

The foreman should inspect the ladder steps as he lays out the ladder legs. Bent steps should be straightened at once, and steps that have previously been straightened

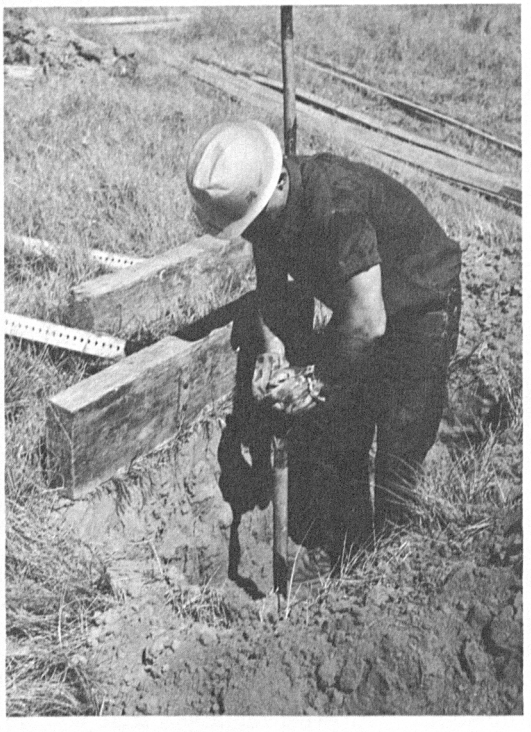

FIGURE 4.—Digging the anchor hole.

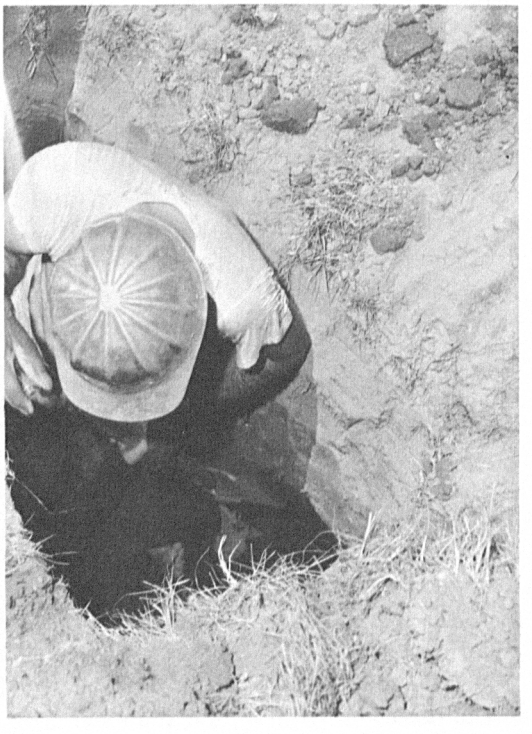

FIGURE 5.—Digging the lockboard hole.

or that are badly deformed should be replaced with new ones. (The foreman should keep several replacement steps in his truck.) It is preferable to inspect and straighten the steps at this stage of the operations and not to wait until after the tower has been erected.

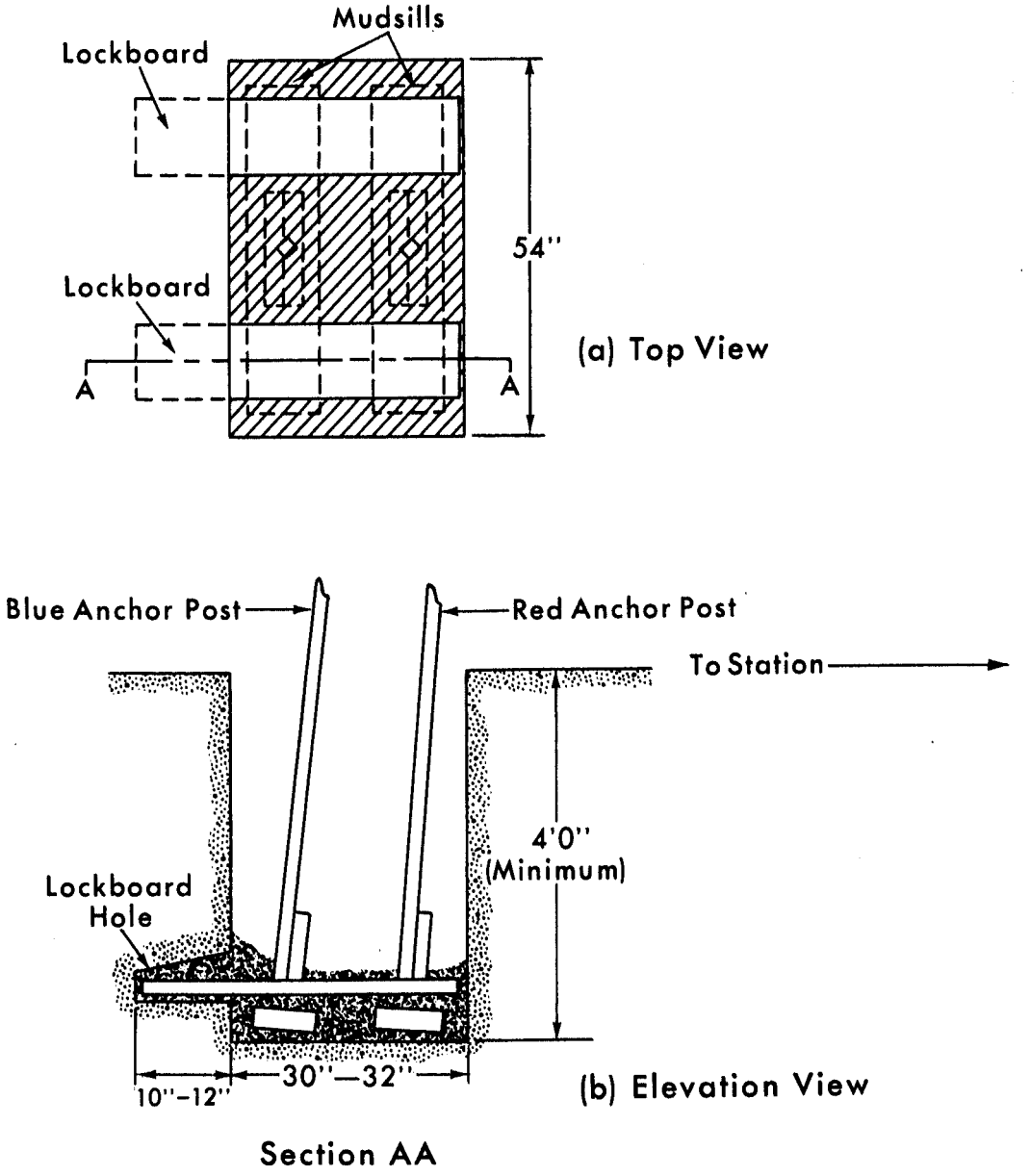

FIGURE 6.—Top and elevation views of the anchor hole showing the placement of anchors and lockboards for a 90-ft. tower.

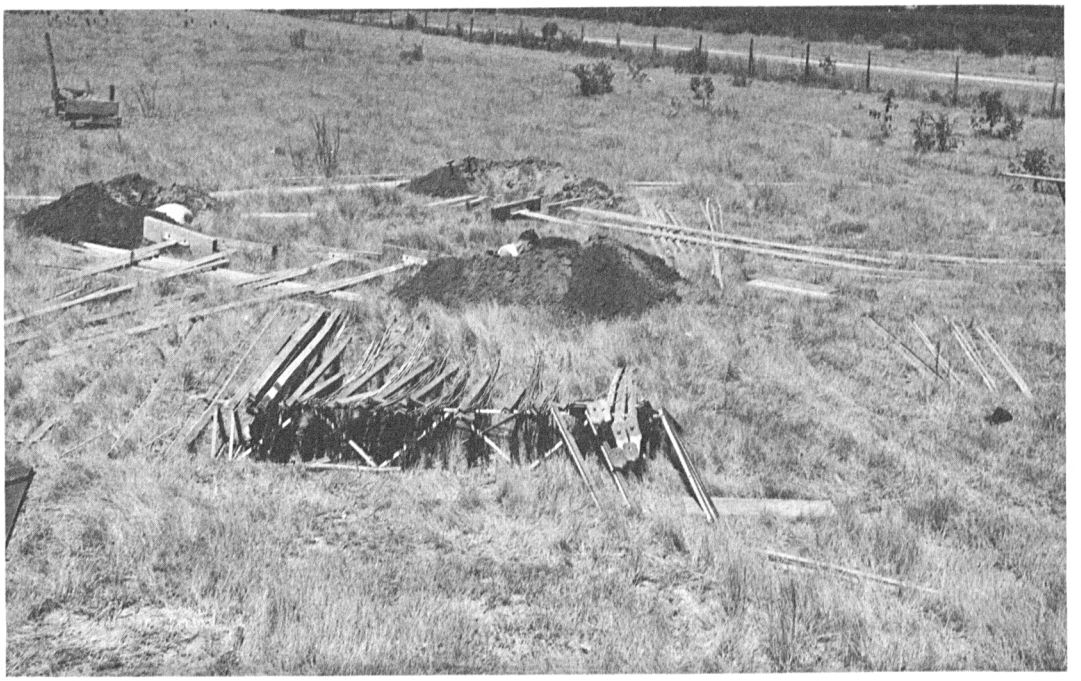

FIGURE 7.—Steel layout. Members to be hoisted are placed on the welded section.

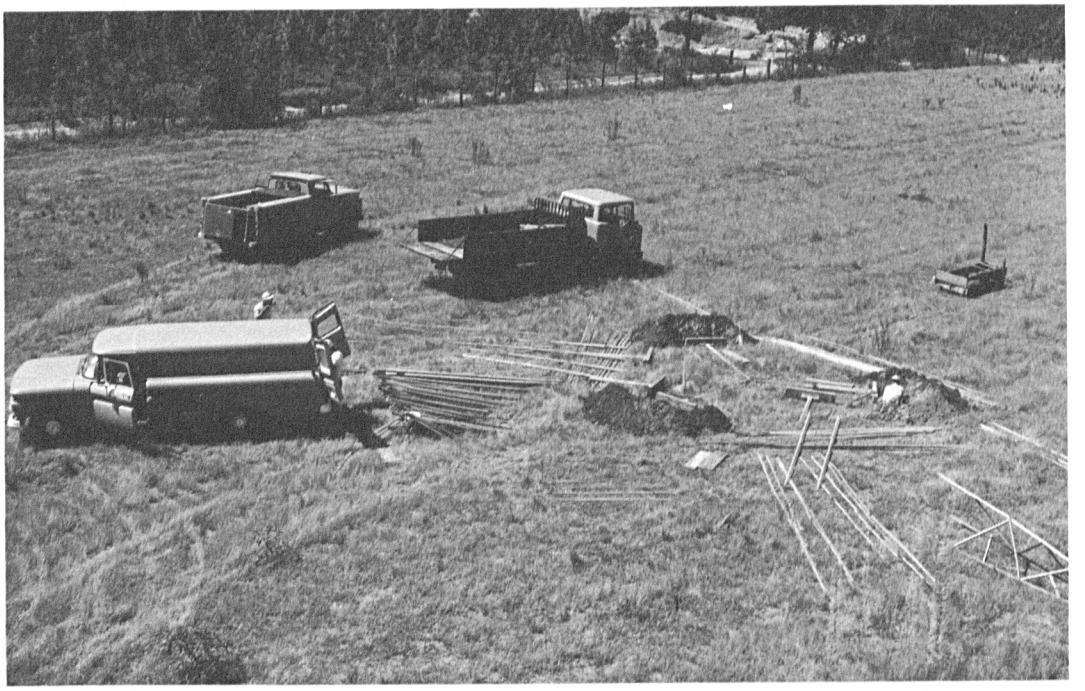

FIGURE 8.—General layout of steel.

LEVELING THE TOWER

After the anchor holes have been completed, the building foreman determines the differences of elevation of the three holes. He then determines the position on each anchor post where the leg of the first section must be bolted in order to have the tower plumb. The following procedure may be used:

Method 1

The foreman sets up the leveling instrument while one of the builders gets a steel tie for use as a leveling rod. The tie is held vertically on a lockboard in the No. 1 anchor hole and the height of instrument (H.I.) is marked on it. This procedure is then repeated for the other two anchor holes.

Selecting the hole of lowest elevation, the builder places the tie vertically on the bottom of the hole and marks the tie at ground level (fig. 9a). The tie is then laid alongside the anchor, with the bottom of the tie flush with the bottom of the mudsill. The builder counts seven or eight bolt holes down on the anchor post from the ground-level mark on the tie and marks the anchor post at this point (fig. 9b). This is the place where the leg is to be bolted on to the anchor post. (Bolting the legs and diagonals to the anchor post below ground level provides greater stability.) The builder slides the tie along the anchor post until the H.I. mark on the tie is opposite the hole where the leg is to be bolted; he then marks the tie at the bottom of the mudsill (fig. 9c). Using this mark as a reference, he lays the tie alongside the second anchor of the pair, and positions the tie so that the "reference" mark is even with the bottom of the mudsill. The bolt hole opposite the H.I. mark is the point where the leg must be bolted to the anchor post.

The tie is then taken to another pair of anchors and placed alongside one of the anchor posts; with the "reference" mark even with the bottom of the mudsill, the bolt hole opposite the H.I. mark for that anchor hole is the point where the leg must be bolted (fig. 9d). This procedure is finally repeated at the third anchor hole (fig. 9e). The legs of the tower will now be at the same elevation when they are bolted to the designated holes in the anchor posts.

Method 2

An alternative method of leveling the tower follows. All anchors are placed upright in the anchor holes. Selecting the hole of lowest elevation, one of the builders places a bolt in the anchor post about seven or eight holes below ground level. Setting a tie on the bolt, and holding the anchor post and the tie in a vertical position, the builder marks the height of instrument (H.I.) on the tie (fig. 10a). Now, by holding the tie beside each of the other anchor posts and sliding it vertically up or down until the H.I. mark is again at the height of the instrument, the bottom of the tie will indicate which bolt hole is at the same elevation as the bolt in the first anchor post (figs. 10b and 10c). A bolt can then be placed in the hole to mark the point where the leg must be bolted. Although this method is more straightforward than the previous one, most builders prefer not to place the anchors in the holes until after the legs of the first section have been bolted on.

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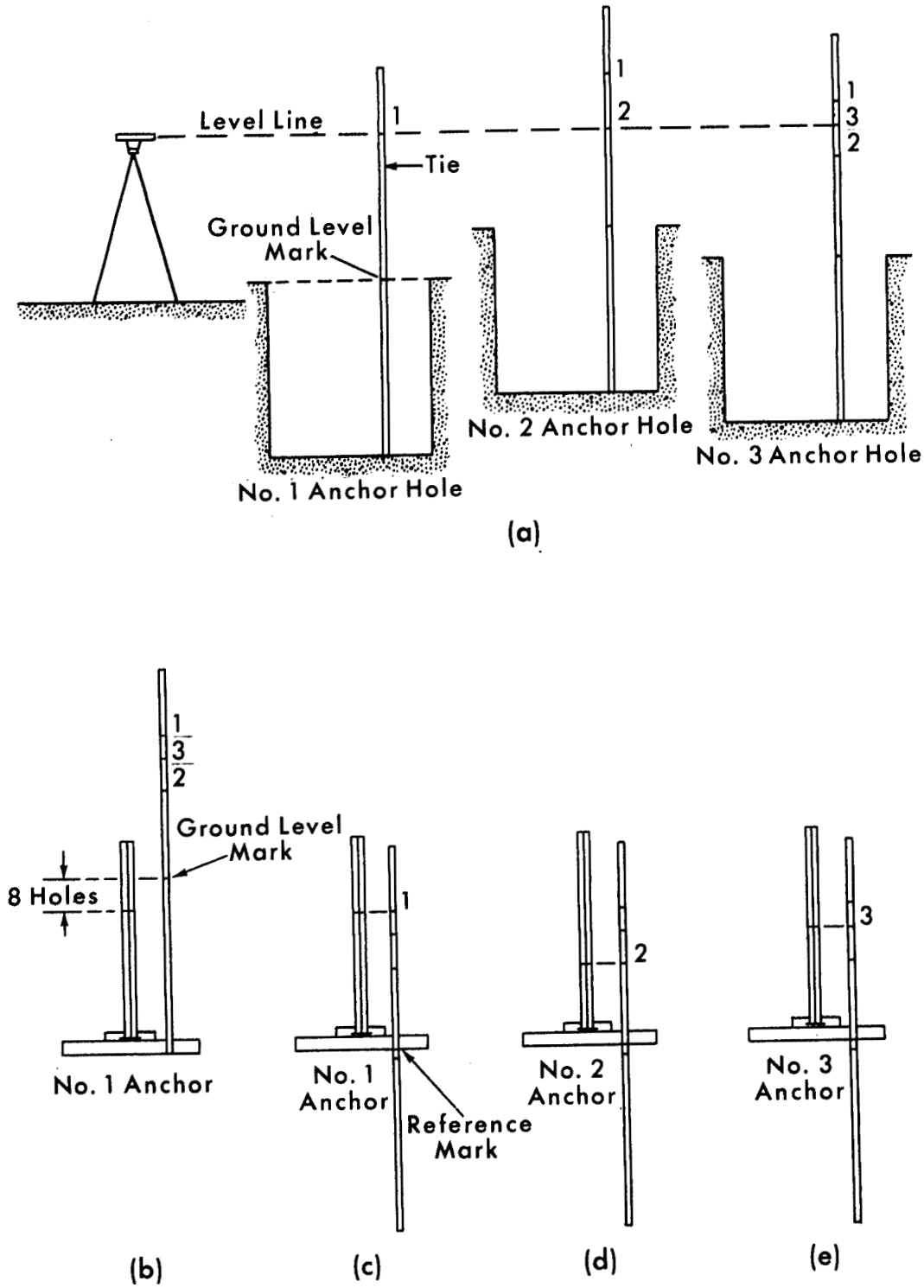

FIGURE 9.—Leveling the tower by method 1.

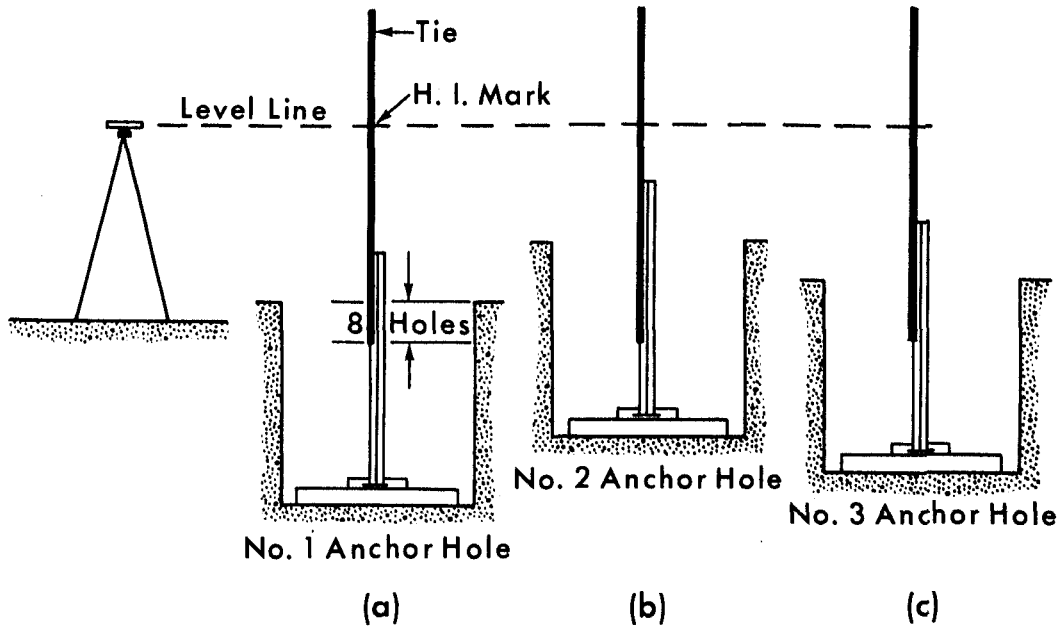

FIGURE 10.—Leveling the tower by method 2.

ERECTING THE BASE OF THE TOWER

Bolt bags, consisting of three leather or canvas pouches on a broad leather belt, are worn by each builder; the bags are filled with ¾-in., 1-in., 1¼-in., and 1½-in. bolts and nuts. Each builder uses two S-type end wrenches. Other equipment used by the building party is listed in appendix F.

Safety hats must be worn by all men until completion of the building operations.

The three leg men bolt the first set of legs onto the anchor posts, making sure that the bottom holes of the legs coincide with the marked holes in the anchor posts. The legs and anchors are ordinarily lying on the ground during this operation. (See fig. 11.) If diagonals are used in the first section, two 1-inch bolts are inserted through the bottom holes of the leg and the holes in the anchor post; nuts are placed on these bolts and tightened. Two 1¼-inch bolts are inserted through the other two holes in the leg, but the nuts are not tightened (because the diagonals will later be placed on these bolts). If rods are to be used in the first section, the leg is bolted on to the anchor post by using ¾-inch bolts in all four holes; the nuts on these bolts are tightened.

The anchors, with the legs attached, are placed in the respective anchor holes. The blue anchors are placed in the holes first and leaned against the backs of the holes; then the red anchors are set in the holes. (See fig. 12.) *On windy days, however,* the red anchors should be placed in the holes and the red half-section ties fastened before the blue anchors are set in the holes. This precaution eliminates the danger of a blue anchor blowing over and injuring a builder who is fastening the ties on the inner tower.

When 37-ft. or 50-ft. towers are erected, the built-up section should be placed inside the tower at this stage of the operations. Because of the size of the built-up

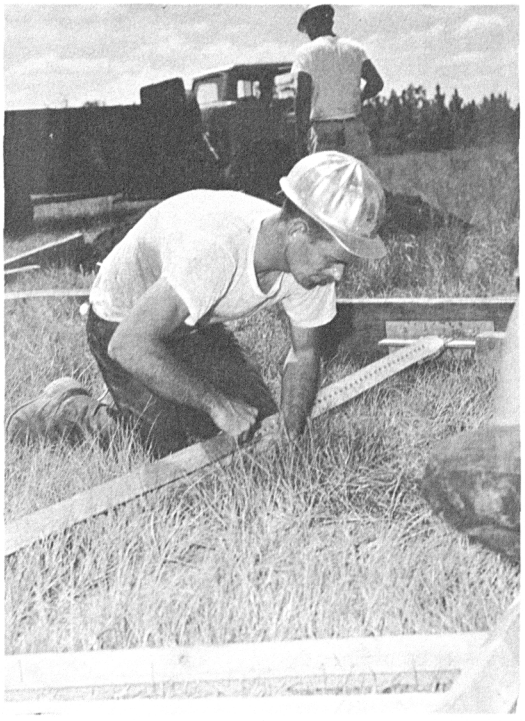

FIGURE 11.—Bolting the base leg to the anchor post.

FIGURE 12.—Placing anchor with attached leg in the anchor hole.

section, it is difficult to maneuver inside the smaller towers after construction of the base sections.

In general, the following procedure is used when erecting the base of a Bilby tower. A 90-ft. tower will be taken as an example. The reader is referred to the glossary (app. A) for definitions of the terms used.

90-ft. Section

1. The leg men hold the red legs while the foreman and the marksetter pick up the red half-section ties. A tie is handed to the No. 1 and No. 2 men, who bolt it to the red legs at the midpoints. This procedure is repeated on the other two sides of the tower.[1] (See fig. 13.)

2. A twisted red diagonal is held in place for the No.1 man, who bolts it to the red tie near the center of the tie. A straight red diagonal is then held in place, and the No. 1 man bolts it to the red tie. This operation is repeated by the No. 2 and No. 3 men.[1] (See figs. 13 and 14.)

[1] In steps 1 and 2, the No.1 man does not necessarily have to build first; the construction procedure may commence with the man who is ready first.

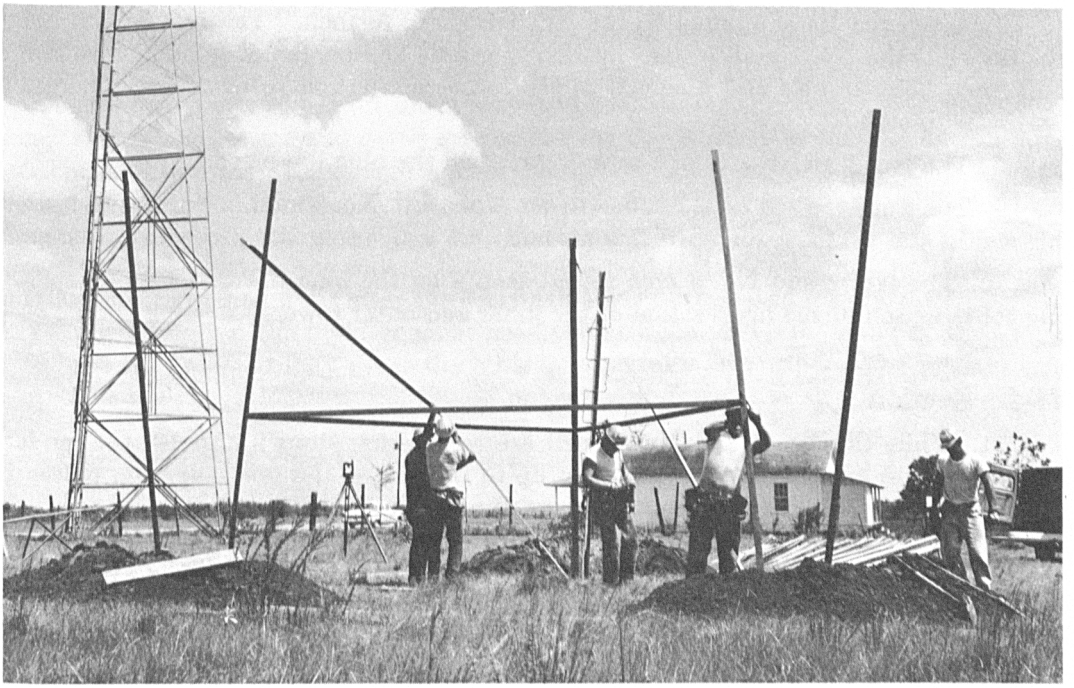

FIGURE 13.—The 90-ft. section. Red half-section ties in place.

3. The lower ends of the six red diagonals are bolted to the bottom ends of the red legs, using the upper two 1¼-inch bolts that are already in place in each anchor post.

4. Steps 1, 2, and 3 are repeated for the outer tower.

5. The builders place their construction platforms on the red half-section ties, and then climb up and stand on the platforms. The painted end of a top red tie is handed to the No. 2 man, who swings the other end over to the No. 1 man. While the No. 1 man holds the tie, the No. 2 man inserts a bolt through his end of the tie and through the red leg, hangs the top end of the red diagonal on the bolt, and puts on the nut. The No. 1 man then proceeds, in a similar manner, to bolt his end of the tie and the top end of his diagonal to the leg. During this operation, the No. 1 man may have difficulty in placing the top end of the diagonal on the bolt, as bends in the various members may cause an improper fit. (Although the tower members should be straightened when they become bent, slight bends and twists that are almost impossible to remove will inevitably occur after much usage.) In this case, the foreman or the marksetter places a crowbar between the red and blue ties at the half-section, and uses the bar as a lever to raise or lower the red diagonal enough for the top end to slip onto the bolt.

6. The No. 1 and No. 2 men bolt the top blue tie and the upper ends of the blue diagonals to the blue legs, following the procedure explained in step 5.

7. A top red tie is handed to the No. 1 and No. 3 men. The No. 3 man holds the tie while the No. 1 man fastens his end of the tie and his red diagonal. The No. 3 man then bolts the tie and diagonal in his corner of the red tower. This operation is similar to step 5.

8. The No. 1 and No. 3 men repeat step 7 on the blue tower.

9. The third top red tie is handed to the No. 2 and No. 3 men. No. 3 man fastens his end of the tie first, then No. 2 man bolts his end, using the procedure in step 5.

10. The No. 2 and No. 3 men repeat step 9 on the blue tower. This completes the construction of the first section of the inner and outer towers.

77-ft. Section

11. While the No. 2 and No. 3 men are completing steps 9 and 10, the ladder-leg man moves his construction platform up to the top of the 90-ft. section, places it on the red ties, and climbs up and sits on the blue ties. He then proceeds to bolt the blue 77-ft. section ladder leg to the top of the blue 90-ft. section leg.

This operation of "hanging a leg" is one of the more difficult tasks on the tower. (See fig. 15.) The builder first inserts a bolt into one of the two lower holes at the top of the 90-ft. section leg. Receiving the 77-ft. section leg from the man on the ground,

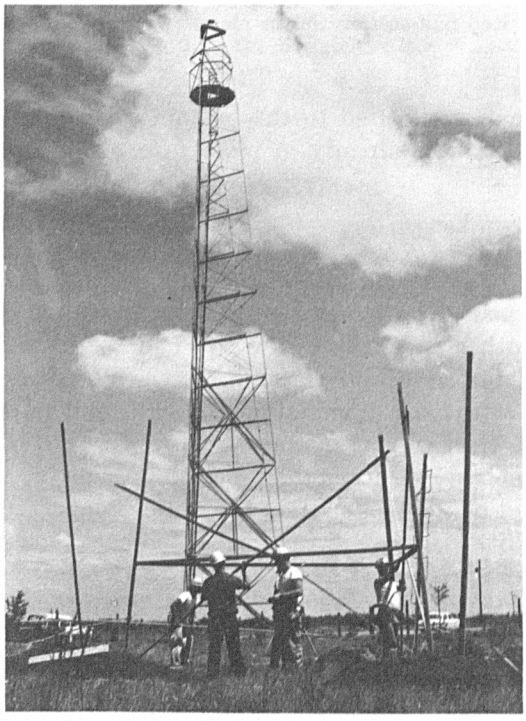

FIGURE 14.— The 90-ft. section. Erecting the red diagonals.

FIGURE 15.— The 77-ft. section. Hanging a leg.

the builder holds the leg upright, with the top end tilted slightly outward (away from the center of the tower), and slides the bottom hole of the leg onto the bolt.[2] It is necessary to hold the bolt in place with the thumb of one hand during this operation. (Some builders prefer to use the toe of a boot to hold the bolt in place. This practice is acceptable if it is easier and more convenient for the builder, as long as he can adequately maintain his balance and anchor himself with his other foot.) Once the leg has been placed on the bolt, the builder rests it there with one hand while he puts the nut on the bolt with the other hand. He then inserts a bolt through the other lower hole and tightens the nuts. Bolts are inserted in the two upper holes, but the nuts are not tightened until after the diagonals have been placed on the bolts.

On windy days, the builders must use caution when they are "hanging the legs". A sudden gust of wind may cause the builder (especially an inexperienced one) to lose control of the leg. Construction should not proceed during strong winds. (See page 60.)

After the blue ladder leg has been bolted into position, the No. 1 man fastens the loose end of the connecting step.

12. As soon as the No. 2 and No. 3 men complete step 10, they place their construction platforms on the top red ties and climb up to the platforms. Following the procedures that are outlined in step 11, they bolt the No. 2 and No. 3 blue legs to the tops of the 90-ft. section legs.

The procedures for the completion of the 77-ft. section will be described only briefly for the purpose of outlining just the general sequence of operations.

13. The three red legs are handed up to the leg men, who bolt them on to the 90-ft. section red legs.

14. The red ties are bolted to the legs at the half-section.

15. The blue half-section ties are bolted to the blue legs.

16. The twisted red diagonals are bolted to the centers of the red half-section ties.

17. The twisted blue diagonals are bolted to the blue half-section ties.

18. The bottom ends of the twisted red and blue diagonals are bolted to the respective legs.

19. Steps 16, 17, and 18 are repeated with the straight red and blue diagonals.

20. The builders' construction platforms are moved up to the half-section, and the red ties for the top of the 77-ft. section are passed up to the leg men. The top red ties and the top ends of the red diagonals are bolted to the legs.

21. The top blue ties and the upper ends of the blue diagonals are bolted to the blue legs. This operation completes the construction of the second section.

While steps 20 and 21 are underway, the marksetter stands at the top of the first section, in order to pass steel up to the leg men. The foreman, meanwhile, lays the steel members up against the ties at the corners of the tower.

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[2] A common tendency for new builders is to lean the top of the leg inward toward the tower; this forces the lower end of the leg outward and it slips off the bolt.

The foreman or the marksetter may also be required to raise or lower the diagonals should the leg men encounter trouble bolting the top ends of the diagonals to the legs.

A precaution regarding climbing on the diagonals should be noted. Before a builder steps on a diagonal to climb from the bottom of a section up to the half-section ties, he should always check to see whether or not a man is near the upper end of the diagonal. Since the diagonal is not bolted at the top, stepping on it will cause the upper end to swing around and possibly strike a builder who may be near it.

64-ft. Section

The procedures for the construction of the 64-ft. section are identical to those for the 77-ft. section. (See figs. 16 and 17.)

50-ft. Section (with diagonals)

If the 50-ft. section contains diagonals, it is constructed in the same manner as the 64-ft. section.

When the 50-ft. section is completed, the builders descend the tower, tightening all loose nuts on the way down, and bolting on the vertical stiffening members ("follies"). (See fig. 18.) These members are fastened on the outer tower in the 64-ft. section and

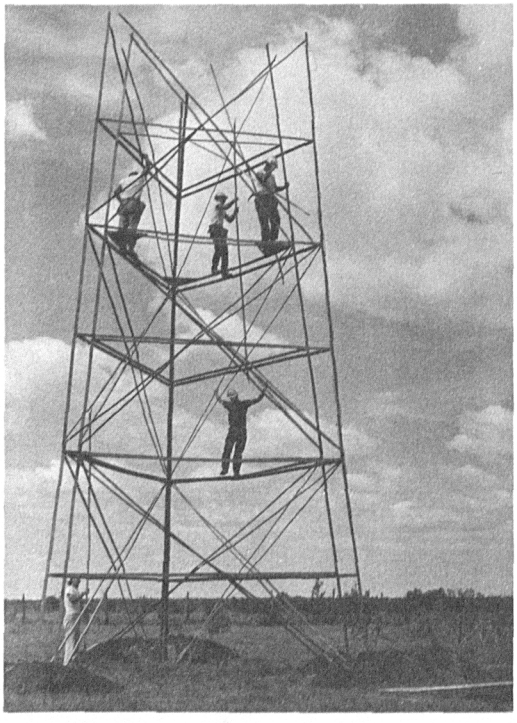

FIGURE 16.—The 64-ft. section. Erecting the diagonals.

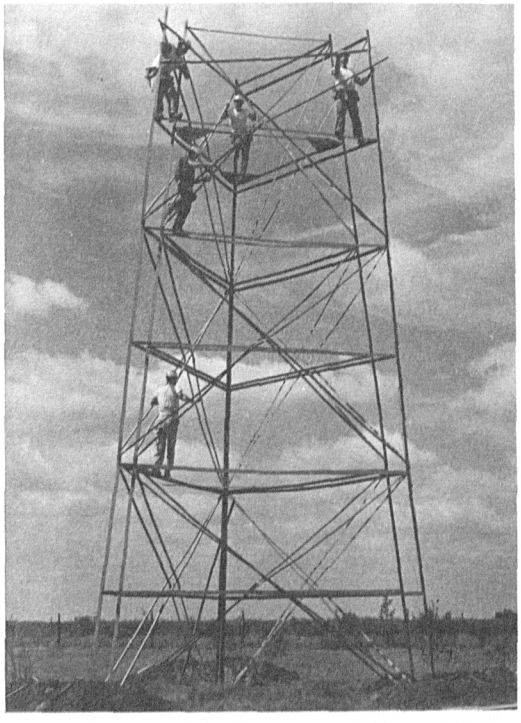

FIGURE 17.—The 64-ft. section. Erecting the top blue ties.

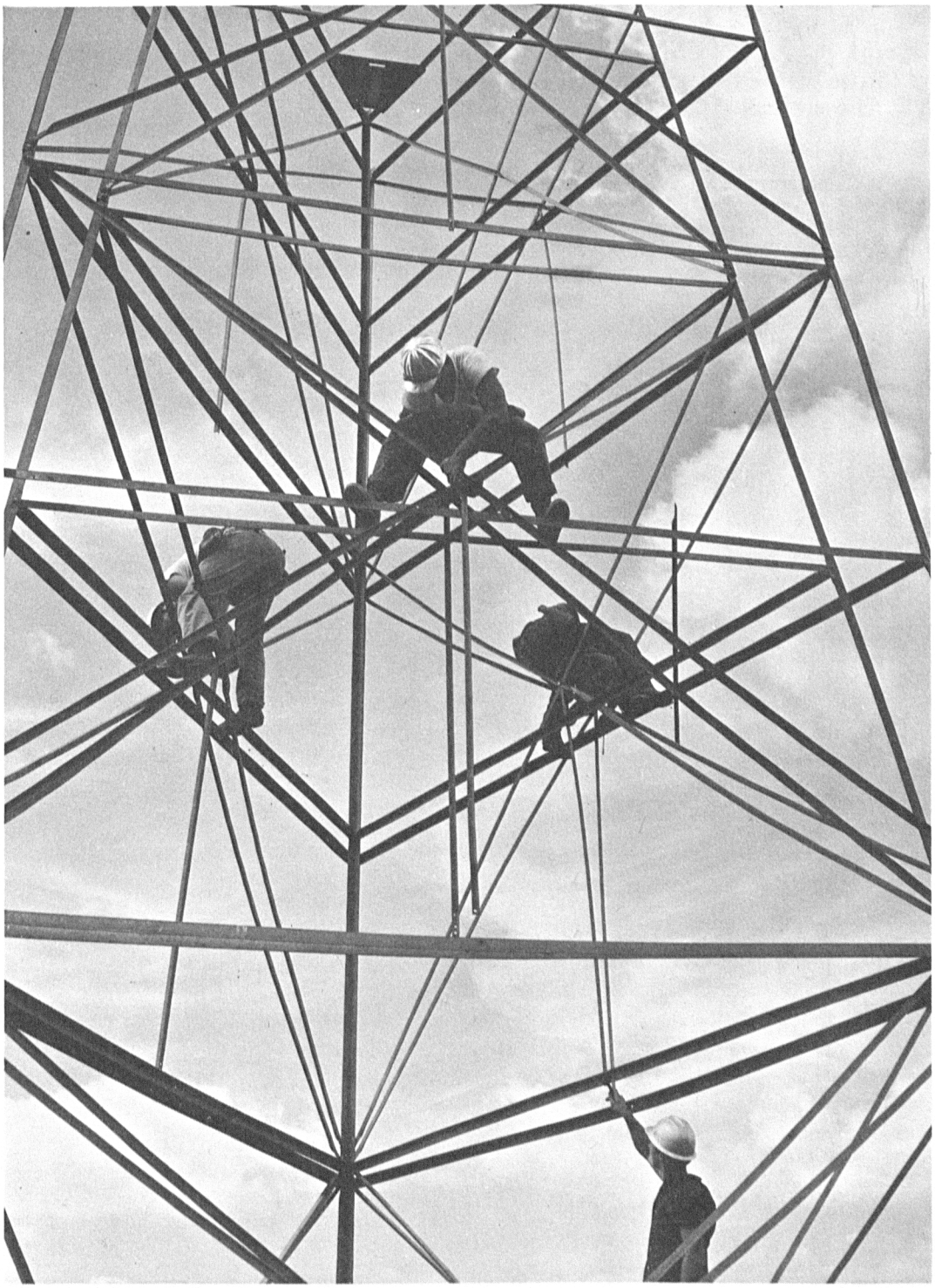

FIGURE 18.—Erecting the vertical stiffening members in the 77-ft. section.

on both the outer and inner towers in the 77-ft. sections. The builders must be especially careful when installing the "follies", since they must stand in the centers of the ties where they cannot hold on to the legs.

This completes the construction of the base of the tower.

50-ft. Section (with rods)

If the 50-ft. section contains rods instead of diagonals, it is not constructed until the topping-off phase of the operations. The construction of the base, therefore, ends with the completion of the 64-ft. section and the installation of the vertical stiffening members.

The reason for not including this section in the construction of the base is that it is easier to hoist the rods, rather than pass them up by hand; no steel should be hoisted until after the anchor holes are filled in.

ALIGNMENT AND FINAL LEVELING OF THE INNER AND OUTER TOWERS

After the builders complete the base of the tower and descend to the ground, the following operations must be carried out:

1. *At a new station:* The inner and outer structures are inspected to make sure they are in proper alignment with each other. Small adjustments in the positions of the anchors at one or two corners of the tower will usually be necessary.
2. *At a previously-established station:* Not only should the alignment of the inner and outer towers be checked, but the plumbing and centering of the towers over the station mark must also be verified. (The latter operations are not critical at a new station, because the station mark is not established until after completion of the tower.)

When these tasks are completed, the anchor holes are filled in.

Tower at New Station

In order to check the inner and outer structures for alignment, the building foreman stands outside the tower, midway between two legs (at the intersection of the diagonals), and sights toward the opposite red and blue legs. If the blue leg is not directly behind the red leg, the blue anchor is shifted in position with a pinch bar until the blue leg is in line with the red leg and the foreman's eye. (See fig. 19.) The foreman then moves to the center of another side of the tower and again aligns the opposite legs. This procedure is finally repeated for the third pair of legs.

The foreman must now make sure that each pair of red and blue legs are in alignment throughout their entire height. Standing at the center of one side of the tower, he inspects the opposite legs; if they are not in alignment at the top of the tower, the high end of one of the mudsills is tamped with a steel member until the blue leg is directly behind the red leg throughout the entire height of the legs. The other two pairs of legs are then checked in a similar manner. (See fig. 20.)

FIGURE 19.—Shifting the anchor to obtain proper alignment of the red and blue legs.

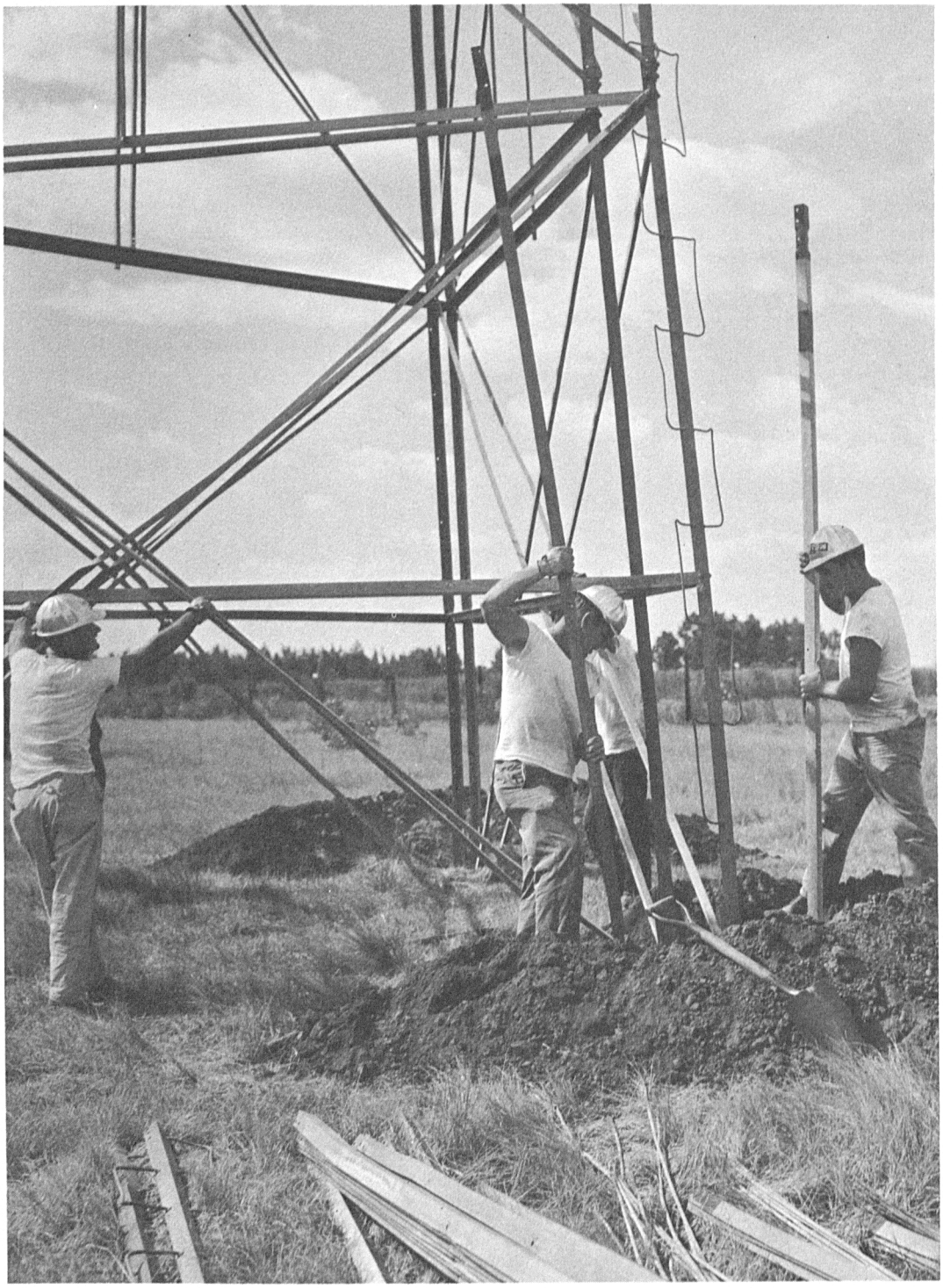

FIGURE 20.—Tamping the anchor mudsill for alignment of tower legs.

The tower should be settled by tamping all of the mudsills. (This task is independent of the alignment operations.)

Before the anchor holes are filled in, the foreman checks each pair of anchors to make sure that the red and blue mudsills are not touching each other and that there is no object, such as a boulder, between the mudsills that could transmit movement from the outer tower to the inner tower.

Each leg man fills in his own anchor hole. The mudsills are covered with at least a 2-inch layer of soil before the lockboards are placed in their holes. As the anchor holes are filled in, the soil is well tamped.

Tower at an Old Station

The foreman must first verify that the legs of the inner tower are exactly equidistant from the station mark. This is accomplished by measuring the distance from the mark to the inside of each red leg at the first half-section tie. These three measurements should agree within about 1 inch.

The foreman then sets up the leveling instrument. Using a board or a steel member as a leveling rod, a builder holds the rod at one of the red legs, making sure that the top of the rod is firm against the bottom of the first half-section tie. The height of instrument is marked on the rod. By repeating this procedure at the other corners of the tower, the differences in elevation of the red legs are obtained.

If the inner tower is not level and/or not centered over the station mark, the red anchors must be moved as follows: If a leg is high, the mudsill is tamped with a steel member; if a leg is low, the mudsill is raised (using the pinch bar as a lever) and soil is tamped under it. In order to center the red tower over the station, the anchors must be shifted horizontally with the pinch bar.

A final round of level observations and tape measurements are taken to make sure that the inner tower is centered and is plumbed. After this is done, the blue tower is alined with the red tower, using the same procedures as those described for a tower at a new station. The anchor holes are then filled in as previously explained.

TOPPING OFF THE TOWER

During this phase of the construction, the steel is hoisted up the tower rather than passed up by hand. The hauling line consists of a 250-ft. length of ¾-in. manila rope. The line is roved through a 6-in. single fixed block that is hooked to the tower. Attached to a ring on the running end of the line are: A ring or small block which runs on the hauling part of the line, a haul-back line (125 feet of ⅜-in. or ½-in. manila rope), and two or three heavy harness hooks. (See fig. 21.)

While the anchor holes are being filled in, the marksetter helps the foreman prepare for the hoisting operations. The building truck is positioned about 30 feet from the ladder leg, the right-rear wheel is jacked off the ground, and the other wheels are chocked to prevent the truck from rolling. The winch drum is bolted to a special flange on the right-rear wheel.

The foreman commences to tie the steel into bundles for hoisting. A 6-ft. length of ½-in. rope, with a 2½-in. metal ring on one end, is hitched around each bundle of steel.

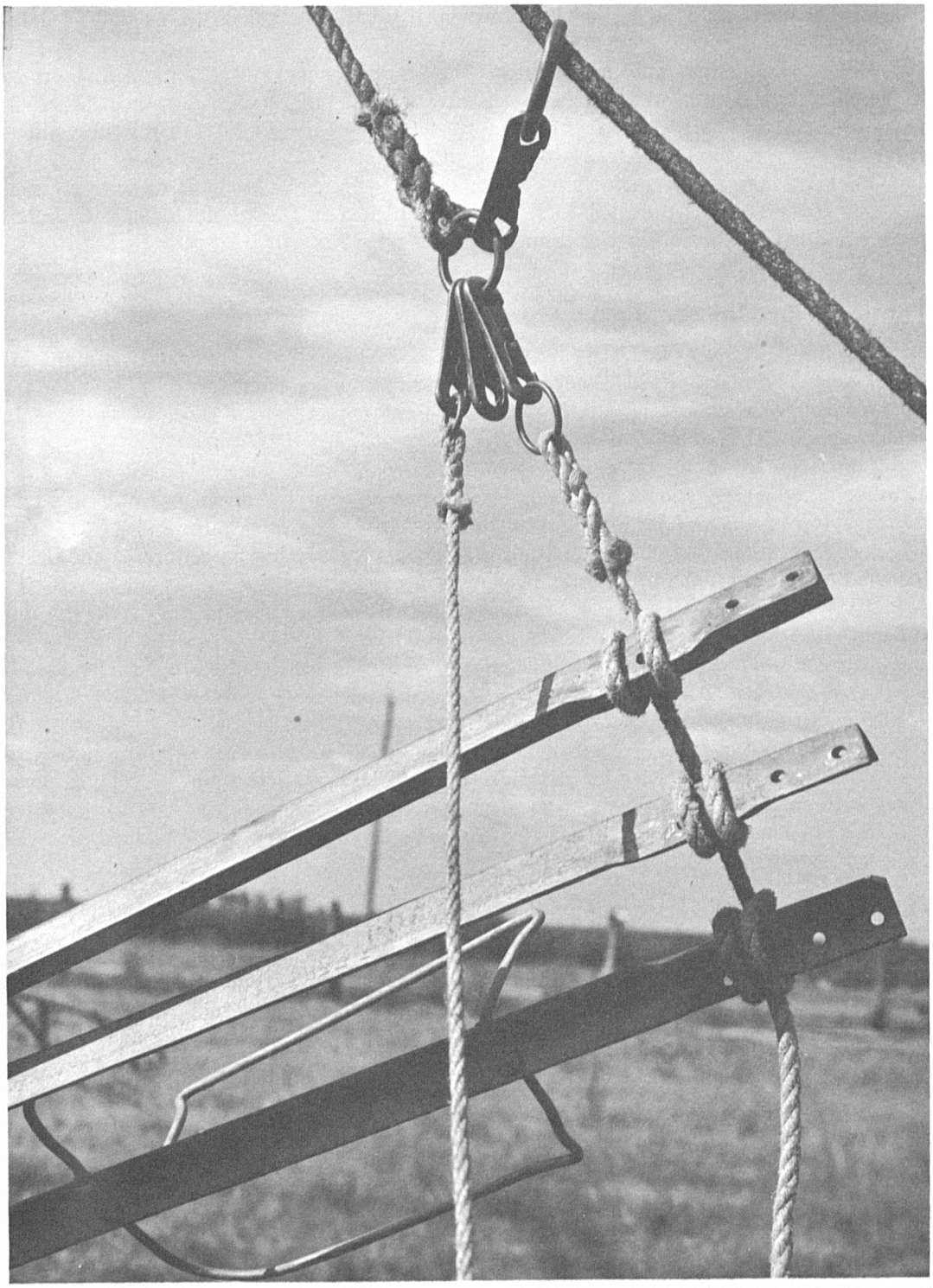

FIGURE 21.—Hoisting apparatus.

(Each bundle will, in turn, be attached to the ring on the end of the hauling line with a harness hook.) (See fig. 21.)

The leg men ascend to the top of the highest section, with the ladder-leg man carrying the block and the hauling line. The block is hooked to the bottom of the topmost step, and a hook or chain is attached to the ladder leg to prevent the block from sliding to the outer edge of the step.

The marksetter now acts as takeoff man. He stands one half-section below the ladder-leg man, his primary duty being to remove the steel from the hauling line and to pass the members up to the leg men. Depending on his speed and ability, he may also assist the ladder-leg man in fastening his blue rods up to the top of the 37-ft. section, and he may tighten the nuts on all three blue legs.

The foreman remains on the ground and operates the winch. With the truck in high gear, the throttle is set equivalent to a speed of about 20 miles per hour. Steel is hoisted by taking turns of the rope around the revolving winch drum (fig. 22); the foreman can control the actual speed of the hauling line by varying the tension on his end of the line.

There should be an auxiliary ignition cut-off switch on the right side of the building truck for the purpose of stopping the engine in an emergency. An iron pinch bar should be stuck upright in the ground about two feet from the winch drum, with the free end of the rope placed outside the bar; this arrangement should prevent the line from becoming fouled in the rotating truck wheel or around the foreman.

The construction of the remaining sections of the tower will be described briefly. It will be assumed that the 50-ft. section has been completed.

FIGURE 22.—Hoisting steel with the revolving winch drum.

37-ft. Section

The topping-off operation commences by hoisting the blue 37-ft.-section legs. The takeoff man removes the three legs from the hauling line, hands the ladder leg to the No. 1 man, and then passes the other legs to the No. 2 and No. 3 men. (See fig. 23.) While the blue legs are being bolted on, the red legs are hoisted up the tower. The red legs are then erected.

The next step is to hoist, in one group, all red and blue rods and ties for the lower half-section. (See fig. 24.) This bundle of steel is so tied that the rods can be removed from the rope first. The takeoff man hands the steel to the ladder-leg man, who lays it across the top 50-ft.-section ties. The blue rods are bolted first, at their lower ends, and then the lower ends of the red rods are fastened. The half-section is completed by bolting the blue half-section ties and the top ends of the blue rods, followed by the red ties and the upper ends of the red rods. (See fig. 25.) Before the red ties and rods are erected, the block is moved up one half-section; this permits the foreman to hoist another load — containing the top ties and the rods for the upper half-section — while the builders are completing the lower half-section. (See fig. 25.)

24-ft. Section

When the top of the 37-ft. section is reached, work on the inner tower is discontinued, and the leg men construct the outer tower only. The blue legs are hoisted

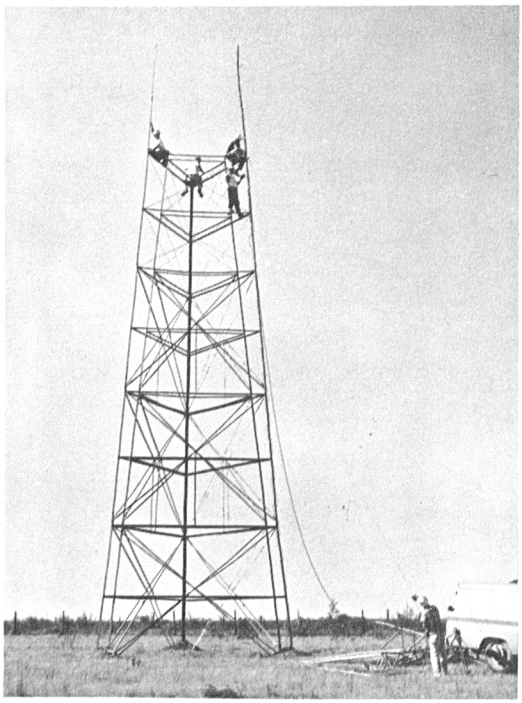

FIGURE 23.—The 37-ft. section. Hanging the blue legs.

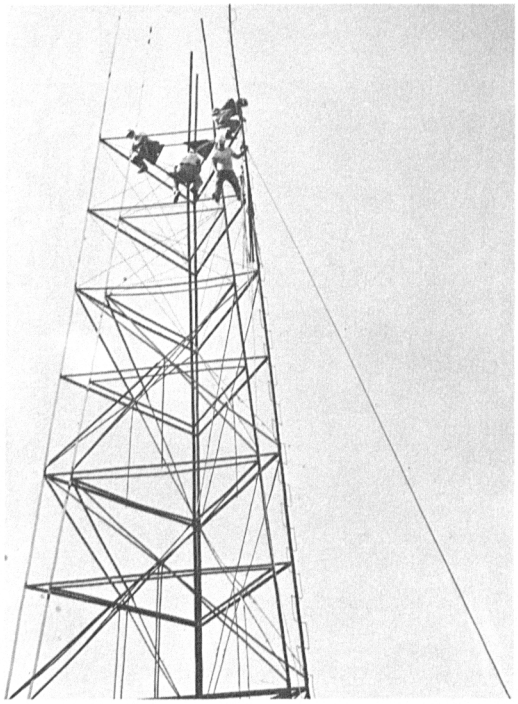

FIGURE 24.—The 37-ft. section. Takeoff man preparing to remove rods from the hauling line. Back-leg men complete erection of red legs.

first, followed by the blue ties and rods for the lower half-section, and finally by the blue ties and rods for the upper half-section. Construction procedures are similar to those for the 37-ft. section. (See fig. 26.)

Knob-leg Section and Cage

The reader is referred to the glossary for complete definitions of the colloquial terms — such as wishbones, spaghetti, window legs — that appear in this section.

After completion of the blue 24-ft. section, the knob legs are hoisted. While these legs are being erected, the ties and rods for the half-section and the lower set of wishbones are hoisted as a group. The erection of the half-section ties and the wishbones is the first step in the construction of the cage. (See figs. 27 and 28.)

The second set of wishbones and the first set of spaghetti are then hoisted. (The foreman should leave the bundle of spaghetti wired, as a precaution against any of the pieces slipping out of the bundle while they are being removed from the hauling line.) While the wishbones are being bolted to the top ends of the knob legs (fig. 29), the takeoff man carries the builders' construction boards down to the top of the 37-ft. section and sets them on the blue ties. He then descends to the ground to assist the foreman.

The next step is to hoist the three platform boards that make up the floor of the cage. (See fig. 30.) The boards are placed in position on top of the ties and wish-

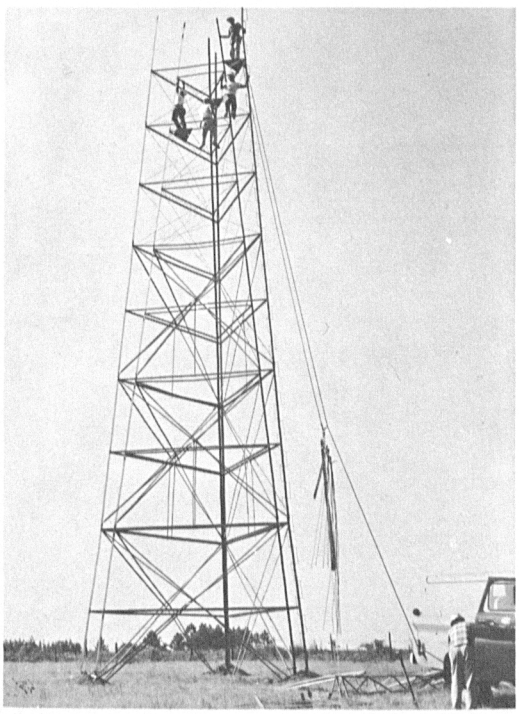

FIGURE 25.—The 37-ft. section. Hoisting the top ties and rods.

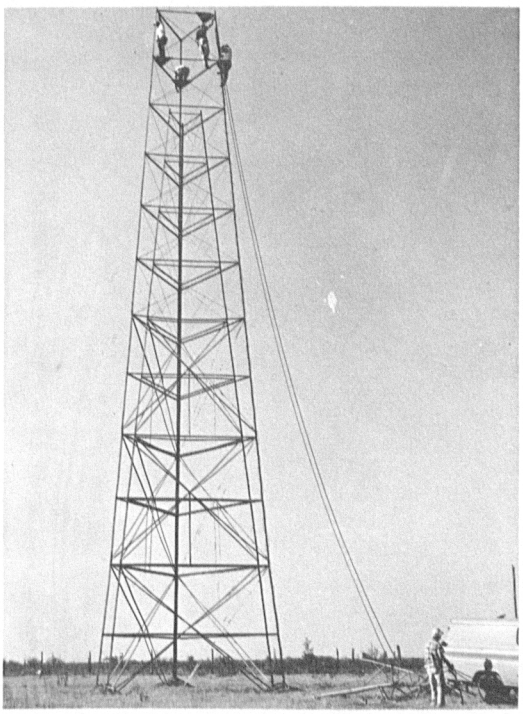

FIGURE 26.— The 24-ft. section. Erecting the top ties and rods.

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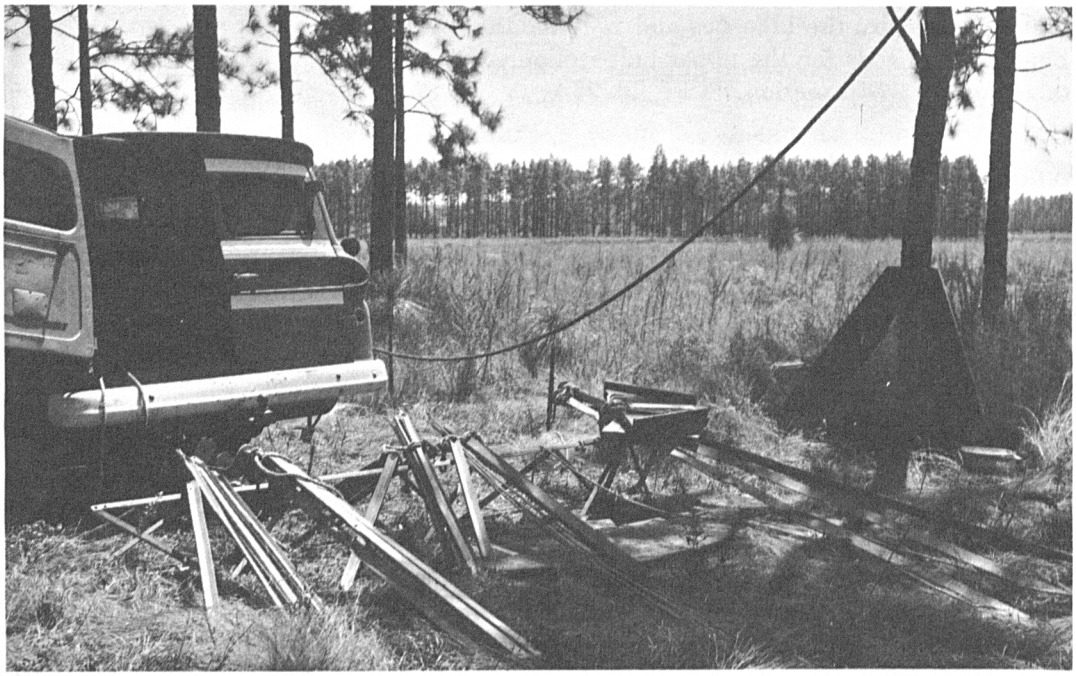

FIGURE 27.—Knob-leg section and cage steel tied for hoisting.

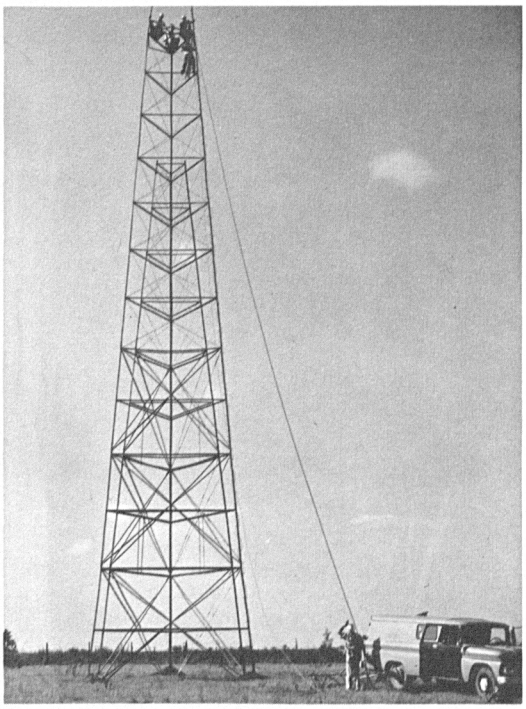

FIGURE 28.—The knob-leg section. Lower wishbones in place.

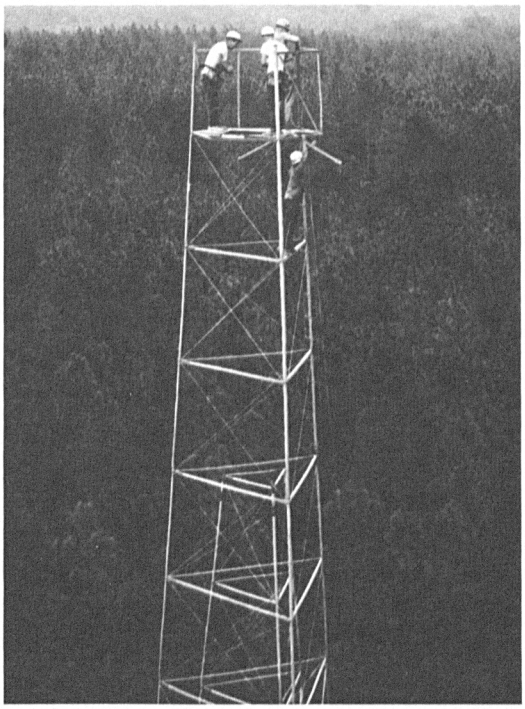

FIGURE 29.—The knob-leg section. Erecting wishbones and spaghetti.

bones, and are either wired or bolted down to prevent strong winds from blowing the small boards off the tower or the large board up against the welded section. (See fig. 31.)

On windy days, the haul-back line should be tied to the large platform board and handled by the takeoff man as the load is being hoisted. The takeoff man (who is on the ground) should maintain tension on the line in order to prevent the board from swinging around, striking the tower, or becoming tangled in the hauling line.

The three window legs are then hoisted (fig. 31) and bolted to the tops of the knob legs. (See fig. 32.) Finally, the third set of wishbones, the second set of spaghetti, the lightplate and triangle head, and the lightkeeper's platform are hoisted in one load. This is the last load of parts for the outer tower. (See fig. 33.)

Hoisting the Built-up and Welded Sections

After the last piece has been removed from the hauling line, the foreman and takeoff man carry the built-up section and the welded section inside the tower (unless this has already been done). The welded section is then bolted to the top of the built-up section. (See fig. 34.)

When the leg men complete the construction of the cage (fig. 35), the No. 2 and No. 3 men descend to the top of the 37-ft. section and stand on the construction boards.

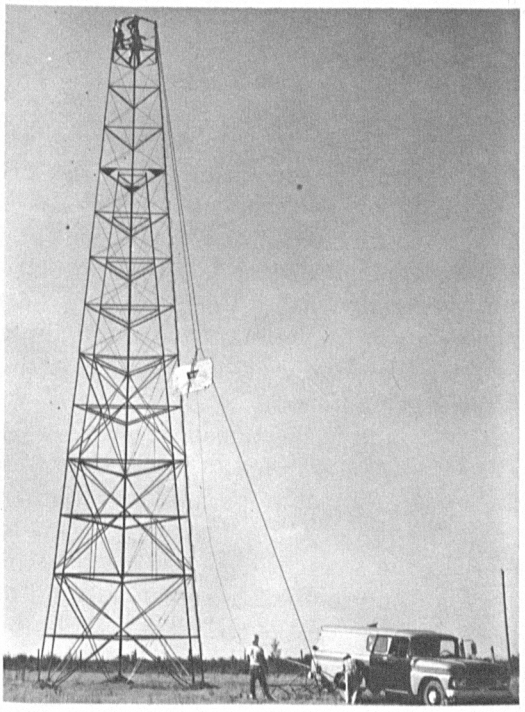

FIGURE 30.—Hoisting the platform boards. Notice the takeoff man on the ground and the construction platform at the top of the 37-ft. section.

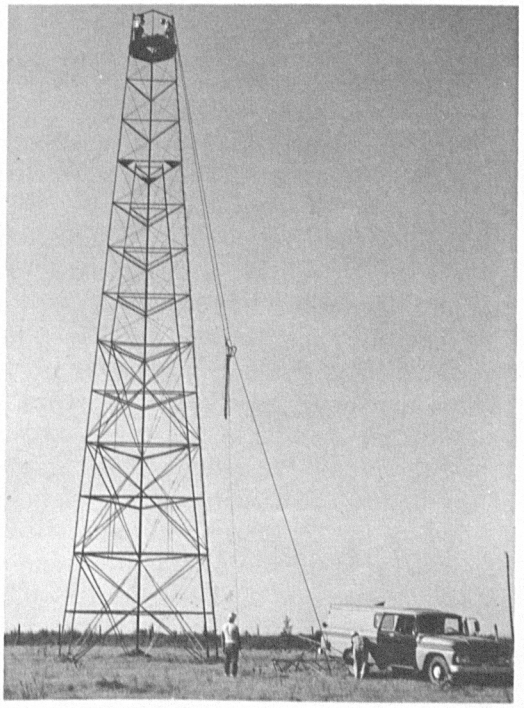

FIGURE 31.—Hoisting the window legs. Note that the observer's platform is in place.

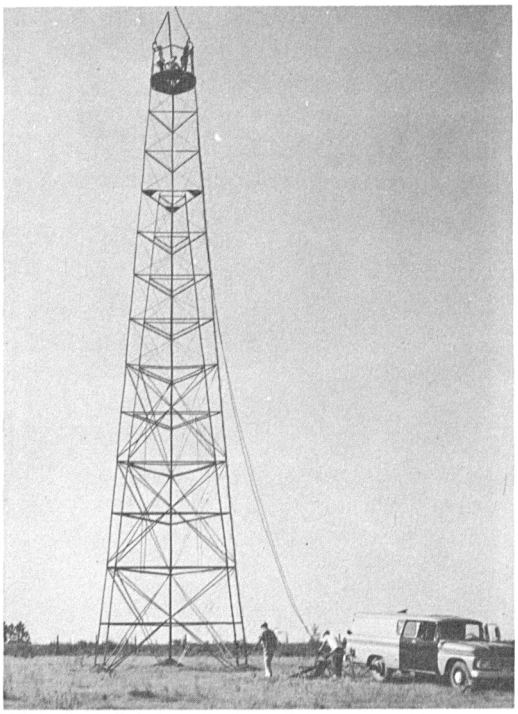

FIGURE 32.— Erecting the window legs.

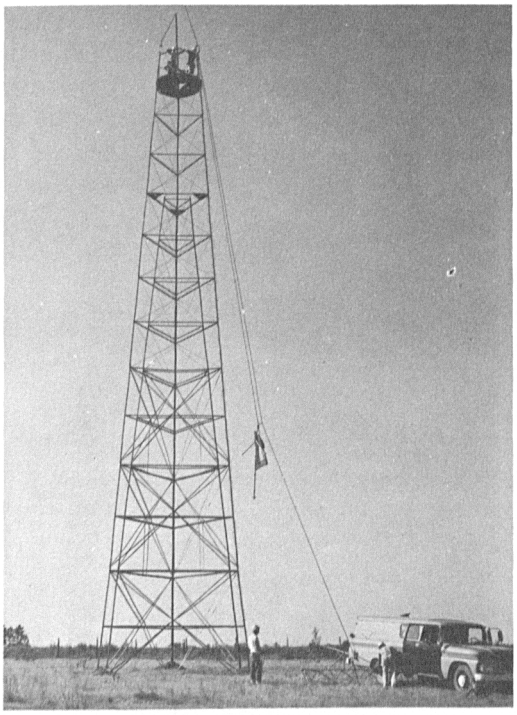

FIGURE 33.— Hoisting the last load of parts for the blue tower.

The ladder-leg man hooks the block to the triangle head and lowers the hauling line down through the center of the tower to one of the ground men, who in turn ties the line to the top of the welded section. (The rope must be attached to the main part of the welded section — not to the adjustable head — in such a manner that it will pull the load up straight.) A screwdriver for adjusting the lightplate is tied to the welded section. The welded and built-up sections are now ready for hoisting. (See fig. 36.)

As a safety precaution, the takeoff man should sit in the building truck and apply the brake when the load reaches the proper height. The ladder-leg man, who is in the cage of the tower, guides the rope while the load is being hoisted.

The No. 2 and No. 3 men guide the welded and built-up sections into position on top of the red 37-ft. section. (See fig. 37.) The men then proceed to bolt the bottom of the built-up section to the top of the 37-ft. section, but do not completely tighten the nuts if the tower is at an old station (in case the top of the welded section has to be moved slightly while collimating the tower). If the tower is at a new station, the ladder-leg man (in the cage) centers the welded section in the triangular opening of the observer's platform (maintaining at least a 1-in. clearance on all sides), while the No. 2 and No. 3 men tighten the nuts at the bottom of the built-up section. (See fig. 38.)

The ladder-leg man unties the rope from the welded section and lowers it to the 37-ft. section, where the construction boards are attached and lowered to the ground. He then slides the block down the rope and drops the rope to the ground.

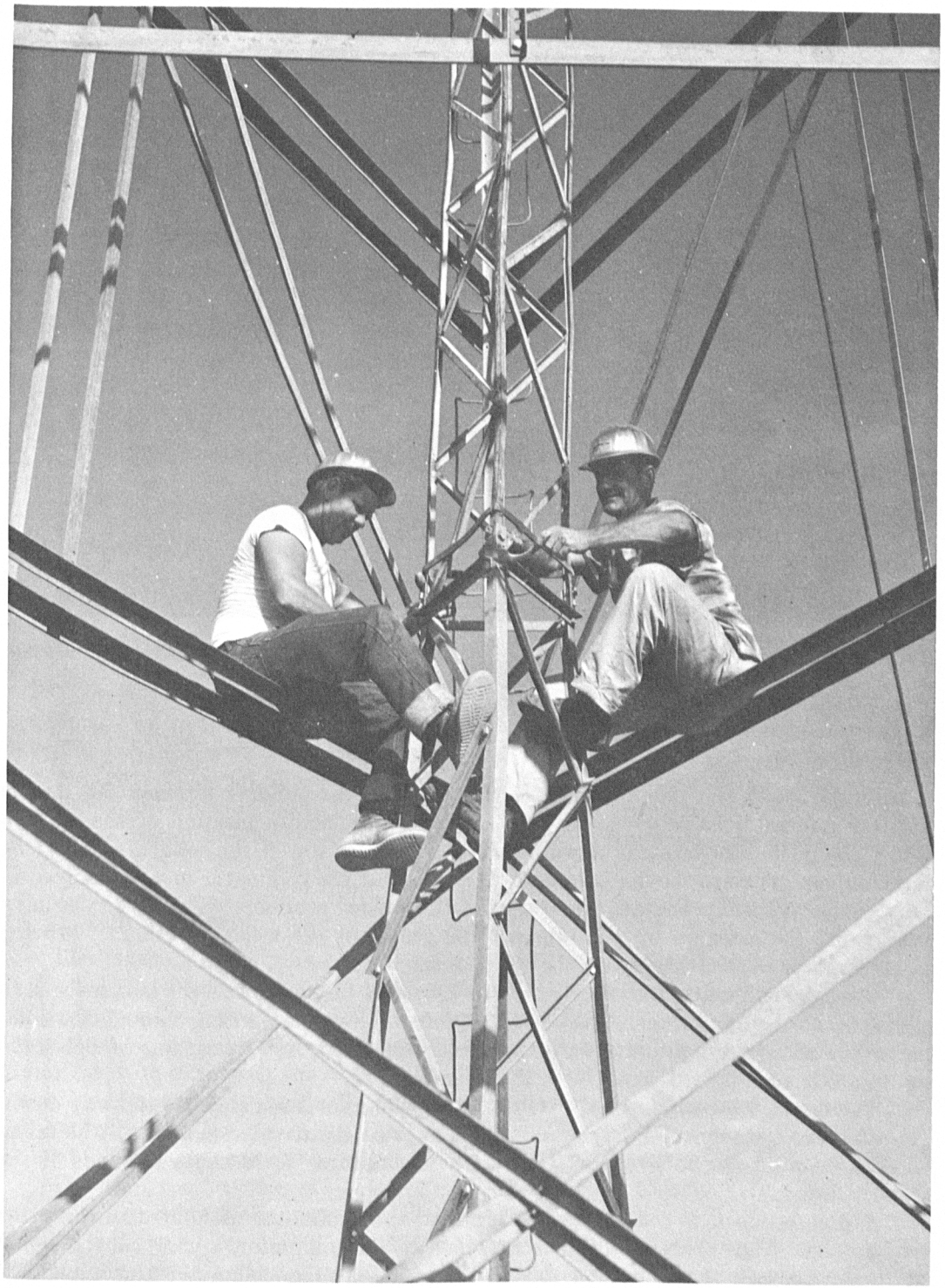

FIGURE 34.—Bolting the welded section to the built-up section.

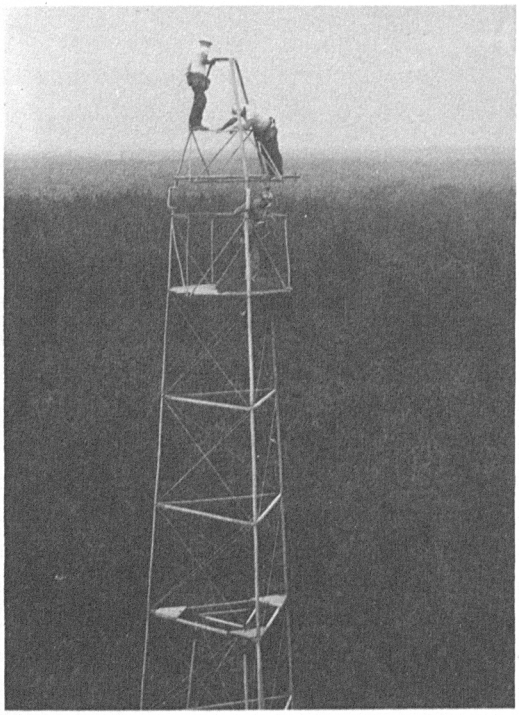

FIGURE 35.—Completing the cage.

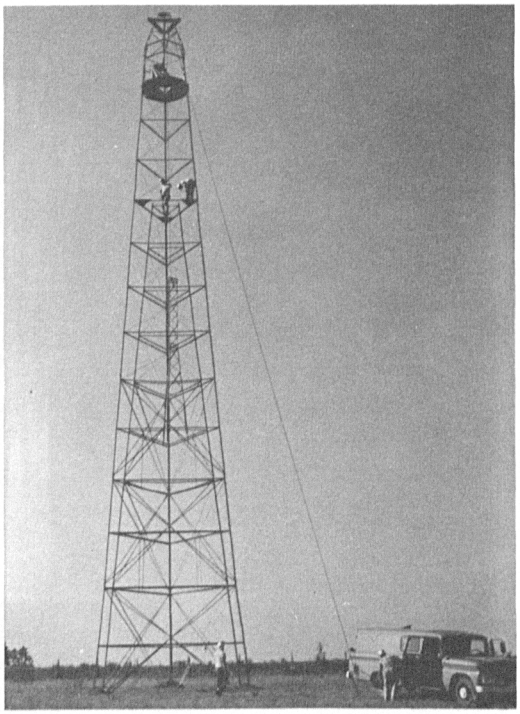

FIGURE 36.—Hoisting the welded and built-up sections.

COLLIMATING THE TOWER

At a New Station

As the No. 2 and No. 3 men descend the tower, the building foreman sets up the vertical collimator over the stake marking the approximate position of the station. Using the collimator to sight upward at the triangular top of the welded section, the foreman can estimate the distance and direction that the collimator must be moved in order to be vertically beneath the center of the welded section. (The ladder-leg man may assist the foreman by pointing out the center of the welded section.) Moving the collimator once is usually all that is necessary.

With the collimator now located at the center of the red tower, the ladder-leg man climbs up to the lightplate. Guided by the foreman, who is sighting through the collimator, he slides the lightplate until the center hole is in the vertical line of sight; the lightplate is then bolted securely to the triangle head.

The ladder-leg man descends the tower, checking for loose steps on the way down, and, if necessary, replacing any steps that cannot be tightened. (Care must be taken when tightening the nuts on the steps, as excessive force could cause the ends of the steps to break.)

A plumb bench is constructed underneath the collimator without disturbing the tripod. By means of the plumb bob attached to the collimator, a point on the bench vertically beneath the collimator axis is determined. The collimator and tripod are then removed from underneath the tower, the plumb bench is swung aside, and the digging of the station-mark hole begins. The underground and surface station marks

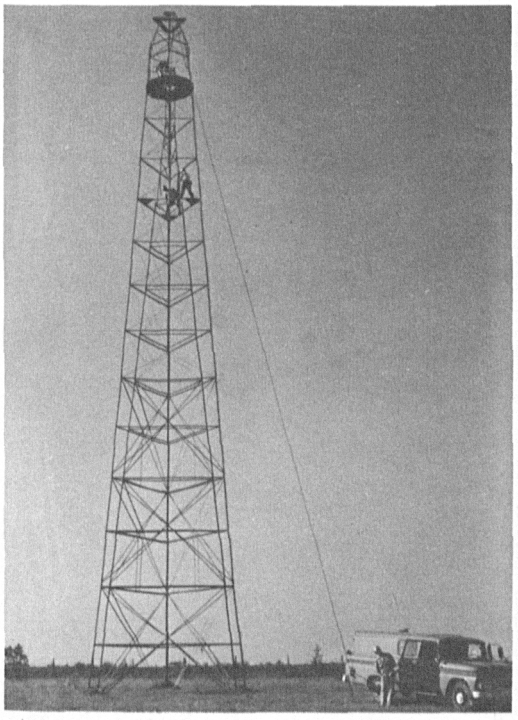

FIGURE 37.—Guiding the built-up and welded sections into place.

FIGURE 38.—Bolting the built-up section to the top of the red 37-ft. section.

are plumbed directly under the designated point on the bench. All marks are established in accordance with the specifications and procedures set forth in Special Publication No. 247, "Manual of Geodetic Triangulation," 1959, pages 84–95. The witness post should be set underneath one of the red ties of the first section; in this location it is near the station mark, yet not in a position where anyone using or dismantling the tower could fall on it. (See figs. 39 and 40.)

At an Old Station

The foreman sets up and plumbs the vertical collimator over the station mark. If the welded section is not centered directly over the mark, the foreman instructs the ladder-leg man to move the top of the welded section until its center is collimated over the station. The ladder-leg man then holds the welded section in place while the No. 2 and No. 3 men tighten the nuts at the bottom of the built-up section. When this operation is completed, the No. 2 and No. 3 men descend to the ground, and the ladder-leg man climbs to the top of the tower and collimates the lightplate as previously explained. He then descends the tower, checking for loose ladder steps on the way down.

The basic construction of the tower is now complete. (See fig. 41.) Occasionally, certain safeguards for the protection of the public — such as warning lights, protective fencing, and guy wires — must be added to the tower. (See page 61.) All towers should have a danger warning sign attached in a conspicuous position on or near the ladder leg.

With the aid of the reconnaissance sketch, the foreman checks the lines to other stations from the top of the tower to determine whether or not any lines are obstructed.

FIGURE 39.—Using the vertical collimator. Notice the witness post at right.

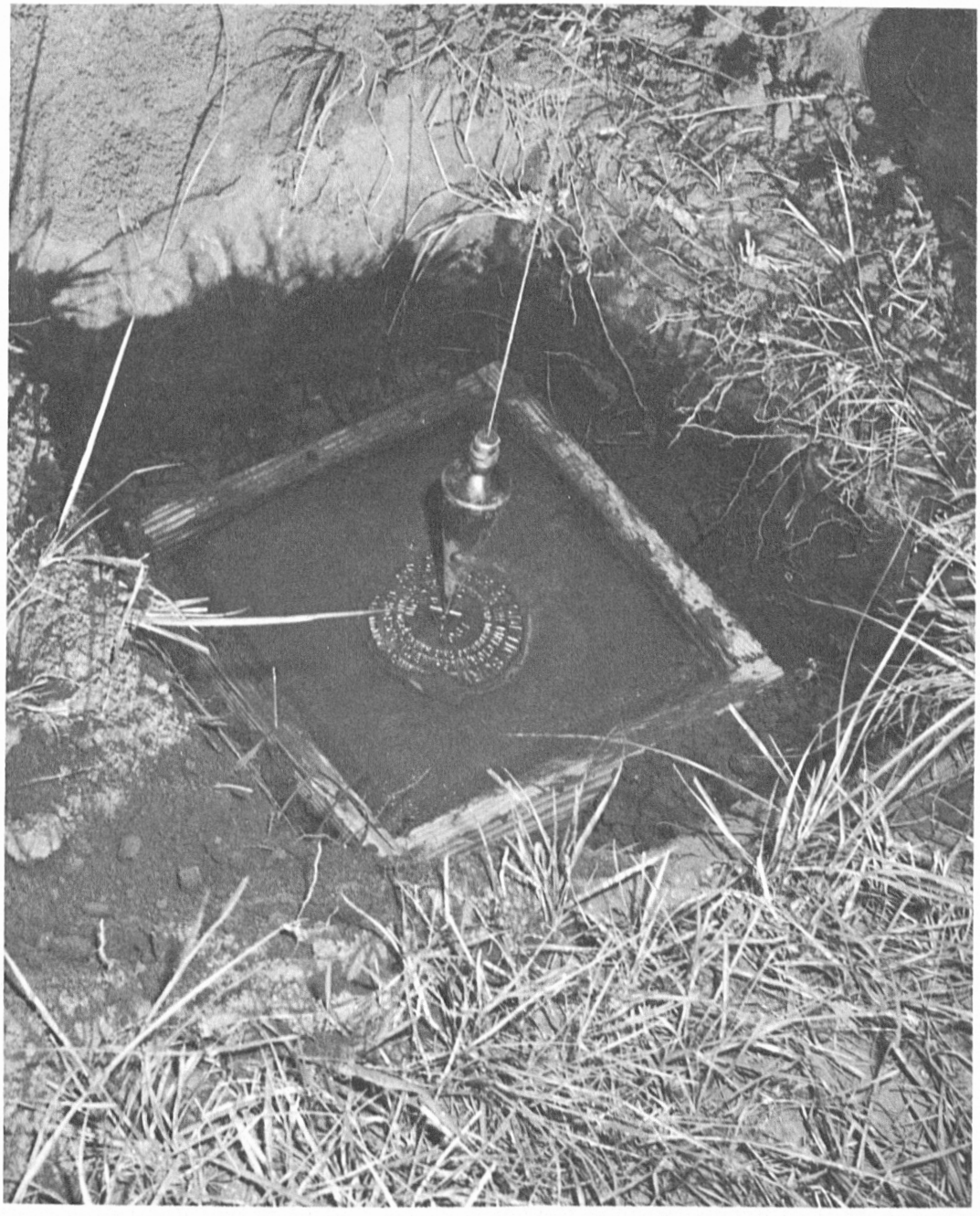

FIGURE 40.—Triangulation station mark.

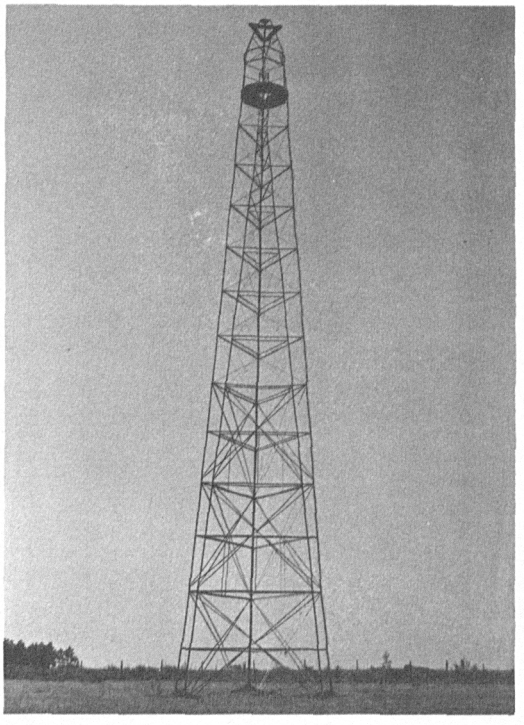

FIGURE 41.—The 90-ft. tower, complete.

If a line is blocked, some clearing may be required or the addition of a vertical extension on the tower may be necessary.

Before leaving the station, the foreman makes sure that all equipment and tools have been picked up and that the site is left in a clean and orderly condition.

USE OF GUY WIRES AND SANDBAGS

Guy wires should be used in the following cases:

1. When the anchor holes can not be dug to the minimum depths specified in table 1.
2. When two or more 10-ft. vertical extensions are added to the tower.
3. In areas where severe windstorms are prevalent.
4. When a tower is located less than the tower's height from the edge of a highway, an occupied residence or building, railroad tracks, or high-tension lines.

Ordinarily, the ends of the guy wires are hoisted up the tower with the last load of steel, although it may be necessary to guy the tower before it is completed. The guy wires are attached to the legs of the outer tower. The smaller towers are usually guyed near the top only, whereas the larger towers may be guyed from two or more places, at different heights, on each leg. The exact number of guys required depends, of course, upon the instability of the tower, and must be determined by the building foreman.

The lower ends of the guy wires may be anchored to trees, large boulders, or "deadmen" (4″ x 4″ x 60″ timbers). When guys are anchored to trees, the wires should be attached as close to the ground as possible; guys placed too high on a tree

could break or become loose because of the swaying of the tree. If no trees or boulders are available, "deadmen" buried at least 3 feet in the ground may be used as anchors.

Each guy on a tower consists of two strands of No. 9 galvanized wire. Turnbuckles must be used to apply tension to the wires. In populated areas, the guy wires may have to be flagged in order to be visible to people after dark.

When anchor holes can not be dug to the specified depth, not only should guy wires be used, but, in addition, each anchor should be weighted down with sandbags or boulders. On rare occasions, the tower may have to be placed on concrete, rock, or some other surface where no anchor holes can be dug; in this situation, a 90-ft. tower should have sixteen 150-lb. sandbags at each of the three corners of the tower, and arrangements should be made to complete the observations and dismantle the tower as soon as possible (within 1 or 2 days).

CONSTRUCTION OF THE VERTICAL EXTENSIONS

After a tower has been erected, it is sometimes found that additional height is needed to clear intervening obstructions that are on line to another station. Supplemental 10-ft. vertical extensions for both the outer and inner towers may then be inserted at the base of the knob-leg section (outer tower) and at the base of the welded section (inner tower). In order to perform these operations, the top 20 feet of the tower must be dismantled.

The inner tower extension is similar in construction to the welded section, except that it does not have the adjustable head. The outer tower extension is made up of vertical legs, ties that are of the same length as the top 24-ft.-section blue ties, and rods.

A brief description of the procedure for dismantling the top 20 feet and for erecting a 10-ft. vertical extension follows:

The bolts are removed from the bottom of the built-up section, and the welded and built-up sections are lowered to the ground inside the tower. Maintaining standard teardown procedures, as described on pages 51 and 52, the builders then dismantle the cage and the knob-leg section. When this is completed, the 10-ft. vertical extension for the outer tower is erected on top of the blue 24-ft. section; construction procedures are similar to those for the 37-ft. or 24-ft. sections. The knob-leg section and cage are then reconstructed on top of the vertical extension. After the inner tower extension has been set up underneath the tower, the welded section is unbolted from the built-up section and bolted to the top of the vertical extension. The welded section and vertical extension are then lifted to the top of the built-up section and bolted on. Finally, the complete unit, consisting of the welded section, vertical extension, and built-up section, is hoisted up through the inside of the tower and bolted to the top of the red 37-ft. section. This completes the construction of the vertical extensions. The tower must, of course, be recollimated after this operation.

Occasionally, it is found that one 10-ft. vertical extension does not provide enough additional height; in this case, two or three extensions may have to be installed on the tower. Since the stability of the tower decreases considerably when three or more extensions are erected, only one or two vertical extensions are ordinarily used.

Because the legs of a tower extension are vertical instead of sloping, extra care must be taken when climbing the ladder leg. Guy wires should be attached to the tower when two or more extensions are used.

ADDITIONAL SAFETY PRECAUTIONS

It is the responsibility of each person on the triangulation party to become thoroughly familiar with all rules and precautions regarding safety on steel towers. The building and teardown foremen should be constantly alert to correct any unsafe actions of the men on the towers and ground.

The efficient building or teardown foreman does not push his men. Good progress in the construction or dismantlement of a tower is not so much a result of speed as it is of *teamwork.* Because coordination and teamwork are so essential to safe, smooth operations, it is preferable to have the same group of men remain with one foreman throughout the season.

A builder must have a certain amount of confidence in order to perform his job well. However, he must not become overconfident to the point where he feels he is too good to make mistakes; if this happens, carelessness and negligence may soon follow. Each man must remain alert and "safety conscious" at all times.

Special precautions must be taken when training new builders. No more than one inexperienced man should be allowed on the tower at any one time. The foreman or an experienced builder should work alongside the new man until he becomes familiar with the operations. (Training procedures are described in ch. VII.)

Tools, nuts, bolts, and tower parts falling from the tower are constant hazards in steel-tower work. Warnings must be shouted immediately by any worker who accidentally drops a tool or part from the tower. The building foreman should make sure that the bundles of steel are tied in such a way that they can not slip out of the rope when they are hoisted. The takeoff man must take care not to release another bundle of steel when he removes the first bundle from the hauling line. When handing steel up to a leg man, the man below should not release the member until he is sure that the leg man has a firm grip on the steel.

No one should stand either underneath the tower or directly under the block or hauling line while loads are being hoisted.

Special care must be taken when bolting the ties, especially the heavy ties of the 103-ft. and 116-ft. sections. While one end of a tie is being bolted to the leg, the builder holding the other end must take care not to suddenly jerk or drop the tie.

Iron bars, shovels, and other tools should never be stuck upright in the ground around the tower while men are working aloft. Tools should either be laid flat on the ground between the inner and outer structures or else be completely removed from the vicinity of the tower.

Each builder must ascertain that the bolts and nuts in a member are secure before he stands or climbs on the member.

Bolt bags and belts should be maintained in good condition.

Safety belts and lanyards are recommended for the builders while they are bolting the centers of the diagonals and erecting the "follies".

Spectators should be kept at least 100 feet from the tower during construction and teardown. People who have no business thereon should be warned and discouraged from climbing the tower at any time.

Chapter VI

PROCEDURE FOR DISMANTLING A BILBY TOWER

A tower is dismantled by generally reversing the order of operations used in its construction. Three men (no more nor less) work on the tower during the teardown operations, while one man — usually the foreman — remains on the ground. All men wear safety hats. Each leg man wears one large bolt bag in which he places the nuts and bolts as the tower is dismantled. Construction platforms are not required. A standard ¾-in. manila hauling line, without the haul-back line attached, is used to lower steel to the ground. Additional equipment used by the teardown party is listed in appendix G.

Rules such as keeping spectators away from the tower, shouting warnings when tools and parts are accidentally dropped, and most of the other safety precautions described previously for building parties are also applicable to teardown crews. Additional precautions, which are peculiar to teardown operations, are discussed with the teardown procedures that follow.

The ladder-leg man carries the block and the hauling line up the tower (fig. 42); as he ascends, he unbolts the tops of the connecting steps and swings the top ends down. Above the top of the 37-ft. section, he may loosen the nuts in the blue rods. When he reaches the top of the tower, he hooks the block to the triangle head and lowers the end of the hauling line down to the top of the welded section. He then descends to the observer's platform and ties the hauling line to the welded section, making sure that the rope is secured to the main section and not to the adjustable head. The ladder-leg man then proceeds to unfasten the platform boards and loosen the nuts in the cage members.

Meanwhile, the foreman and back-leg men clear the soil away from the lower ends of the first-section diagonals. *Under no conditions should the anchor holes be excavated and the lockboards removed before the tower is dismantled.*

The back-leg men ascend the tower, loosening the nuts on the inner structure on the way up. Care must be taken not to loosen the nuts so much that the vibration of the tower could cause them to fall off the bolts. The nuts in the blue rods below the top of the 37-ft. section may be loosened if desired. However, *no other nuts in the blue tower should be loosened by the back-leg men as they ascend the tower.*

When the back-leg men reach the top of the 37-ft. section, they unbolt the bottom diagonals of the built-up section and drop them to the ground. (See fig. 43.) After these members have been dropped, the foreman attaches a drum or cathead to the ladder leg, pulls the hauling line taut, and takes two or three turns of the rope around the drum. (The fabrication of a suitable teardown cathead is described in app. H.)

The No. 2 and No. 3 men unbolt the legs of the built-up section from the top of the 37-ft. section. Before removing the last bolt, they make sure that the rope is secured at the top of the welded section and at the bottom of the tower. The built-

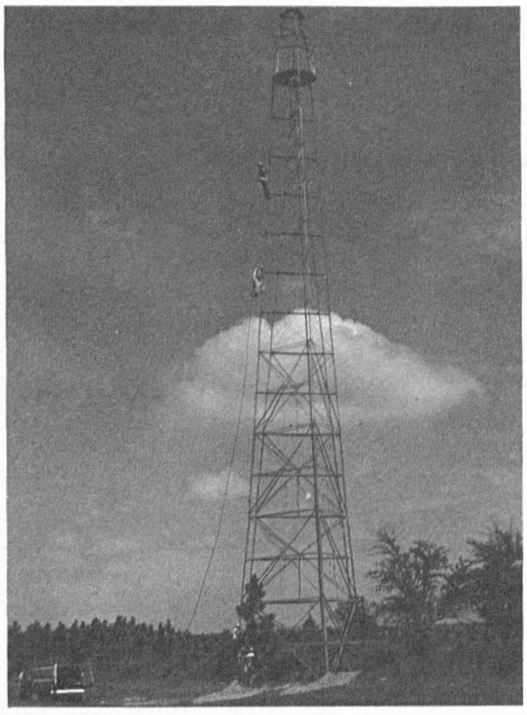

FIGURE 42.—Preparing to dismantle a 103-ft. tower. Ladder-leg man carrying block and hauling line up the tower.

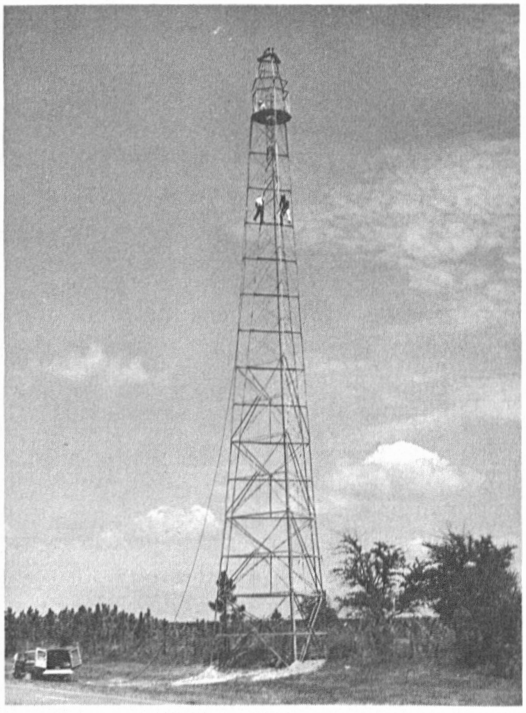

FIGURE 43.—Dismantlement of a 103-ft. tower. Back-leg men unbolting the bottom diagonals of the built-up section.

up and welded sections are then carefully lowered to the ground by the foreman. (See fig. 44.) The back-leg men guide the rope to keep the load in the center of the tower. (The ladder-leg man should not stand underneath the block during this operation.) After the built-up and welded sections have reached the ground, the foreman unties the rope and hoists the line to the top of the tower. (See fig. 45.)

The back-leg men climb to the top of the tower and remove the lightkeeper's platform and the triangle head and lightplate. (See fig. 46.) After hooking the block to the topmost ladder step of the knob leg, the ladder-leg man ties the two small boards of the observer's platform, the triangle head and lightplate, and the lightkeeper's platform board to the hauling line. The load is then lowered to the ground (outside the tower) by the foreman. The foreman no longer uses the cathead attached to the ladder leg, but lowers each load directly by hand with the aid of a thick leather "burner" around the rope.

The upper set of wishbones and the upper set of spaghetti are dismantled by the back-leg men, who hand the pieces to the ladder-leg man. The ladder-leg man in turn ties the steel to the hauling line and places the load outside the tower for the foreman to lower. The three window legs are then dismantled, bundled, and lowered (fig. 47), followed by the second set of wishbones and the lower set of spaghetti.

The back-leg men remove the lower set of wishbones, lay the members on the large platform board, and then descend to the base of the knob legs. The ladder-leg

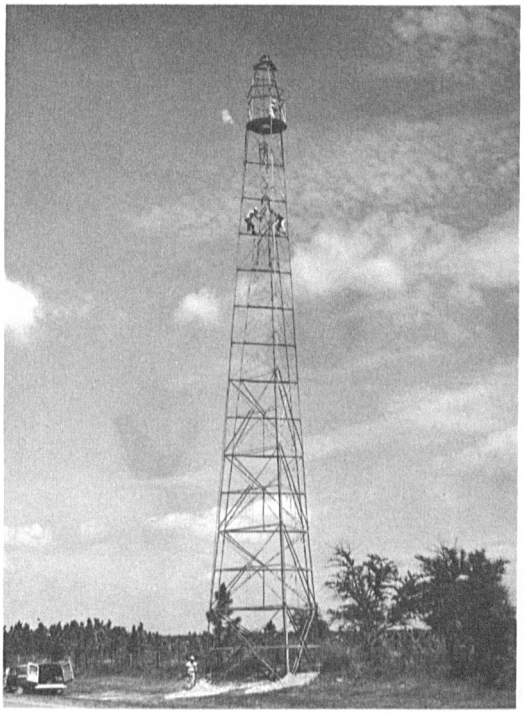

FIGURE 44.—Dismantlement of a 103-ft. tower. Lowering the welded and built-up sections.

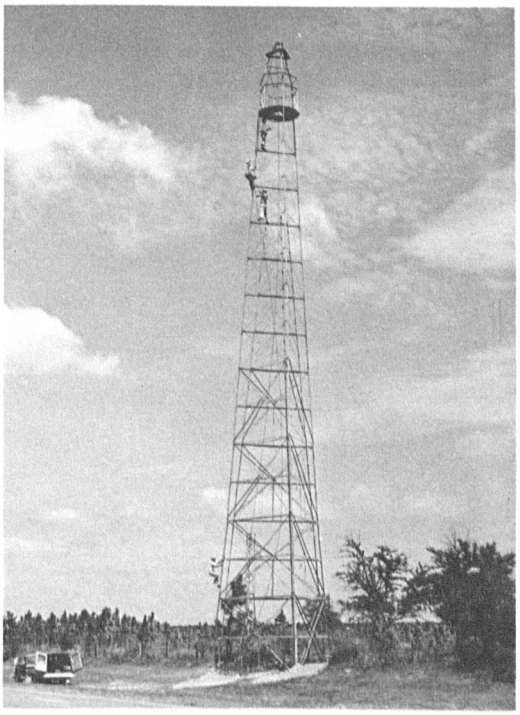

FIGURE 45.—Dismantlement of a 103-ft. tower. Welded and built-up sections just lowered to the ground.

man ties the large platform board and the wishbones to the hauling line; after this load has been lowered (fig. 48), the ladder-leg man descends with the block to the base of the knob-leg section. The half-section ties are unbolted and either dropped to the ground or lowered by rope. This completes the dismantlement of the cage.

Subject to the limitations given below, all of the steel below the cage, except the rods, may be dropped to the ground by the leg men. If the ground surface is rocky, frozen, or extremely hard, all steel must be lowered by rope to avoid damage to the members. Furthermore, no pieces should be dropped: (1) at stations that are located on lawns, (2) if there is a possibility that the steel may strike objects such as trees, buildings, or telephone wires which are adjacent to the tower, and (3) if the tower is located near pedestrian or vehicular traffic in urban areas. Regardless of the location of the tower or the condition of the ground, all cage members (including the light-plate), platform boards, and rods must always be lowered by rope.

Continuing with the teardown operations, the leg men dismantle the rods in the knob-leg section and lay them across the ties. The knob-legs are then unbolted and dropped to the ground, knob ends first. (See fig. 49.)

The rods from the knob-leg section are passed down one half-section and laid across the ties. The top ties of the 24-ft. section are then removed and dropped to the ground. After the rods in the upper half of the 24-ft. section have been unfastened, all loose rods are passed down to the bottom of the section where they are laid across

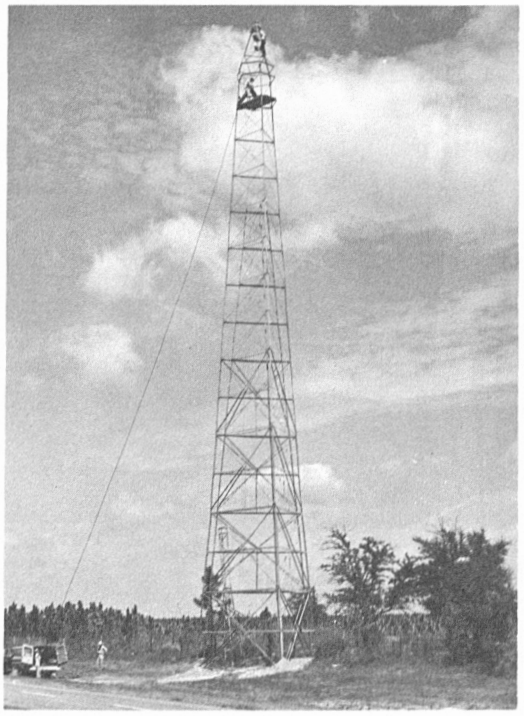

FIGURE 46.—Dismantlement of a 103-ft. tower. Removing the lightplate and lightkeeper's platform.

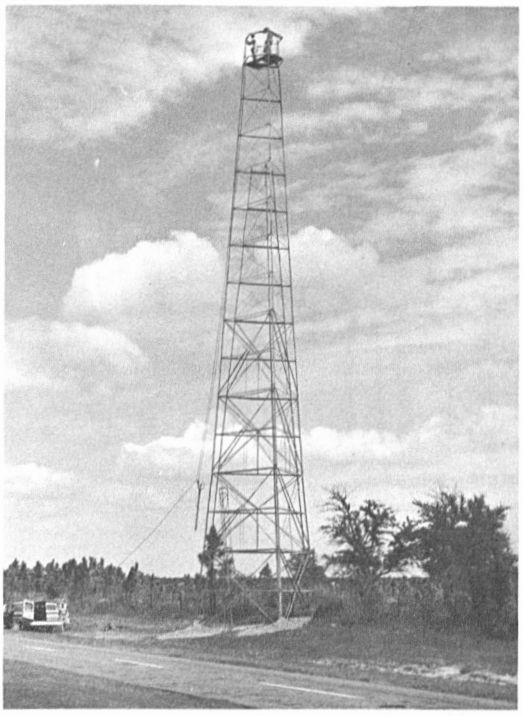

FIGURE 47.—Dismantlement of a 103-ft. tower. Lowering the window legs.

the ties for lowering by rope. The half-section ties are then dismantled and dropped. The rods in the lower half-section are dismantled next; these pieces are bundled with the other rods and lowered to the ground. Finally, the blue legs are unbolted and dropped, completing the dismantlement of the 24-ft. section. (See fig. 50.)

In the 37-ft. section, the members are dismantled in the following order:

(1) top red ties;
(2) top blue ties;
(3) red rods of the upper half-section;
(4) blue rods of the upper half-section;
(5) half-section red ties;
(6) half-section blue ties;
(7) red rods of the lower half-section;
(8) blue rods of the lower half-section;
(9) red legs; and
(10) blue legs.

Each half-section group of rods is lowered to the ground by rope. The ties and legs are dropped, except under conditions given above.

If the 50-ft. section contains rods instead of diagonals, it is dismantled in the same manner as the 37-ft. section.

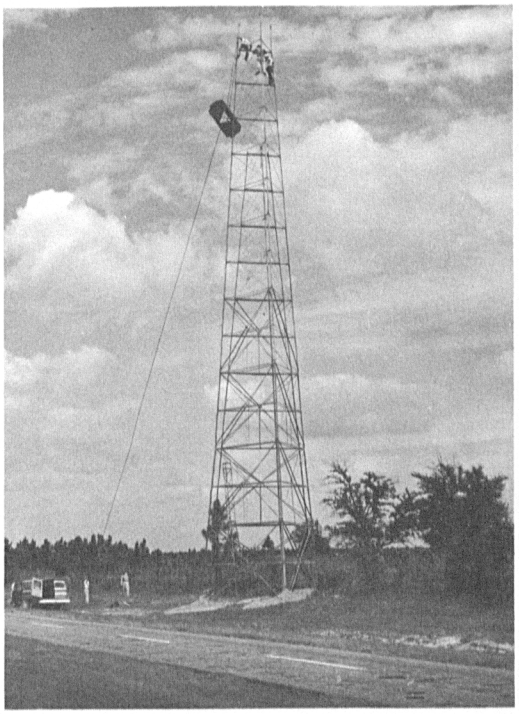

FIGURE 48.—Dismantlement of a 103-ft. tower. Lowering the large platform board and wishbones.

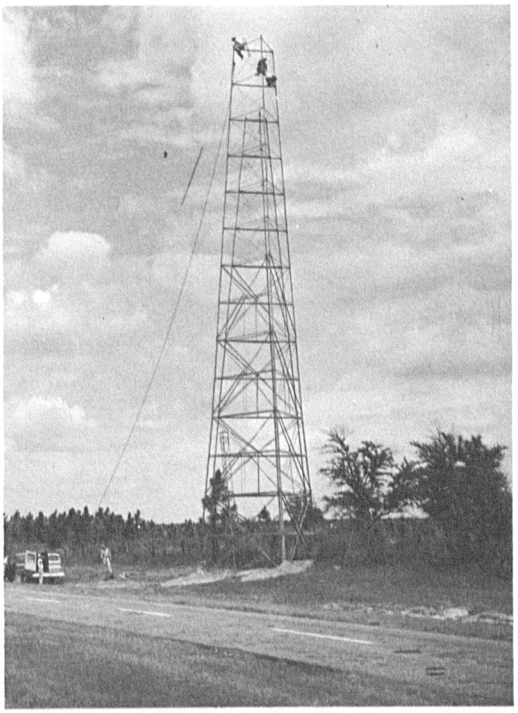

FIGURE 49.— Dismantlement of a 103-ft. tower. Dropping the knob leg.

In the sections that contain diagonals, the leg men first unbolt and drop the top blue ties, then they unbolt and drop the top red ties. (Since the same bolts hold the top ties and the diagonals, the upper ends of the diagonals are also unfastened in this process.) After descending to the bottom of the section, the leg men unbolt the lower ends of the blue and red diagonals. The men then walk out to the centers of the ties, unbolt the blue diagonals (straight diagonals first, then the twisted diagonals) and drop them to the ground, after which they similarly dismantle the red diagonals. The blue half-section ties are removed and dropped next, followed by the red half-section ties. (The ends at the ladder leg are unbolted first.) The disassembly of the section is completed by unbolting and dropping the legs — red legs first, then the blue legs. This procedure is repeated in the remaining sections of the tower.

Before unbolting a tie, each leg man should first check to see that one of the other leg men is not sitting on, or bracing himself against, the other end of the tie. Furthermore, the leg men must never drop the end of a tie that is still bolted at the other end.

Extreme caution is necessary when dropping steel from the tower. The leg men *must not throw* the steel members; instead, they should let each piece slide carefully from their hands in such a manner that one end will stick in the ground without falling over, leaving the member approximately vertical. (See fig. 50.)

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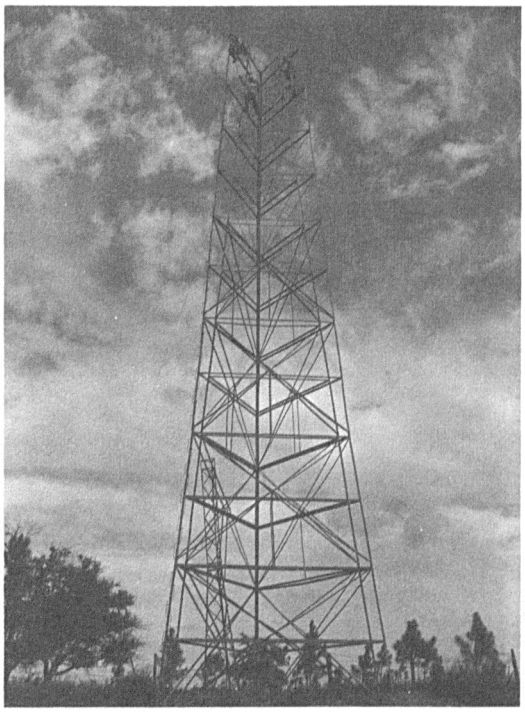

FIGURE 50.—Dismantlement of a 103-ft. tower. Unbolting the 24-ft. section ladder leg. Notice the dropped member stuck upright in the ground to the left of the tower.

Dropping the steel off the tower at random is prohibited. Before dropping a steel member, the leg man must: (1) be sure he knows where the ground man is standing, (2) warn the ground man that steel is about to be dropped by shouting "Steel!", and (3) make sure that the ground man has heard the signal and has moved to a safe distance from the tower.

The leg men must make sure that all bolts have been removed from the ends of the legs and ties before dropping them off the tower. The No. 1 man must be especially careful when dismantling and dropping the ladder leg, as the loose connecting step at the top of the leg could easily snag his clothing.

After each round of steel has been dropped, the teardown foreman picks up the members and stacks them in a convenient place for the steelhauler. If the steelhauler is present, the members are loaded directly on the steel truck. The foreman wires all rods in groups of six — by color and length; for example, the blue rods from the lower half of the 37-ft. section are wired together, the red rods from the lower half of the 37-ft. section form another group, and the blue rods from the upper half of the 37-ft. section compose still another group, etc. (See fig. 51.) Diagonals are wired in groups of three — by color, length, and type; for example, the three twisted blue diagonals from the 64-ft. section make up one bundle, the three straight blue diagonals from the 64-ft. section form another group, etc. Each bundle is wired on one end only; if the steel is

FIGURE 51.—Dismantlement of a 103-ft. tower. Wiring the rods in bundles.

to be stored or shipped, the bundles are wired on both ends. Baling wire of size 14 or 14½ is used to bind the steel.

After the tower has been dismantled down to the half-section ties of the second section, the leg men unbolt the welded section from the built-up section and lower the welded section to the ground. If there is enough room under the tower, the welded and built-up sections are immediately laid flat on the ground; otherwise, they are left upright under the tower until they can be removed.

When the leg men reach the first section, they dismantle the ties and diagonals, and then proceed to dig out the anchor holes. (The legs are sometimes left bolted to the anchor posts in order that they may be used as levers to dislodge the anchors. Since this operation could easily result in bent or twisted legs and anchor posts, it must be performed with care. Consequently, it is preferable that the legs be removed from the anchor posts before the anchor holes are excavated.) After the lockboards and anchors have been removed from the holes, the holes are filled in, well tamped, and rounded up to allow for settling.

The teardown foreman is responsible for inspecting the steel and the platform boards as the tower is dismantled. (See p. 62) Bent members should be straightened before

they are loaded on the steel truck. The steelhauler should be notified of any defective parts, so that he may have them repaired or replaced.

Before leaving the station, the foreman makes sure that the area has been restored, as much as possible, to its original condition, and that it is left with a neat appearance. Public relations are of the utmost importance; if the station site is left in an unsightly condition, the property owner may forbid future use of the station.

Chapter VII

SAFETY PRECAUTIONS

VEHICLE SAFETY

Each truck must be equipped with the safety items required by state and local regulations and by the regulations of the U.S. Coast and Geodetic Survey. These items include:

(1) fire extinguisher, dry-chemical type;

(2) turn-indicating lights;

(3) set of red reflectors or highway flares;

(4) first aid kit;

(5) set of tire chains; and

(6) side-mounted rear view mirrors.

In addition, a spare tire and a set of tools — lug wrench, tire tool, jack, crescent wrench, pliers, and screwdriver — should be provided for each truck.

The chief of party or the field foreman should periodically inspect all vehicles to ensure that operators have maintained the equipment in a usable condition.

All personnel should possess both State and Federal drivers' licenses. Anyone who will be required to operate a four-wheel drive truck should be thoroughly indoctrinated in the operation of this type of vehicle. All drivers should carry public-liability and property-damage insurance. Each driver who has a truck assigned to him is responsible for its condition and care.

Trucks must be driven at safe speeds in accordance with the road conditions and the visibility. Drivers must be especially cautious when traveling "cross-country" through fields, up steep hills, etc.

The trucks should always be refueled, the oil and water levels checked, and the tires inspected before departing for the station site at the beginning of the day.

WEARING APPAREL

Safety hats must be worn by all personnel engaged in building and teardown operations. The hard hats in common use are made of either aluminum or fiberglass. (A disadvantage of the fiberglass hats is that they may split if they fall from the tower.) The men on the tower ordinarily prefer the cap-type hat, which has a bill in front and only a slight brim on the sides and back. Each hat should be equipped with a chin strap, to prevent the hat from falling off the builder's head when he bends over or from being blown away in windy weather. Hard hats should also be equipped with warm winter liners for cold weather. Sweat bands are useful for summer work.

Gloves should be worn by the steelhaulers while they load and unload steel and by the ground men on building and teardown parties. It is a matter of individual choice whether or not the leg men wear gloves. Gloves may be somewhat of a hindrance to a builder while he is using his wrenches and handling the nuts and bolts. Nevertheless, many builders prefer the protection to the hands afforded by the use of gloves. Gloves made of thin, soft leather, with a tight-fitting cuff, have been found to be suitable for men working aloft on the towers; the gloves should fit snugly.

Sturdy leather boots should be worn by the men on the building and teardown crews and by all personnel, such as observers and lightkeepers, who use the towers. An 8- or 10-inch boot with a rubber or cork sole and heel is satisfactory. Boots with half soles or with no projecting heels are not desirable; half soles are especially hazardous, for they could catch on a tower member and trip the man. Boots that have gotten wet and muddy are also dangerous. If the ground is muddy, it is recommended that the leg men on building crews wear rubber overshoes over their boots while they are digging the anchor holes. The overshoes may then be removed before the builders climb on the tower; in this way the boots are kept clean and dry.

Loose-fitting or torn garments should be avoided, as they may become snagged on a steel member and cause a builder to lose his balance. Adornments such as watches and bracelets should be avoided for the same reason. Trousers without cuffs are recommended. Jackets with zippers are preferable to those with buttons.

Winter clothing should be insulated and relatively lightweight; heavy, bulky garments may tire the builder and restrict the movement of his arms and legs. The lightweight thermal underwear is especially recommended.

INCLEMENT WEATHER

Inclement weather produces many hazardous conditions that require special precautionary measures on the part of personnel engaged in steel-tower work.

One of the most common hazards to building and teardown crews is the wind. Gusty winds are extremely dangerous, for a sudden increase or decrease in the wind velocity may cause a builder to either lose his balance or lose his grip on a steel member (especially if he is in the process of bolting or unbolting a leg). Ordinarily, a light, steady breeze is not objectionable. However, a wind velocity in excess of about 20 or 25 miles per hour should generally be considered unsafe for building and teardown operations, depending somewhat on the experience of the crew and the outside temperature. The foreman is responsible for discontinuing operations when the wind becomes hazardous. Since he usually remains on the ground, he may not be completely aware of the wind conditions high on the tower; for this reason, he often has the ladder-leg man inform him when it becomes too windy to work. Moreover, any man on the tower who feels that the wind is too strong for safe operations should immediately notify the foreman, and the work should then be discontinued.

Towers located in a hurricane area may have to be partially dismantled if a hurricane threatens, in order to reduce the risk of structural failure.

In extremely hot weather, salt tablets and an ample supply of cool drinking water should be available to the men at all times.

Building and teardown operations should not be carried out while it is raining, as the steel becomes slick and hazardous to work with. Steel that has become extremely wet and muddy on the ground should be dried before it is used. Builders who ascend a tower after a rainstorm should make sure that their boots are as clean and dry as possible.

Special precautions must be taken when constructing or dismantling towers in freezing weather. Time must be alloted for the men to come down from the tower periodically and warm themselves. It is especially important that the men keep their hands warm. Although the builders should wear gloves during periods of cold weather, their fingers may, nevertheless, become extremely cold after handling the cold steel. Cold, numb fingers may result in the accidental dropping of wrenches, nuts, and bolts, and may cause a builder to lose his grip on the steel. Wet gloves, of course, should never be worn in freezing weather.

When the temperature falls as low as zero (Fahrenheit), it is probably too cold for safe building and teardown operations, especially if there is any breeze blowing. The conditions under which operations should cease, however, is a decision that must be left to the good judgment of the supervisors on the party.

Under no circumstances should steel tower work be performed while it is snowing or while there is ice on the steel. Ice and snow must be removed from the steel before the members are handled. Ice may have to be melted with a blowtorch. If there is snow on the ground during the building operations, each tower should be delivered to the station on the day it is to be built, and the steel members should either be laid against the tower after the first section is completed or laid against the bed of the steel truck, instead of on the ground. In addition, the hauling line should be kept as dry as possible to prevent it from freezing. Snow should be cleared off the ground in the vicinity of the winch.

If a snowfall is expected, tower members on the steel trucks should be covered with canvas.

PROTECTION OF THE PUBLIC

Supervisory personnel on steel-tower parties must take the necessary precautions to protect the local populace from accidents or injuries which may be attributed to party activities.

When towers are erected in schoolyards, campuses, public parks, playgrounds, residential areas, or any other place where children may be present, protective fencing should be placed around the bases of the towers for the purpose of preventing or discouraging children from climbing the towers. A 5-ft.-high fence of the woven slatted type (snow fence) is very good for this purpose. All parties should keep such fencing on hand. Fencing will not prevent a determined child from climbing the tower, but it should discourage most children, especially small ones.

Regardless of the location of the tower, a danger warning sign should always be posted on the tower near the ladder leg.

If it is necessary to build a tower at the edge of a road or a city street, reflectors or flares should be set up at the base of the tower. This is especially important when the tower is located on the outside of a curve. If the building truck must be parked along-

side the road, the truck's blinker lights should be turned on, reflectors or flares should be placed near the truck, and warning signs should be set alongside the road at least 500 feet in each direction from the tower. One or two flagmen may be necessary when the building operations obstruct the normal flow of traffic. Plastic or rubber traffic cones are desirable for keeping motorists outside the danger zone of falling tools and parts.

Aircraft warning lights may be required on the tops of towers erected at airports or in the vicinity of runways. Local airport authorities should be contacted if there is any question whether or not warning lights are necessary. An aircraft warning light is usually a flashing red light — visible for 360 degrees on the horizon — which is bolted to the lightplate on the tower. If commercial power is available, a 110-volt light may be used; otherwise, a 6- or 12-volt light, with power supplied by a wet-cell battery, may be used. Arrangements should be made to have the light turned on at sunset and turned off at sunrise; an automatic timer may be used for this purpose.

If possible, guy wires should be attached to any tower that is in a location where failure of the tower (due to severe storms) could result in the loss of life or property. (The use of guy wires is described on page 48.)

All children and onlookers should be kept at least 100 feet from the tower during the construction and teardown operations. This is especially important while steel is being hoisted, lowered, or dropped from the tower. Falling tools and steel members may glance off the tower and fall in any direction.

INSPECTION, MAINTENANCE, AND STORAGE OF STEEL

An inspection of tower parts is carried out by the teardown party as each tower is dismantled. The inspection should consist of the following:

1. Each steel member is inspected for signs of cracks in the steel — especially around the bolt holes — and for excessive bends or distortion of the member. Bent members are straightened before they are loaded on the steel truck.
2. Anchor posts are checked for loose or defective rivets. The bolts through the mudsills are inspected.
3. All wooden members — the observer's platform boards, the lightkeeper's platform, the anchor mudsills, and the lockboards — should be renewed when they become split or otherwise damaged or deteriorated in any manner that could endanger personnel.
4. The welded and the built-up sections are inspected for defective members.
5. Defective steps are removed from the ladder legs for replacement.
6. Bolts that show distortion or damage, such as bending, crooked heads, and stripped or damaged threads should be discarded.
7. Ropes are inspected for worn, frayed portions.
8. The block should be checked to make sure it is in good condition.

The field foreman should be notified when tower parts are found to be defective. The steelhauler sees that repairs are made.

Although a detailed inspection is usually not performed by the building foreman, he should, nevertheless, be alert for flaws in the members as he lays out the steel prior

to construction. Particular attention should be given to the hauling line, block, winch, and ladder steps.

The field foreman should conduct a thorough inspection of the tower parts at least once a year for the purpose of surveying old or damaged steel and ordering new parts. The field foreman should also ascertain that the towers are being properly maintained.

The ends of the steel members should be repainted with the appropriate red or blue colors at least once a year. Painting the steel is especially helpful for new employees who are not familiar with the various pieces.

After a tower has been used for several years, special care should be taken when inspecting the steel members. Pieces that have been bent and straightened a number of times should be discarded and replaced.

When loading or unloading steel from trucks or railroad cars, the following precautions should be maintained: (1) gloves and safety hats should be worn, (2) personnel should know the correct method for lifting heavy loads in order to avoid strained muscles and back injuries, and (3) each man should be aware of the other men around him when he is carrying steel.

Steel towers are usually stored outside on land owned either by the Federal government or by State or municipal governments. The storage yard should be in a location where the steel is relatively safe from theft. The towers should be stacked in neat piles so that there is no danger of the steel falling over. The steel should be placed on a solid foundation, and should not exceed six towers per stack; stakes should be driven beside each stack as a further precaution against the pile tipping over. Platform boards must be covered with a waterproof material. Bundles of diagonals and rods are wired at both ends. The built-up sections are dismantled.

Most parties prefer not to separate the various sections of a tower. For example, if a 90-ft. tower has been dismantled and delivered to a site where a 77-ft. tower is required, the 90-ft. section is usually unloaded and stacked beside the tower. In cases such as this, however, the loose steel on the ground has occasionally been pilfered. In order to avoid theft of steel, it is therefore recommended that extra sections be taken back to the storage yard and not left at stations located alongside highways or in populated areas.

SAFETY PRECAUTIONS FOR OBSERVING PARTIES AND LIGHTKEEPERS ON STEEL TOWERS

The purpose of this section is to set forth the safety precautions that are related to the use of the Bilby tower. The functions and duties of the observing parties and lightkeepers (subjects which are beyond the scope of this manual) are well covered in Special Publication No. 247, "Manual of Geodetic Triangulation."

Observing parties and lightkeepers should keep off steel towers during strong winds, icy conditions, electrical storms, and snow or rain storms. Since observing tents create considerable wind resistance, they should not be left in place on the towers in a rising wind. When an approaching storm is evident, the observing parties and lightkeepers should attempt to remove their instruments and equipment from the towers before the storm occurs.

After measuring the eccentricity of the lightplate (if necessary), but before the equipment is hoisted, the observing party should check the stability of the tower. If previous storms have disturbed the anchors or so affected the collimation of the tower that the height of a leg on the anchor post would have to be changed in order to correct the collimation, the tower should not be occupied; a party of only two men is not sufficient to make any major changes in the centering and plumbing of the tower. The observing party must ascertain that the outer and inner structures are not in contact. The bolts on the inner tower, particularly at the bottoms of the welded and built-up sections, should be checked, and tightened if necessary. The ladder steps, platform boards, and the bolts in the cage members should also be inspected. The adjustable head of the welded section is checked for defects; the V-bolt clamps are tightened after the head is adjusted for the height of the observer.

An observing party uses a hauling line and a block — similar to those used by the building parties — for hoisting the instrument and other equipment up the tower. The loads are hoisted either by hand or by an electric winch mounted in the observer's truck.

Surveying instruments, such as the theodolite, Tellurometer, and Geodimeter, should be hoisted separately from the other gear, in strong and well-padded containers. For example, the theodolite should be hoisted in a container, such as a five-gallon can, which has a 1½- to 2-in. layer of foam rubber glued to the sides and bottom of the can. Two or more harness hooks on the hauling line are attached to a ring at the top of the can.

Special precautions are necessary for hauling electronic distance-measuring instruments up the tower. A suitable hoisting apparatus is shown in appendix I.

The condition of the hoisting apparatus should be inspected before it is used. The block must be well secured to the tower. Leather gloves should be worn when hoisting and lowering equipment by hand; when equipment is lowered, the man on the ground must use a leather "burner" on the rope. No one should be permitted under the tower while loads are being hoisted or lowered.

The gear should be pulled inside the tower and onto the platform before unfastening from the hauling line, and then stowed securely where it will not be kicked or blown off. It is advisable to attach the instrument-case carrying strap to a cage member. After all of the gear has been hoisted, the hauling line should be pulled taut at the ground and secured to the bottom of an outer leg on the lee side of the tower.

Since the observing parties and lightkeepers must occupy the towers at night when visibility is limited, special care should be taken when climbing and descending the towers. The following precautions should be noted:

1. When climbing the ladder, each man should test his handholds and footing before trusting his entire weight to the step; he should climb as though a step could break at any time.
2. Extra care is necessary when climbing in and out of the cage.
3. When climbing up to the lightplate, each man should always use the ladder, not one of the back legs or the side of the cage.
4. When descending the tower on an extremely dark night, each man should make sure that he has reached the bottom step before stepping off the ladder; injuries have occurred in the past when men, who erroneously thought they had reached the bottom step, jumped off the ladder.

The above precautions are especially necessary for lightkeepers, since they must carry their equipment up and down the towers in packsacks and must usually work alone, often in remote areas where aid would be difficult to summon if needed. Lightkeepers must be cautioned to remain alert and to guard against dozing on the tower. Safety belts are recommended.

After an observing party has completed its work on the tower, the instrument and equipment are lowered to the ground by rope. Sometimes the observing tent is dropped to the ground instead of lowered; when this is done, the man on the tower must first shout a warning and make sure that anyone on the ground is standing at a safe distance from the tower. (See fig. 52.)

HIRING AND TRAINING NEW EMPLOYEES FOR STEEL TOWER WORK

Qualifications

It is recommended that each man who applies for duty with a steel-tower party be required to take a medical examination, to show that he is physically qualified to perform the arduous tasks required in the construction and dismantlement of Bilby towers. The applicant should:

(1) be at least 5 feet 10 inches in height;
(2) not be excessively overweight (to the point where active physical function is impaired);
(3) be physically strong and in good health;
(4) have full use of both arms and legs;
(5) be agile and surefooted;
(6) have no abnormal fear of height; and
(7) preferably be under 35 years of age.

The physical qualifications and the medical examination of each applicant should be thoroughly reviewed by the chief of party, who must decide on the applicant's acceptability.

In addition to the physical requirements, each applicant must also be dependable, attentive, and willing to accept and carry out orders.

Training

One of the responsibilities of the chief of party and the building and teardown foremen is to see that new employees are thoroughly and properly trained in the erection and dismantlement of steel towers and in the safety rules and precautions relating thereto. Each party chief, therefore, should maintain a training program, with emphasis on steel-tower safety, for each new employee who is hired on the party.

It is recommended that a period of *at least* 5 days be devoted to instruction in building operations, followed by at least 1 day's instruction in teardown operations. During this time, the trainee should be used as an extra hand, and should preferably be instructed by the foreman while the senior builder on the crew performs the foreman's duties.

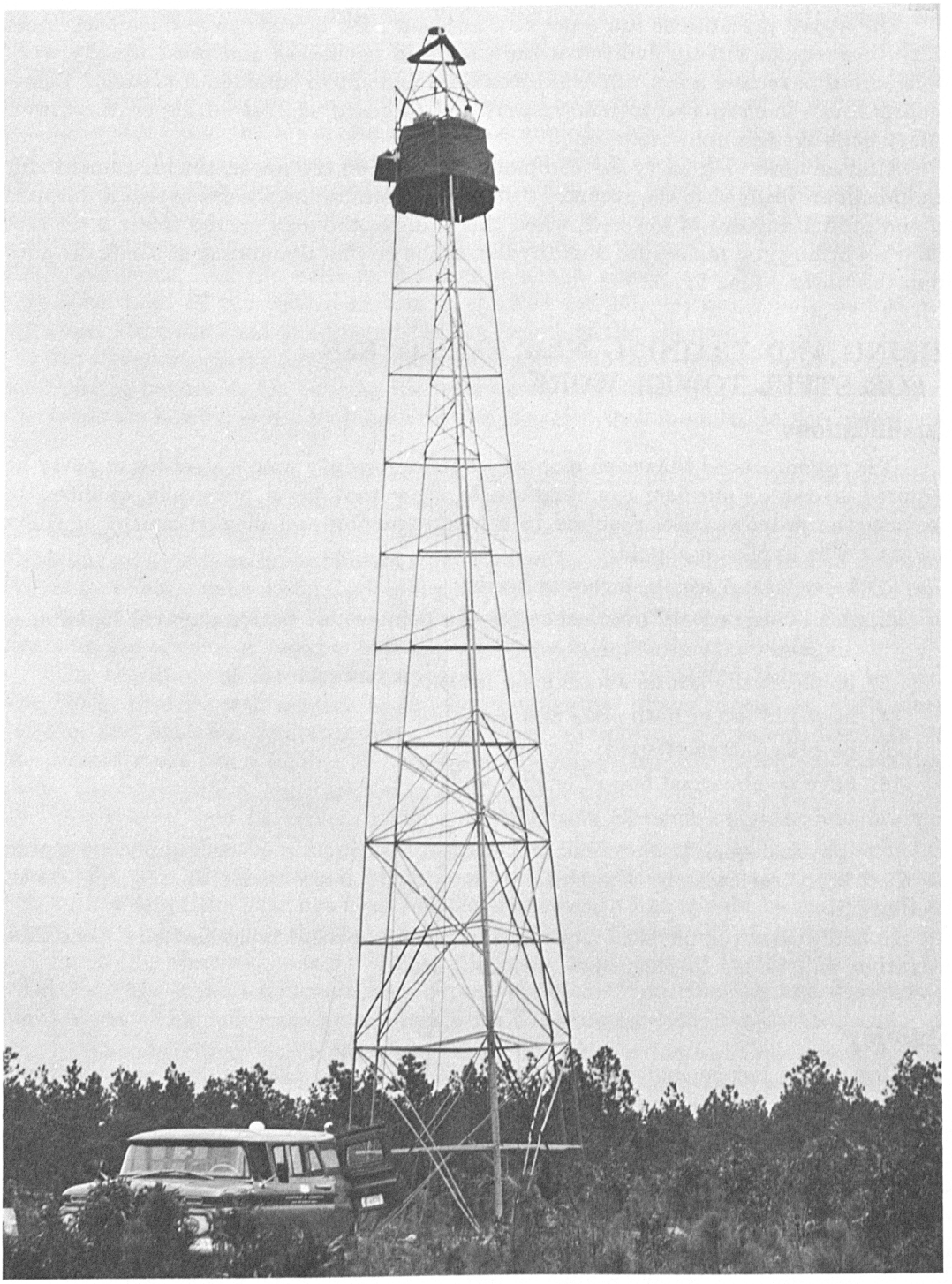

FIGURE 52.—A 77-ft. tower. Wall of the observing tent in place. Note the booms for hoisting the Geodimeter.

No more than one new man should be trained on a tower at one time. This may require a judicious scheduling of training programs when several new men are hired during the same week.

It may be necessary to instruct one or more of the new employees in teardown procedures, lightkeeping duties, or wood-stand building for several days until one of the building foremen is free to train another man on his building crew. It may also be necessary, during a rapid party build-up, to send two or more new men out with each building crew; however, only one trainee at a time should be allowed up on the tower.

Many factors enter into the formation of adequate training programs at the party level. These factors include: (1) the size of the party, (2) the number of experienced builders, (3) the number of new men hired at one time, and (4) the physical and mental capabilities of the individual trainees. Because these circumstances will vary from one party to another and from time to time on the same party, it is impractical to outline one standard training schedule that could be uniformly adopted by all parties. The following sample schedule, however, should serve as a guide to show the type of training program that is desired.

CONSTRUCTION

First day: A brief orientation period for the new employee is provided by the chief of party on the day the new man reports for duty. This orientation includes instruction in the following subjects:

1. Party organization — general functions and duties of the various members of the party.
2. Building and teardown procedures — a brief discussion to familarize the new man with the general chronology of events during building and teardown operations.
3. Safety regulations of the Bureau, as outlined in the Coast and Geodetic Survey Regulations.

If a night observing schedule is planned, the new employee is sent out with either an experienced observing crew or an experienced lightkeeper. The new man ascends and descends the tower and starts becoming accustomed to the height. The observer or lightkeeper instructs the new man in the safety precautions that concern the use of the tower.

Second day: On the second day of work, the new employee commences his training on the building party. Supervised by the building foreman, the trainee helps dig an anchor hole and/or helps lay out the steel. While the base sections are being erected, he assists in handing steel up to the leg men. During the "topping off" operations, he tightens nuts on the tower; this provides him with the opportunity of becoming more accustomed to the height of the tower and used to moving around and working on the tower.

Third day: The trainee helps set the reference marks or helps dig an anchor hole. During the erection of the base, he is given the opportunity to work as No. 2 or No. 3 leg man under the foreman's supervision. The foreman remains with the trainee and explains all the procedures for erecting the base. During the "topping off," the trainee assists the takeoff man and tightens nuts; the foreman may act as takeoff man in order to

have closer supervision over the new man. By the end of the third day, the trainee should have started to become familiar with the various tower members.

Fourth day: Same procedure as the third day.

Fifth day: The trainee works the No. 2 or No. 3 leg all the way up the tower. He digs the anchor hole and performs all the duties of the leg man. He is continually supervised by the foreman, who remains with the new man at all times, reminding him of the correct bolt sizes, explaining the procedure for erecting the upper sections and the cage, aiding the new man when he falls behind in his work, and correcting unsafe procedures.

Sixth day: The procedure for the fifth day is repeated.

Seventh day: The trainee works the No. 2 or No. 3 leg on his own. The foreman remains on the ground but keeps a watch on the new man, looking for unsafe practices, offering worthwhile advice that could accelerate the trainee's progress, and remaining ready to assist him if necessary.

By the end of the seventh day, the trainee should have become familiar enough with the building procedures to be able to work as one of the regular members of the building crew. He will, of course, be slow and may not be able to carry his full load on the crew for several months. The experienced men on the tower must continue the new man's education in safe building practices and offer assistance when necessary.

After the new employee is trained in building operations, he works as one of the back-leg men on a teardown crew for at least 1 day (two teardowns). During this time, the teardown foreman runs one of the legs while instructing and supervising the trainee. Particular attention must be given to demonstrating the correct method of dropping the steel.

TEARDOWN

If circumstances require that the new employee be trained in teardown operations first, a schedule similar to the following is recommended:

First day: The trainee receives an orientation from the chief of party and spends the evening with an observing crew or a lightkeeper, as before.

Second day: The new man begins his training on a teardown crew, spending the day wiring and stacking steel and observing the teardown operations, with instructions from the foreman.

Third day: The trainee works as No. 2 or No. 3 leg man, instructed by the foreman who is running another leg.

Fourth day: Same procedure as the third day.

If the trainee has progressed adequately, he may commence his training on a building crew on the fifth day.

PROGRESS REPORT

The building and teardown foremen should report to the field foreman and the chief of party on the progress of each trainee. A new employee who, after a reasonable period of time, cannot handle the job and/or continuously constitutes a hazard on a tower should be separated from duty.

Appendix A

GLOSSARY OF TERMS ASSOCIATED WITH THE BILBY STEEL TOWER

The Bilby steel tower (fig. A1) consists of two skeleton steel tripods, one within the other. The inner structure, which supports the observing instrument, does not have any contact with the outer structure, which supports the personnel, signal lights, and tent. Towers are erected over horizontal-control stations for the purpose of elevating observing instruments and targets above intervening obstructions.

Except for the tie rods, lightplate, platform boards, and mudsills, Bilby towers are composed of structural-steel angle members. Each of the individual members can be handled by one man. The towers are built piece by piece from the ground up, the various structural members being bolted together with ⅝-in. bolts.

Steel towers are normally classified by the height of the inner tower; there are 37-ft., 50-ft., 64-ft., 77-ft., 90-ft., 103-ft., and 116-ft. towers. The top of the outer tower is about 10 feet higher than the inner tower.

Adjustable Head See Welded Section.

Anchor Post The bottom leg of the tower, composed of a steel angle member, 5 feet in length, riveted to a steel footplate, which, in turn, is bolted to a wooden mudsill. An *anchor post* contains 55 bolt holes along the length of each face, thereby permitting the leg of the first section to be bolted to the *anchor post* at various heights. The *anchor post* with mudsill attached is usually referred to simply as the *anchor*. (See fig. A2.)

Blue Of or pertaining to the outer tower. In this manual, the outer tower is often referred to as the *blue* tower, and the various members thereof are referred to as the *blue* ties, diagonals, etc.; so designated because each outer tower member below the cage is painted *blue* at one end for identification.

Base As applied in this manual, the *base* of the tower refers to that part of the tower that is constructed before the anchor holes are filled in and the hoisting operations begun. The *base* ordinarily comprises the sections that contain diagonals. For example, the *base* of a 90-ft. tower is composed of the 90-ft., 77-ft., 64-ft., and the 50-ft. sections (if the 50-ft. section contains rods instead of diagonals, it is not part of the *base*).

Built-up Section The 13-ft. 8½-in. section of the inner tower that is immediately above the 37-ft. section; so designated because it is assembled, or "built up," on the ground and hoisted up (or lowered from) the tower as a complete section. The *built-up sections* are assembled at the beginning of a project and transported intact from one station to another; they are dismantled only when the towers are either shipped between projects or placed in storage. (See fig. A3.)

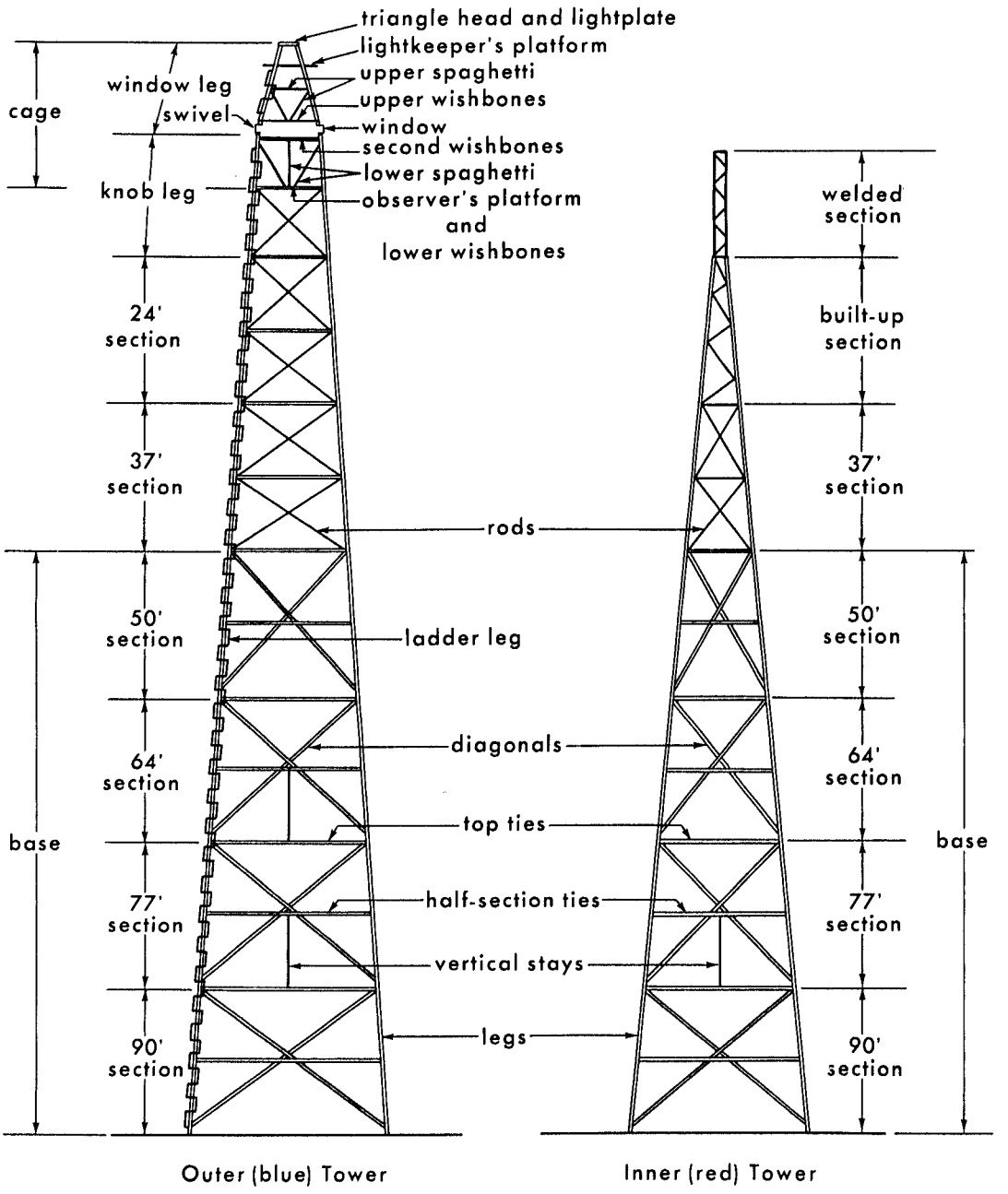

FIGURE A1.—Tower nomenclature.

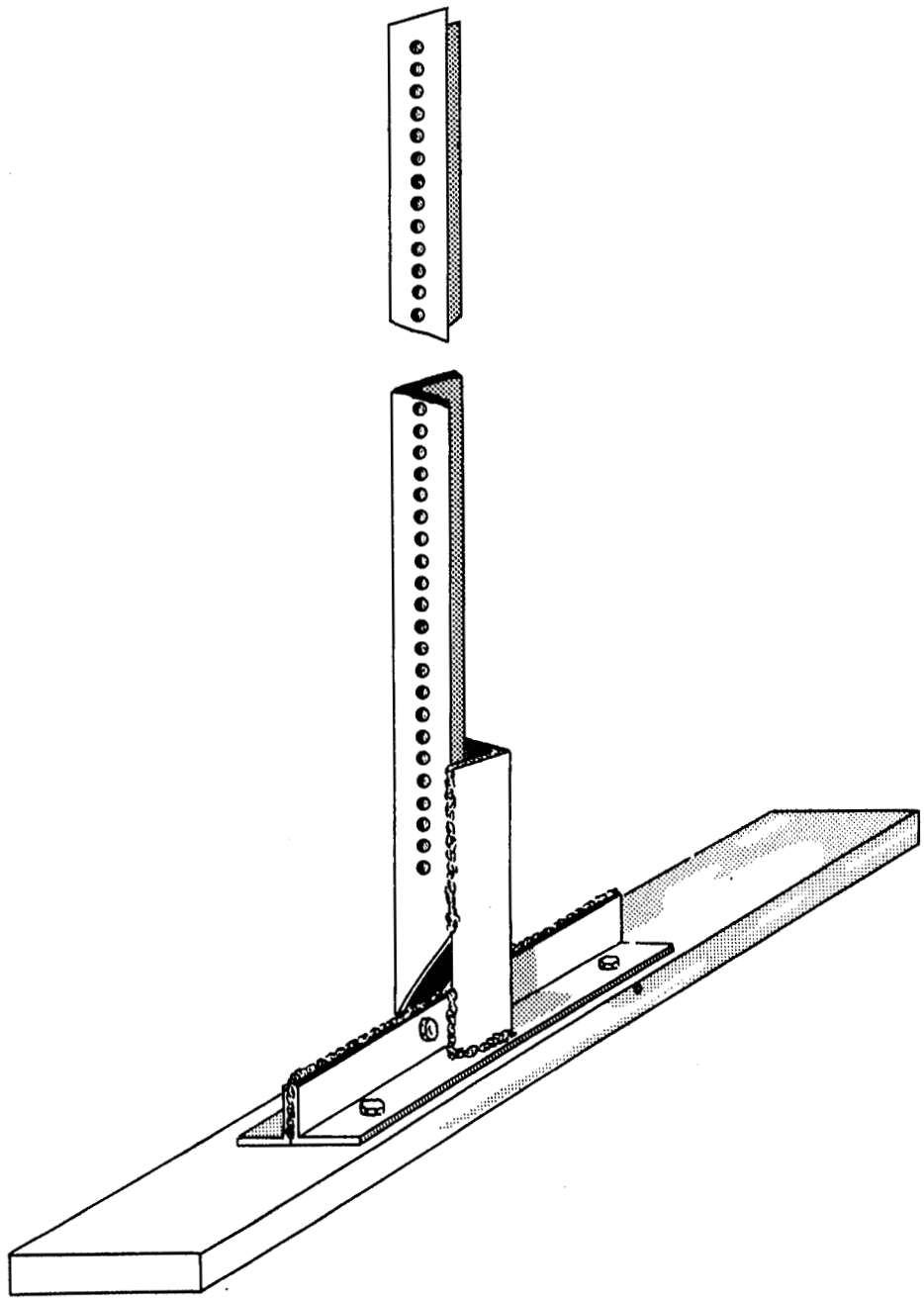

FIGURE A2.—Anchor posts.

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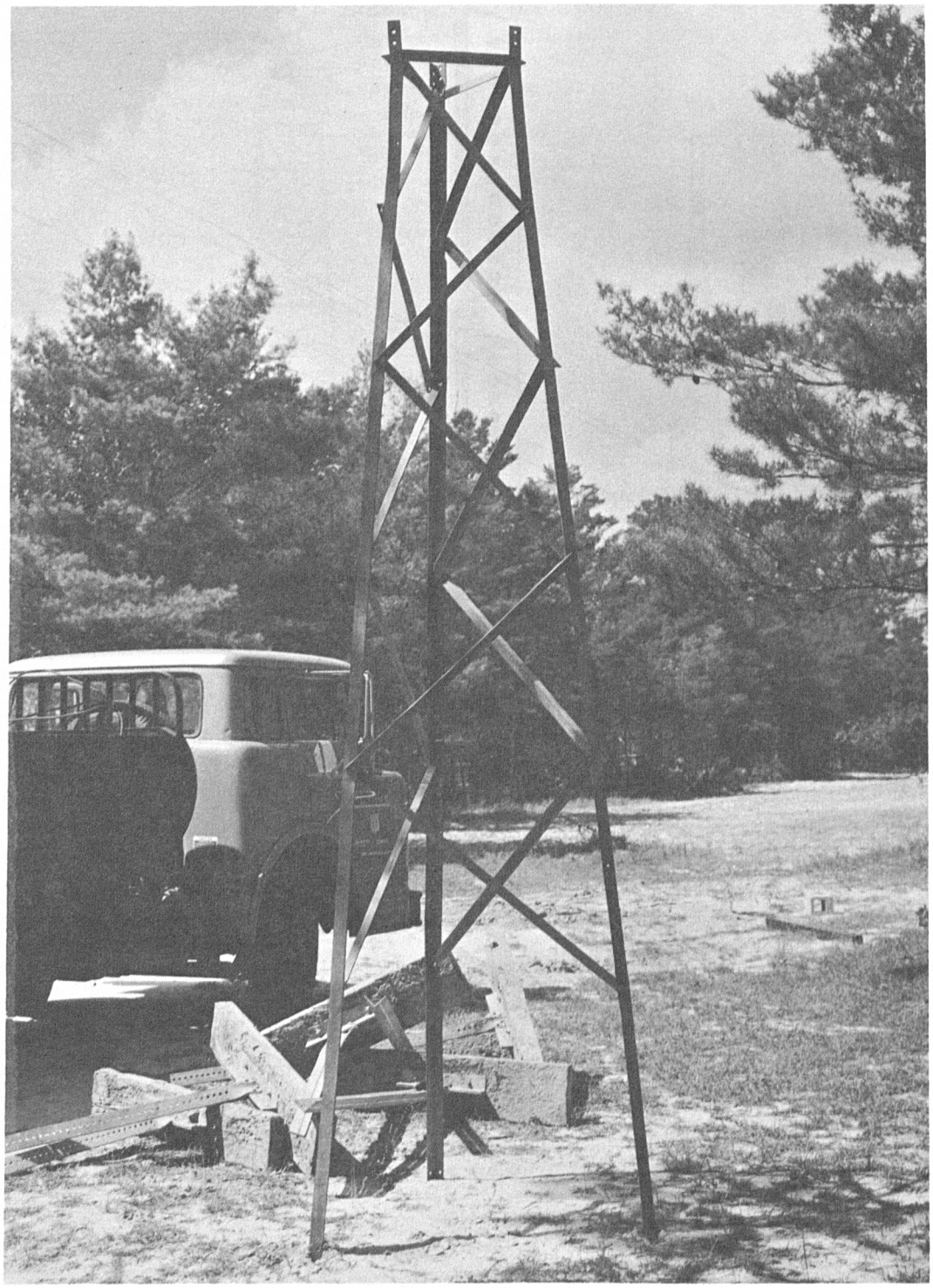

FIGURE A3.—Built-up section and anchor posts.

Cage The portion of the outer tower above the observer's platform. The *cage* supports the observing tent and encloses the observer's and recorder's working area.

Connecting Step The ladder step that spans the point where two legs bolt together. The *connecting steps* are removed from the ladder legs after the tower is dismantled, whereas all other steps remain attached to the legs.

Construction Platforms The small triangular wooden platforms used by the leg men for sitting or standing during construction of a tower. Three *construction platforms* are placed on the ties of the inner tower — one in each corner — and are moved upward as the work progresses. Each platform is about 24 in. on a side, with 2- by 2-in. cleats nailed underneath to fit along the outside of the ties on which the platform rests.

Diagonals The diagonal steel-angle braces, used originally in all sections below the 50-ft. section, but recently used in the 50-ft. section as well. Two types of *diagonals* are used in each section: the *straight diagonal* and the *twisted diagonal*, the latter being distinguished from the former in that it contains a 90-degree twist in its cross section to permit it to butt against both the half-section tie and the *straight diagonal.* (See fig. A4.)

"Follies" See Vertical Stays.

Knob Legs The legs of the outer tower that support the swivel sections; so designated because of the flat, circular steel connection block that is attached to the top end of each *knob leg.* (The lower end of the swivel section bolts to the steel connection block.) The ties and wishbones that support the observer's platform bolt to the *knob legs* near the mid-points of the legs. . The section formed by the *knob legs* is designated in this manual as the *knob-leg section;* the lower half of this section contains the standard tie rods, whereas the upper half forms the sides of the cage.

Ladder Leg The *leg* of the outer tower to which the ladder steps are secured. The *ladder leg* is designated the *No. 1 leg;* the *No. 2* and *No. 3 legs* are known as the *back legs.* Since the block must be attached to the ladder steps, all hoisting and lowering of tower parts takes place at the *ladder-leg* corner of the tower.

Leg A vertical corner post of the inner or outer tower; specifically, (1) the entire corner post, from the bottom to the top of the tower; or (2) the individual vertical member that forms one corner of a section. The *legs* of a tower are designated *No. 1, No. 2, and No. 3,* starting with the ladder leg and progressing clockwise around the tower.

Lightkeeper's Platform A wooden platform for supporting the lightkeeper while he posts or tends the signal lights. The *lightkeeper's platform,* which consists of three boards nailed together to form a triangle, is placed over the window legs about 2 feet below the top of the outer tower.

Lightplate A circular galvanized-iron $\frac{1}{16}$-in. plate, 15 inches in diameter, to which the signal lights are secured. The *lightplate,* situated on top of the triangle head, is secured by bolts to narrow channel sections which are below the horizontal members of the triangle head and which are brought up tight against these mem-

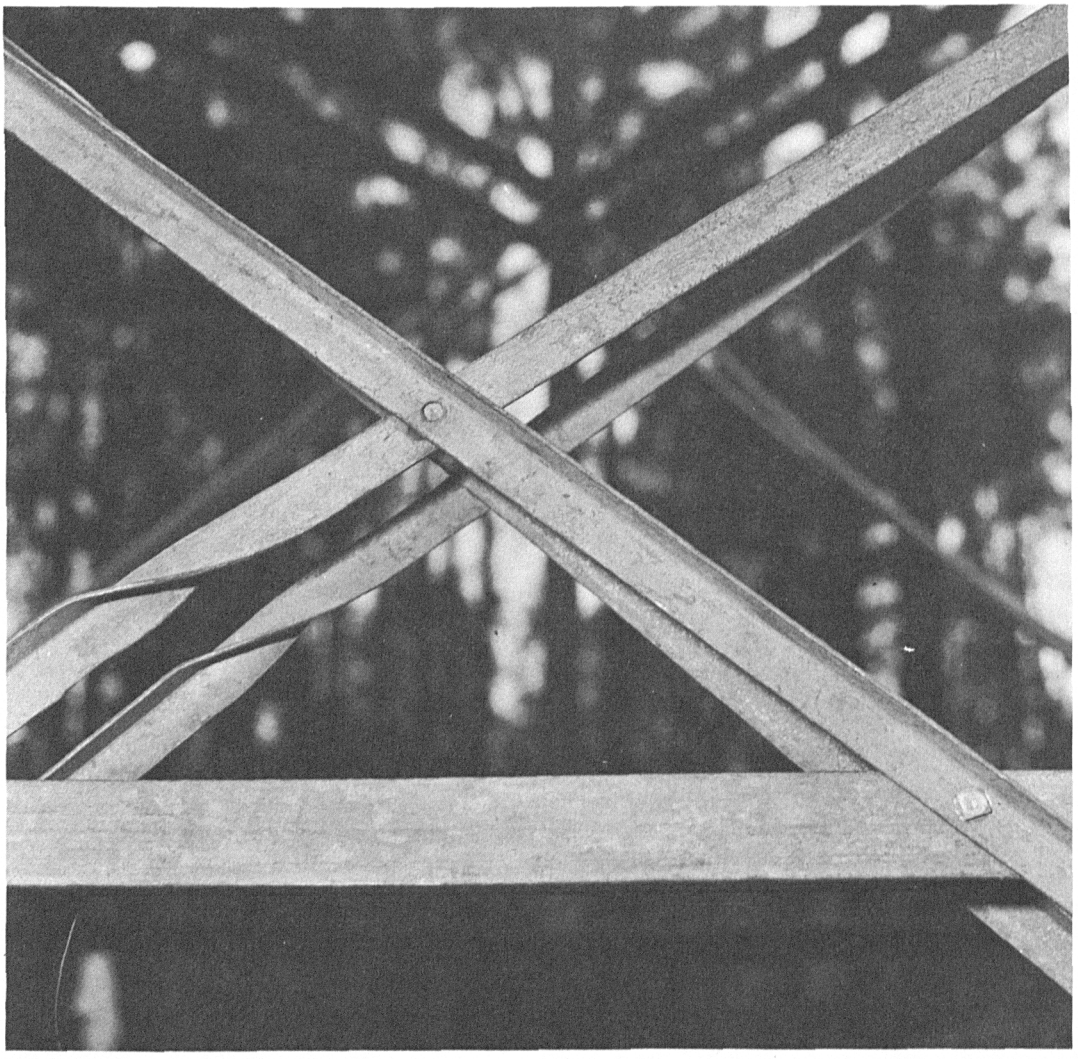

FIGURE A4.—Midpoint of diagonals as seen from outside the tower.

bers to form a rigid connection. Various bolt holes in the *lightplate* provide for sufficient lateral motion so that the center of the plate may be placed vertically over the station mark. There is a ¼-in. hole in the center of the plate for bolting the signal lights. (See fig. A5.)

Lockboards The 2″ x 10″ x 42″ boards that are placed perpendicular to, and about 2 inches above, the red and blue mudsills. In each anchor hole, there are two *lockboards*, one on each side of the anchor posts. One end of each *lockboard* is tunneled horizontally into the outer edge of the anchor hole, thereby "locking" the anchors in place and reducing the chance of the anchors being uprooted. (See fig. A6.)

FIGURE A5.—Lightplate and triangle head.

Mudsill A heavy oak plank, usually 3″ x 8″ x 42″ or 4″ x 10″ x 48″ in size, which is secured to the footplate of the anchor post with four bolts. The *mudsills* provide stability for the tower by acting as anchor plates to prevent overturning and as bearing plates in the anchor holes. The *mudsills* need not be detached from the anchor posts when the towers are dismantled and moved.

Observer's Platform The wooden platform, forming the floor of the cage, on which the observer and recorder work. The *observer's platform* is hexagonal in shape, and is composed of three pieces: the *large platform board*, which contains a triangular opening in its center for the welded section; and the two *small platform boards*, placed one on either side of the large board. The *observer's platform* is constructed of either pine lumber or exterior marine-grade plywood.

Red Of or pertaining to the inner tower. In this manual, the inner structure is often referred to as the *red* tower, and the various members thereof referred to as the *red* ties, diagonals, etc.; so designated because each inner tower member below the welded section is painted *red* at one end for identification.

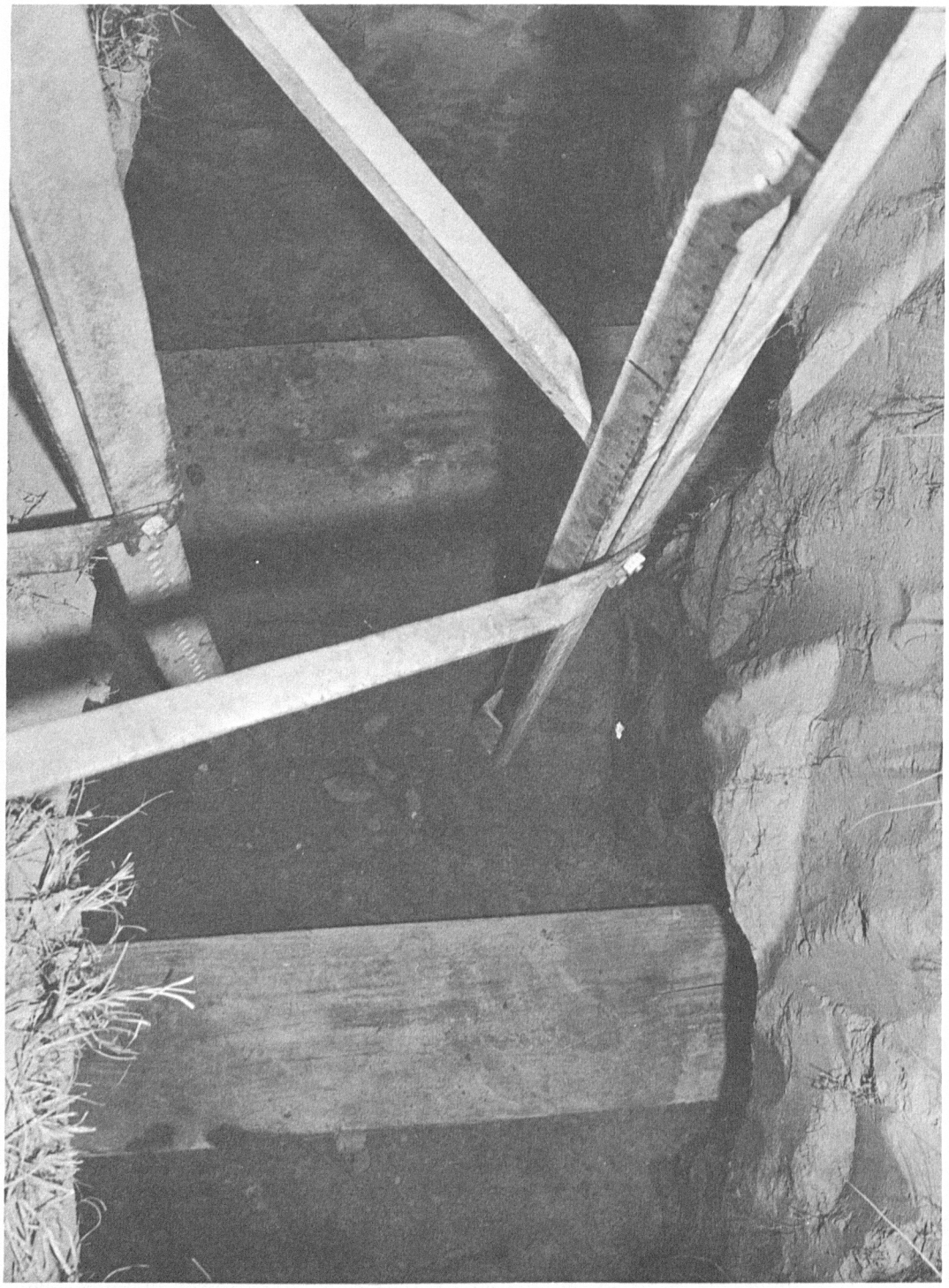

FIGURE A6.—Lockboards in place.

Rods The diagonal steel tie *rods*, ⅝ inch in diameter, used in the 37-ft. section of the inner tower and in the 37-ft. section, 24-ft. section, and lower half of the knob-leg section of the outer tower. The 50-ft. section originally contained *rods*, but modern specifications require the use of diagonals in this section, in order to provide greater structural stability. Two sets of *rods* are used in each section: one set of six *rods* in the lower half of the section and another set of six *rods* in the upper half.

Section An integral portion of the tower, the height of which is equal to the length of one leg member. Both inner and outer towers are built up in *sections;* each *section* below the knob legs of the outer tower and below the built-up *section* of the inner tower is 13 feet 8½ inches in height and is composed of three leg members, six horizontal ties, and either six diagonals (in the lower sections) or twelve tie rods (in the upper sections). A *section* is classified by the vertical distance from the bottom of the *section* to the top of the inner tower; for example, the bottom *section* of a 90-ft. tower is the *90-ft. section,* the second *section* of a 90-ft. tower is the *77-ft. section* (which, in turn, would be the bottom *section* of a 77-ft. tower), the third *section* of a 90-ft. tower is the *64-ft. section* (which, in turn, would be the second *section* of a 77-ft. tower and the bottom *section* of a 64-ft. tower), etc.

Spaghetti The small 1-in.-wide steel angle members that are used as verticals, diagonals, and crosspieces in the sides and roof of the cage. There are two sets of *spaghetti:* the *lower* (first) set is used in the sides of the cage, between the first and second sets of wishbones; and the *upper* (second) set is used in the roof of the cage, above the third set of wishbones.

Swivel Section (Swivel) The adjustable *swivel* U-*section,* located on the lower end of each window leg, at the same height as the observing instrument. The *swivel section* is so designed that it can be turned in a 3½-in. radius in case the leg obstructs the line of sight from the instrument to a distant station; the *swivel* is moved by loosening the bolts provided at its upper and lower ends. The *swivel sections* are usually kept bolted to the window legs when the tower is disassembled.

Ties The horizontal crosspieces, which are used on the outer tower in all sections below the cage, and, on the inner tower, in all sections below the built-up section. Each section contains two sets of *ties:* the *half-section ties,* which are bolted to the midpoints of the legs, and the *top ties,* which are bolted to the upper ends of the legs. The *ties* (except those in the knob-leg section) are spaced 6 feet 8½ inches apart.

Tower The word *tower* generally refers to the combination of both *inner* and *outer* structures, unless specifically preceded by the word *inner* or *outer.*

Triangle Board Same as lightkeeper's platform.

Triangle Head The topmost member of the outer tower, composed of a triangle of 1″ x 1″ x 3/16″ steel angle pieces, welded at the vertices to the top ends of 6-in.-long legs. The *triangle head,* which is bolted to the tops of the window legs, supports the lightplate. (See fig. A5.)

Vertical Extension (Superstructure) A supplemental 10-ft. vertical section which is inserted in the tower at the base of the knob-leg section on the outer structure and at the base of the welded section on the inner structure, for the purpose of providing

additional height when it is found that the tower is not high enough to clear intervening obstructions. The *vertical extensions* are similar in construction to the 24-ft. section of the outer tower and the welded section of the inner tower. Occasionally, two or more *vertical extensions* must be inserted in a tower.

Vertical Stays ("Follies") The 1″ x 1″ x ⅛″ steel angles which are used as vertical stiffening members in the lower sections of towers of 77-ft. height and greater. The outer tower contains *"follies"* in the 64-ft. section and in all lower sections except the bottom one; the inner tower contains *"follies"* in the 77-ft. section and in all lower sections except the bottom one. The top end of each *"folly"* bolts to the diagonals at their crossing point; the bottom end bolts to the center of the top tie in the next lower section.

Welded Section The 10-ft. section that surmounts the built-up section and forms the top of the inner tower; so designated because all members in the section are welded together instead of bolted. The *welded section* has an adjustable top — usually referred to as the *adjustable head* — which can be adjusted for the height of the observer with V-bolt clamps. During the construction of a tower, the *welded section* is bolted to the top of the built-up section on the ground, and both sections are hoisted together as a unit. A tribrach plate, placed on top of the *adjustable head* and bolted to a similar plate placed underneath the horizontal members of the *adjustable head,* is used to support the observing instrument. (See fig. A7.)

Window Legs (Glass Legs) The topmost *legs* of the outer tower; so designated because the lower end of each *leg* is provided with a swivel section in the window of the cage. The *window legs* support the upper cage members, the lightkeeper's platform, and the triangle head.

Wishbones The 1½″ x 1½″ x 3/16″, V-shaped, horizontal steel angle members that form the hexagonal sides of the cage. There are three sets of *wishbones*: The *lower* (first) set helps support the observer's platform; the *second* set, which bolts to the upper ends of the knob legs, forms the lower edge of the observer's window; and the *upper* (third) set, which bolts to the window legs just above the swivel sections, forms the top of the observer's window.

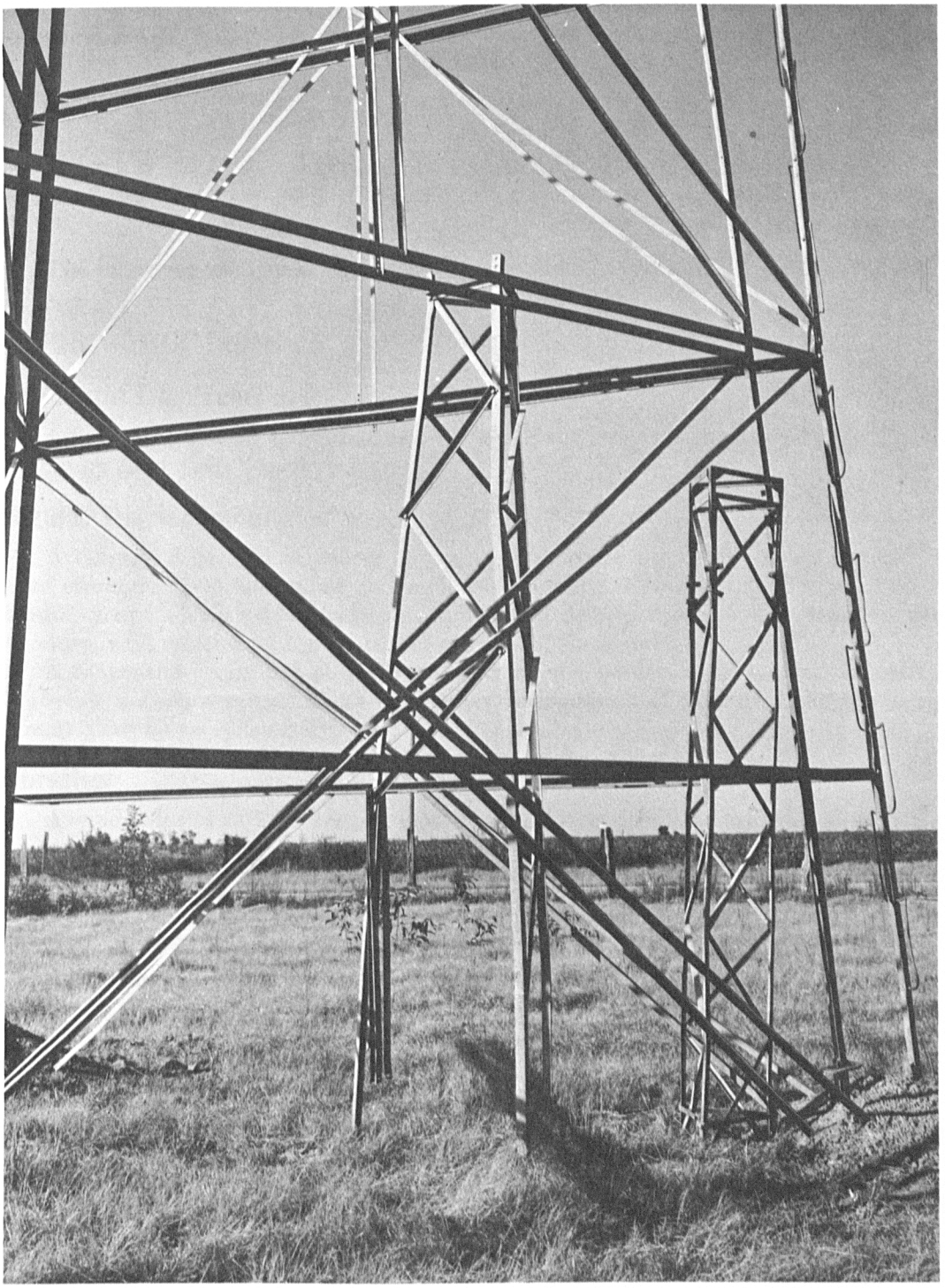

FIGURE A7.—Built-up and welded sections prior to erection on tower.

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Appendix B

TESTS TO BE MET BY THE COMPLETED TOWER

The following tests must be met by the completed tower.

INNER STRUCTURE

Horizontal Displacement

A horizontal pull of 400 pounds at the top of the inner structure must not displace the top by more than ½ inch.

Angular Displacement

A tangential horizontal pull of 50 pounds applied to the corner of the top of the inner structure must not cause an angular displacement of the top of more than 1 minute of arc. This corresponds to a horizontal displacement of the corner of the structure, with relation to the center, of about 2/1000 of an inch.

A tangential horizontal pull of 50 pounds at the corner of the inner structure 23 feet below the top must not cause an angular displacement of the top of the structure of more than 50 seconds of arc.

Vibration

A wind velocity of 20 miles per hour averaged over 1-minute intervals shall cause the top of the inner structure to vibrate in azimuth not more than 10 seconds of arc.

Semipermanent Change in Azimuth

Gusts of wind of a velocity of 35 miles per hour or less shall not cause a semipermanent angular displacement of the top of the inner structure of more than 2 seconds of arc.

OUTER STRUCTURE

A horizontal pull of 500 pounds at the center of the side of the outer structure at the height of the floor platform, the pull being applied through a bridle attached to two of the main posts, must not displace the outer structure horizontally by more than 3 inches nor cause the buckling of any member. The same pull applied to a corner post of the outer structure at the height of the platform must not displace the top of the structure horizontally by more than 5 inches nor cause buckling of any member.

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Appendix C

SPECIFICATIONS FOR THE MANUFACTURE OF THE BILBY STEEL TOWER

Figure C1 is a detailed drawing for a 90- to 103-ft. inner structure and for an outer structure of 10 feet higher. The manufacturer must follow these specifications and details without deviation, except where departure is authorized because of design modifications.

Each structure shall consist of an inner and outer tower. Both inner and outer towers are three-legged; the outer tripod tower is changed to hexagonal shape at sections A–A, B–B, and C–C.

All bolts, of the following dimensions, shall be fabricated from the high-tensile steel complying with specifications of the American Society for Testing and Materials (A.S.T.M.), A–325.

¾″ x 13⁄32″—16 threads per inch
1″ x 13⁄32″—16 threads per inch
1¼″ x 13⁄32″—16 threads per inch
1½″ x 13⁄32″—16 threads per inch

All other metal parts, including nuts for the above bolts, shall be fabricated from steel complying with specifications of A.S.T.M., A–7. All steel parts shall be galvanized in accordance with the best practice after all machining and welding are completed, and shall not be subject to flaking.

There must be furnished with each tower a diagram showing the size and the factory number of each piece of the structure, including bolts, anchors, platforms, etc. The parts of all towers furnished must be interchangeable.

The sectional lengths of the outer and inner towers must be the same as shown in figure C1. The towers must be so constructed that one or more of the lowest sections can be omitted when the full height is not needed. Holes must be made in the anchor posts, as indicated in the detailed plan, in order that the tower may be adjusted in height on the anchor posts.

Ladder steps must be of the same type as shown on the drawing. Steps will be furnished only for the outer towers. Holes shall be punched in the inner tower ladder leg to allow it to be made interchangeable.

Bands of paint, 9 to 10 inches in length, must be applied to all upright, diagonal, and horizontal pieces of the inner and outer towers. Blue paint will be used for the outer tower and red for the inner one. The bands will be placed at the top ends of the leg sections and near the left-hand ends of the ties and diagonals, as viewed from outside the tower.

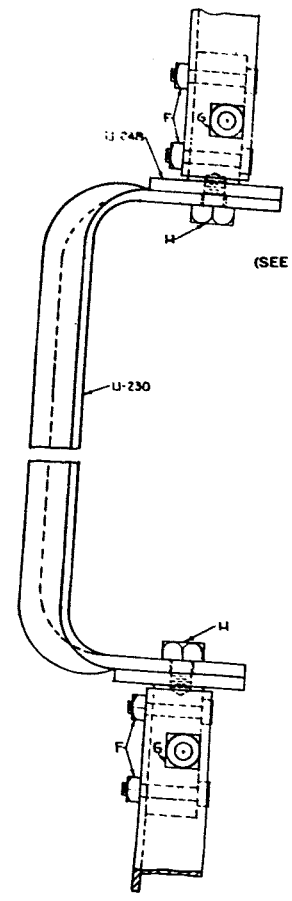
The supplemental 10-ft. vertical sections for the inner and outer towers shall be furnished only when specified. The purpose of the supplemental vertical sections is to

allow the observing platform and the top of the inner tripod to be raised 10 feet without dismantling the entire tower to insert another section at the bottom.

The swivel leg is to serve as an "open corner post" whenever the observer finds this member to be on line between his instrument and a distant target. Three of these legs are required for each tower.

There must be furnished, with each tower and with every extra section, additional bolts in the amount of 20 percent for each size and length of bolt used on the inner and outer structures. A like amount of nuts for these bolts shall also be furnished.

INNER TOWER / OUTER TOWER		BOLT SCHEDULE	
NO.	NO.	SIZE	LOC.
3		3/8 X 3 FL. HD.-SQ NUTS	A
30	12	3/8 X 1 1/2 " "	B
72	60	3/8 X 1 1/4 " "	C
150	123	3/8 X 1 " "	D
51	48	3/8 X 3/4 " "	E
12		3/8 X 2 1/4 " "	F
6		3/8 X 2 1/2 " "	G
6		3/8 X 1 HEX. HD. CAP SCREW	H
80		16" LOOP. STEPS	



DETAIL OF SWIVEL LEG
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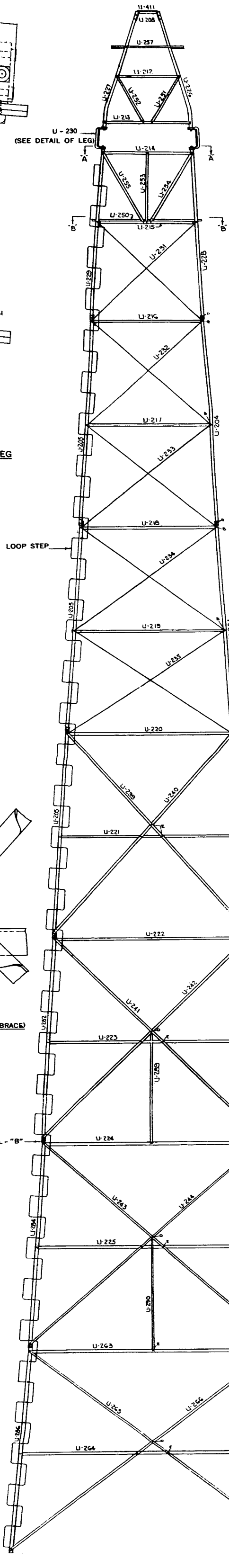
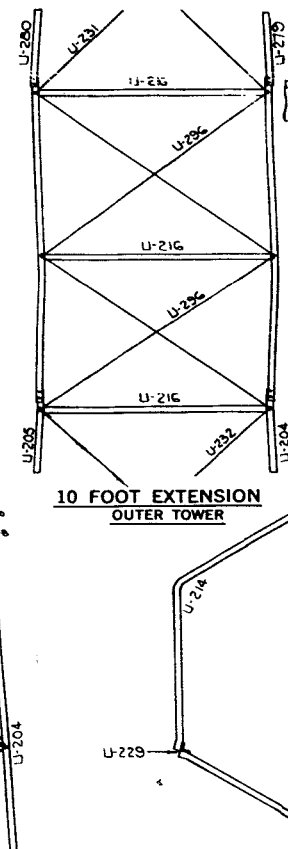
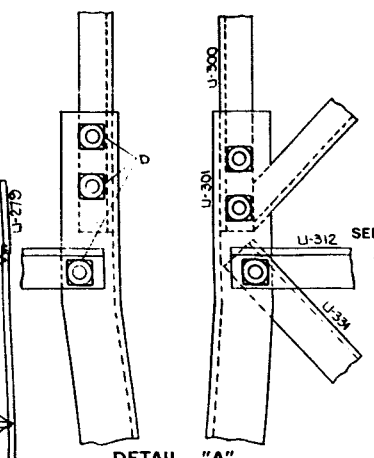
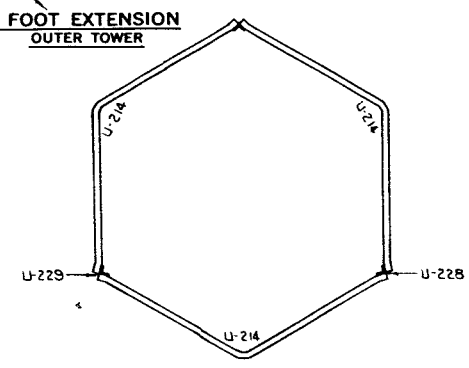


OUTER TOWER

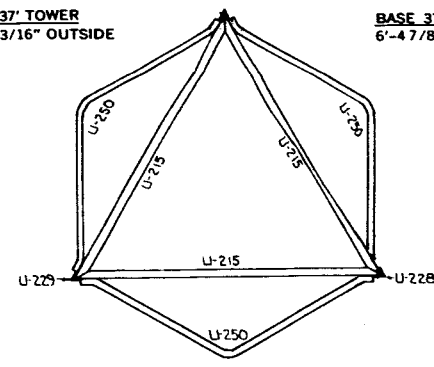




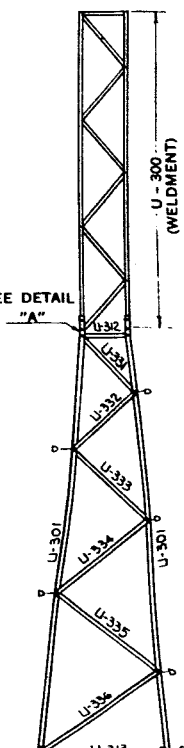
DETAIL - "A"
(SHOWING U - 300 WELDMENT
BOLTED TO INNER TOWER

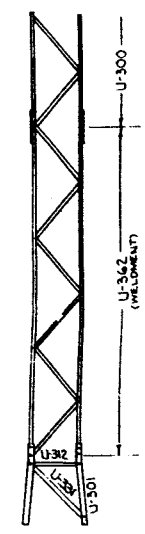


SECTION - "A - A"

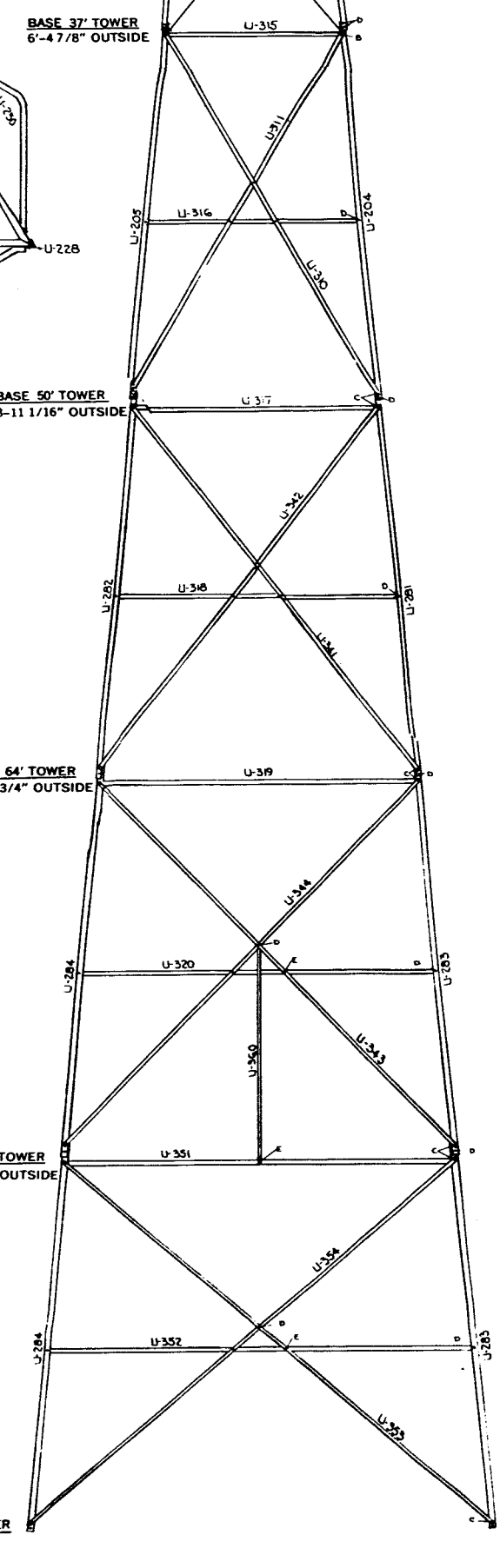


SECTION - "B - B"
(LESS PLATFORM)





10 FOOT EXTENSION
INNER TOWER



BASE 37' TOWER
6'-4 7/8" OUTSIDE

BASE 50' TOWER
8-11 1/16" OUTSIDE

BASE 64' TOWER
11'-5 3/4" OUTSIDE

BASE 77' TOWER
14'-0 1/8" OUTSIDE

BASE 90' TOWER
16'-6 1/8"
OUTSIDE

INNER TOWER

FIGURE C1.—Erection plan of tower.

Appendix D

OBSERVER'S PLATFORM, LIGHTKEEPER'S PLATFORM, AND CONSTRUCTION PLATFORM

Figures D1 and D2 show the details of the observer's platform. Figure D3 gives the details of the lightkeeper's platform. Figure D4 presents the details of the construction platform.

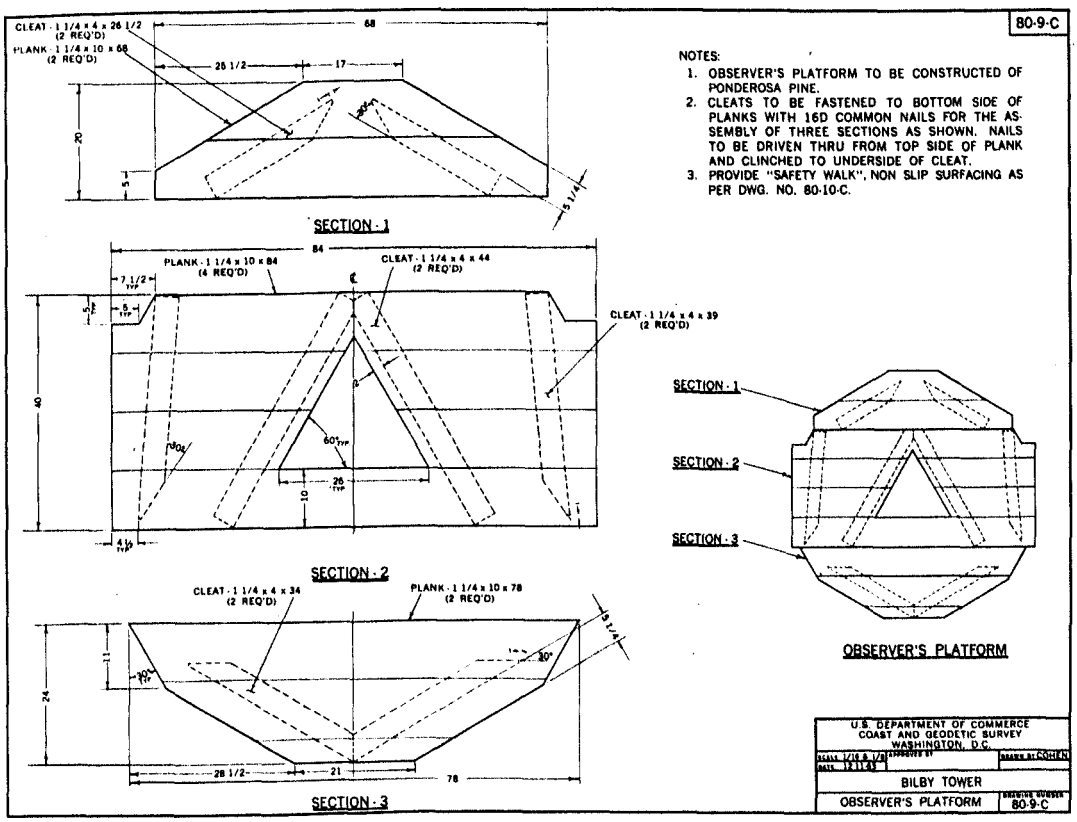


FIGURE D1.—Details of observer's platform.

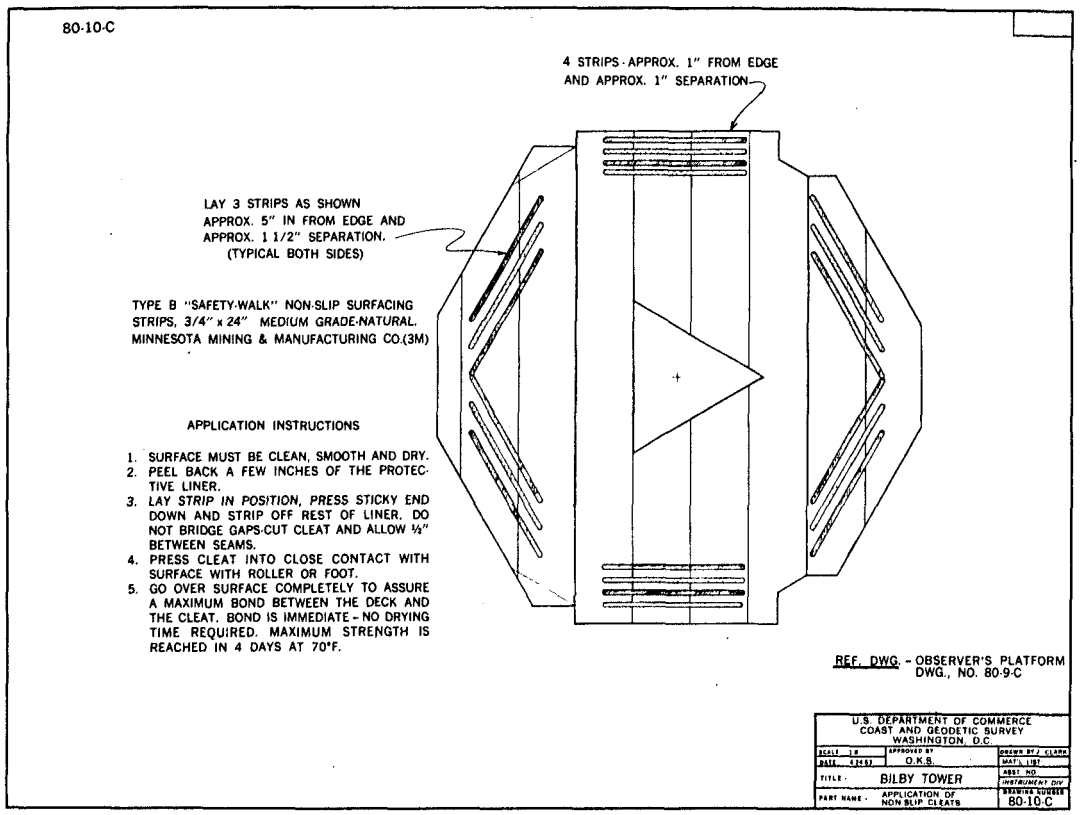


FIGURE D2.—Details of observer's platform. Application of non-slip cleats.

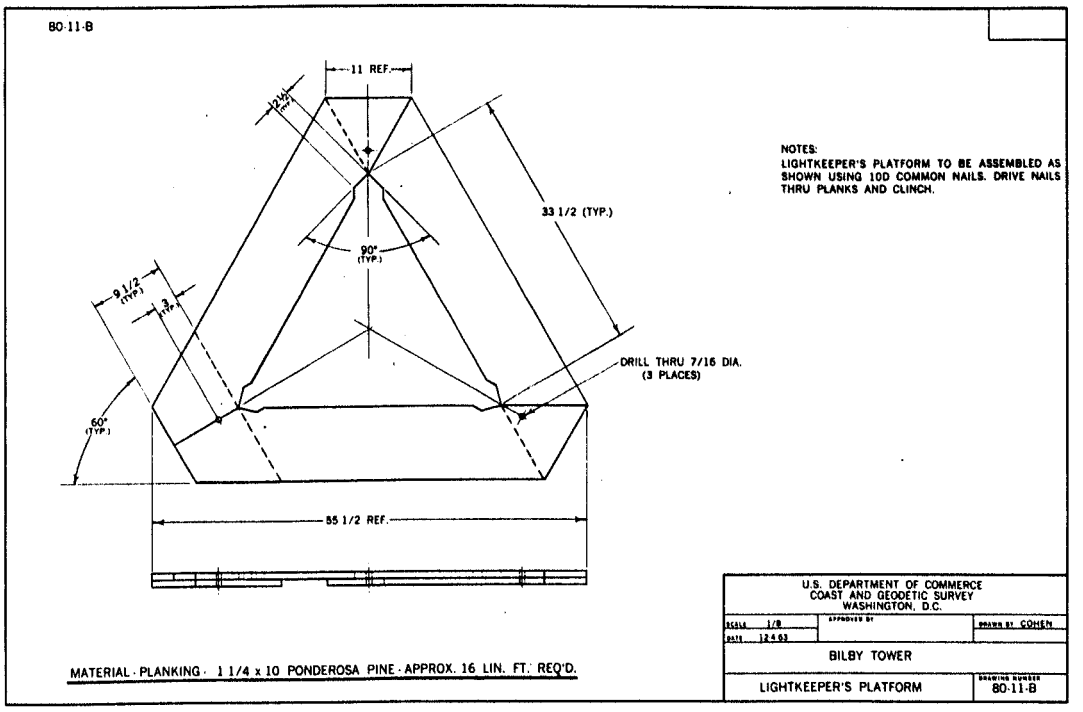


FIGURE D3.—Details of lightkeeper's platform.

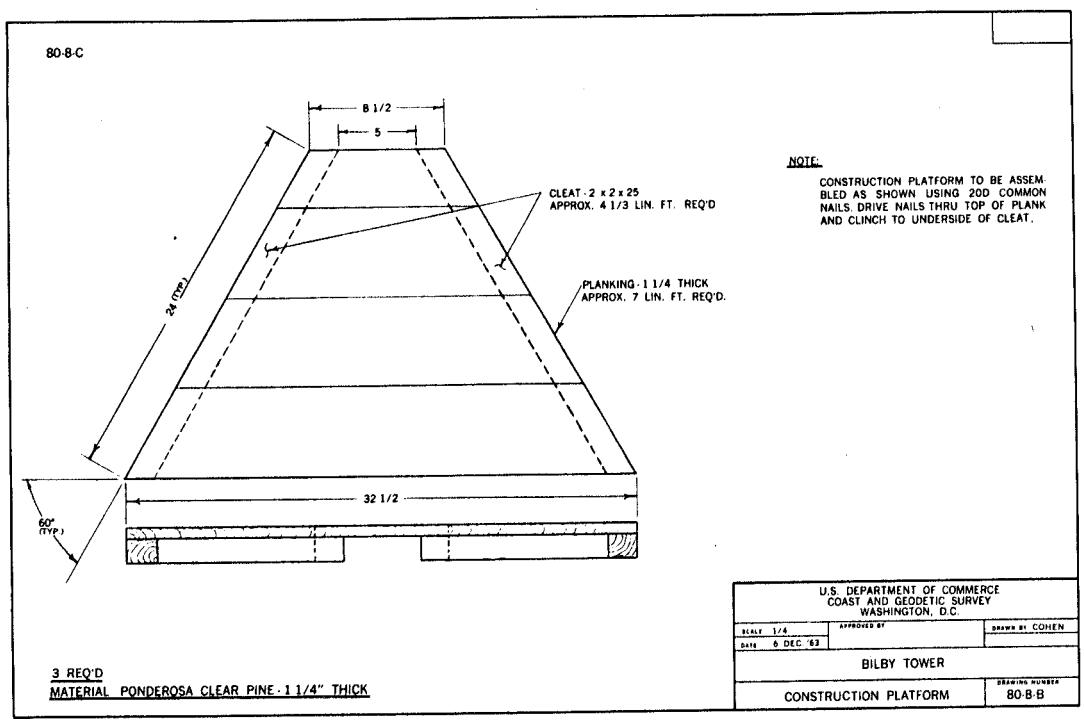


FIGURE D4.—Details of construction platform.

Appendix E

DESIGN OF THE BED FOR THE STEEL TRUCK

Figure E1 shows the details of the design of the bed for the steel truck. The list of materials needed to construct this bed includes the following.

Item	*Number required*	*Size*
Stringers	2	4″ x 6″ x 14′ pine creosoted
Clamps	12	⅜″ x 2″ x 2″ ∟ 11″ long
	12	⅝″ x 16″ bolts
	12	⅜″ x 1½″ x 4″ steel strip
	48	½″ x 4½″ carriage bolts
Sills	6	4″ x 6″ x 81″ pine creosoted
Bed	13	2″ x 6″ x 14′ tongue and grooved pine
Cap on bed	1	¼″ x 3½″ x 3½″ ∟ 81″ long
	2	½″ x 4½″ carriage bolts
Front framework	2	¼″ x 3½″ x 3½″ ∟ 41″ long
	2	¼″ x 3½″ x 3½″ ∟ 81″ long
	1	¼″ x 32″ x 78″ steel plate
	5	2″ x 6″ x 78″ oak
	2	¼″ x 1″ x 32″ steel strip
	1	½″ x 3″ x 112″ steel strip
	1	screen
Side racks	14	⅛″ x 1½″ x 1½″ ∟ 32″ long
	2	⅛″ x 1½″ x 1½″ ∟ 164″ long
	8	1¼″ x 6″ x 14′ pine
	24	⅜″ x 4½″ carriage bolts
	96	⅜″ x 1½″ carriage bolts
	2	¼″ x 3″ x 15″ steel plate
Miscellaneous	---	creosote
		paint
		spikes

Note: 1. Lumber for bed and side racks is painted before construction.
2. Scrap Bilby steel tower members can be used where possible.

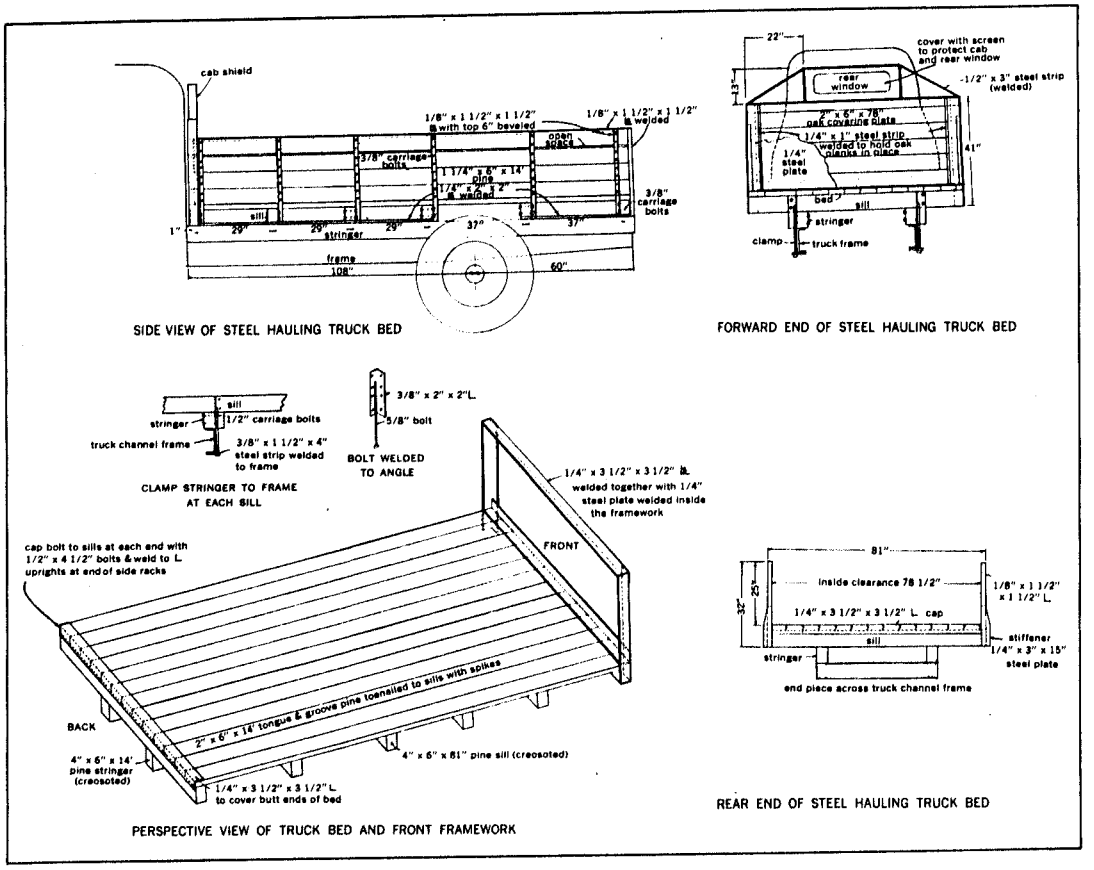


FIGURE E1.—Details of bed of steel-hauling truck.

Appendix F

EQUIPMENT USED BY A FIVE-MAN BUILDING PARTY

BUILDING TRUCK

Each building truck is a 1-ton truck with a front winch and an emergency safety switch. Preferably, it is a 4-wheel drive. Figure F1 shows a typical building-party truck. Each truck carries the following equipment.

FIGURE F1.—Building-party truck.

Article	*Number required*
Axe, small	1
Axes, double-bitted	2
Bags, bolt, leather or canvas, with belts	3 sets
Bars, prodding	1
Bars, digging or pinch	3
Binoculars	1 pair
Block, steel, 6''	1
Boards, builders' construction	3

Article	*Number required*
Bolts, tower, high tensile (⅜″ x ¾″, ⅜″ x 1″, ⅜″ x 1¼″, ⅜″ x 1½″)	Adequate supply for tower
Box, bolt, with five compartments	1
Brace, carpenter's, with bits	1
Climbers, tree	1 set
Collimator, vertical, with tripod	1
Compass, magnetic	1
Cooler, water, 5-gal	1
Cutters, wire	1
Drum, winch, wheel	1
Flashlight	1
Hammers, claw	2
Hammer, sledge, 8-lb	1
Hammer, sledge, 4-lb	1
Jack, hydraulic	1
Level, Wye or Dumpy, with tripod	1
Picks, with handles	3
Plummet	1
Pulley, for running end of line (if desired)	1
Punch, special tower	1
Rope, manila, ¾″ (hauling line)	250 ft.
Rope, manila, ⅜″ or ½″ (haul back line)	125 ft.
Rope, manila, ½″, 6-ft. lengths with 2½″ steel rings in the ends	6 to 15
Saw, hand	1
Screwdriver, large	1
Shovels, short-handle, round-point	3
Signs, warning, tower	Supply
Spades, tile	3
Tape, cloth metallic, 30-meter	1
Tape, steel, 300 ft	1
Turnbuckles	At least 6
Wire, guy, No. 9, galvanized	Supply
Wire, No. 12 or 14 (for lashing platform boards to tower)	Supply
Wrench, crescent, 12″	1
Wrenches, S, open-end, tower	10

Special equipment (signal cloth, obstruction lights, etc.) when required.

MARK-SETTING TRUCK

Each mark-setting truck is at least a 1½-ton truck. In addition to the material for marks, it carries the following equipment.

Article	*Number required*
Bar, digging	1
Block, stamping	1
Box, mortar	1
Cutters, grass or weed	1
Dies, stamping, letters and figures	1 set
Diggers, posthole	1
Disks, triangulation station, reference mark, and azimuth mark	Supply
Drills, star	3 to 6
Drum, water, 50-gal	1
Flashlight	1
Goggles	1 pair
Hammer, claw	1
Hammer, rock	1
Jack, hydraulic	1
Posts, witness	2
Shovel, short-handle, round-point	1
Shovel, short-handle, square-point	2
Spade, tile	1
Tool, underground mark-setting	1
Trowel	2

Snow fence (for protective fencing around tower) when required.

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Appendix G

EQUIPMENT USED BY A FOUR-MAN TEARDOWN PARTY

Each truck used in the teardown operation is either a 1-ton panel truck with an extra seat or a ¾-ton carryall. Each truck carries the following equipment.

Article	*Number required*
Bags, bolt, leather or canvas, with belts	3 sets
Bar, pinch or digging	1 (3 required if ground is frozen)
Block, steel, 6″	1
Box, bolt with five compartments	1
Cooler, water, 5-gal	1
Cutters, wire	1 pair
Flashlight	1
Hammer, claw	1
Hook, anchor	1
Jack, hydraulic	1
Pick, with handle	1 (3 required if ground is frozen or very dry)
Pulley, for running end of line (if desired)	1
Punch, special tower	1
Rope, manila, ¾″	250 ft.
Rope, manila, ½″, 6-ft. lengths with 2½″ steel rings in the ends	3 to 6
Shovels, short-handle, round-point	4
Wire, No. 14½ (for binding steel)	Supply
Wrench, crescent, 12″	1
Wrenches, S, open-end, tower	8

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Appendix H

BRAKE ATTACHMENT FOR LOWERING THE WELDED AND BUILT-UP SECTION OF THE STEEL TOWER

The following brake attachment (teardown cathead) is to be used when lowering the welded and built-up section off a Bilby steel tower.

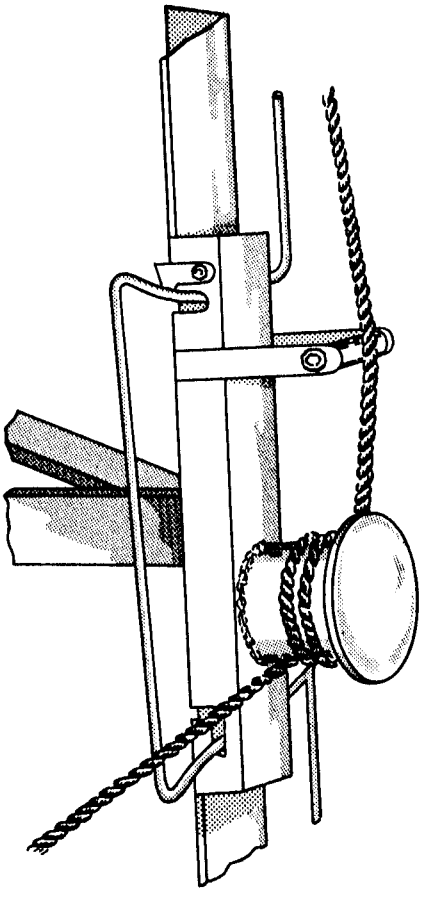

FIGURE H1.—Completed cathead.

The attachment is to be used when the teardown foreman is unable to maneuver his truck close enough to the ladder leg to allow use of the cathead already on the truck. Also, it prevents the rope from being weakened when the ladder steps are used as a brake.

This teardown cathead attachment is completely safe; it is easily and firmly installed on the ladder leg without the use of bolts or clamps. The unit is made by welding two 20-inch lengths of 2- x 2- x ⅛-inch angle iron together to form a channel. A comparable channel member can also be used. Near the lower end, a 4-inch diameter, 4½-inch long section of pipe is welded on to act as a brake drum. On the outer end of the pipe is welded a 7-inch diameter piece of ⅛-inch plate to form a flange to prevent the rope from slipping off the drum. About 9 inches above the center of the pipe is welded a guide block to prevent the rope from fouling on the drum. This block consists of a 6-inch piece of 1-inch pipe, with a bolt through the center, about 3 inches out from the face of the channel; it is welded to the flanges of the channel by 1-inch x 3/16-inch strap iron. The channel is then notched to fit the steps on the ladder leg; the lower notches in and down, the upper notches just in. The cathead is mounted by slipping the bottom notches on the ladder leg step, lifting up and slipping the top notches over the steps and hooking in place.

Figure H1 shows the completed cathead and indicates its use. The top hooks are intended to hold the cathead in place before tension is applied to the rope, after which it automatically locks into place.

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Appendix I

HOISTING APPARATUS FOR THE GEODIMETER

Figure I1 shows a hoisting apparatus that has been used successfully for hoisting the Geodimeter.

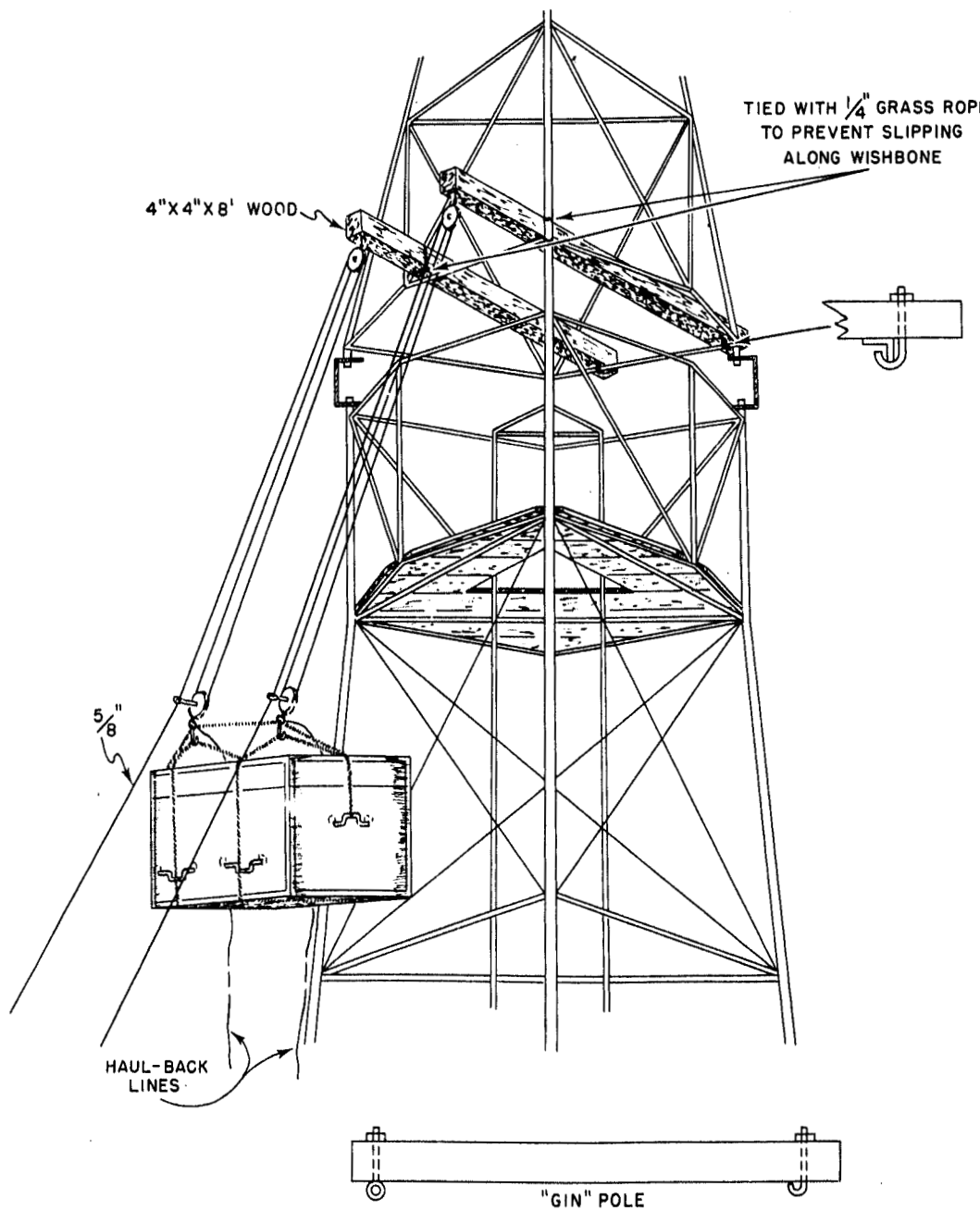

FIGURE I1.—Hoisting apparatus for the Geodimeter.

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