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E. LESTER JONES, DIRECTOR

# RECONNAISSANCE AND SIGNAL BUILDING



By

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Signalman

Special Publication No. 93



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# RECONNAISSANCE AND SIGNAL BUILDING.

By Jasper S. Bilby, *Signalman, U. S. Coast and Geodetic Survey.*

## PART I.—RECONNAISSANCE.

### INTRODUCTION.

This memoir on reconnaissance and signal building is intended to supply information on a subject not fully treated in any previous manual of the U. S. Coast and Geodetic Survey. It is not intended to supplement any part of the instructions for triangulation, but rather to enlarge and illustrate that portion of the instructions which treats of reconnaissance and signal building. It is based on experience with actual cases arising in the routine of field work and is intended to bring out fully the theoretical and practical principles which should govern in carrying on this difficult and important class of work—work which calls for the exercise of a high order of skill and ingenuity and well repays thoroughness in execution. Reconnaissance for precise triangulation is a preliminary survey for the work that follows. The end sought is to select locations for stations that will satisfy all conditions called for by the general instructions for triangulation and such special instructions as may govern the particular project.

It is seldom necessary on reconnaissance to observe horizontal and vertical angles and compute the elevations and geographic positions of points. It is only necessary to determine the positions of points closely enough to plot them on a sketch or map in order to determine the strength of the figures and to investigate lines between main scheme stations. This can be done by magnetic compass bearings, by estimated and known distances to objects whose positions are known, and by the map system if suitable maps are available. In this connection it should be remembered that the control surveys, for which the reconnaissance is being made, are usually executed in advance of the topographic surveys, and therefore accurate topographic maps of the area through which the reconnaissance extends are seldom available.

Reconnaissance does not require a high degree of accuracy, but it is none the less important. The total cost of the reconnaissance, building, and observing must be considered in the selection of stations, and the reconnoitering officer must therefore be thoroughly acquainted with each branch of the work. If the reconnaissance alone is considered, the building and observing will often be unnecessarily expensive in time, labor, and money.

## CLASSIFICATION OF TRIANGULATION.

The requirements are different for the various classes of triangulation, and since the nomenclature applying to the different grades has been recently changed the accuracy desired for each class, as given in U. S. Coast and Geodetic Survey Circular No. 30, February 15, 1922, will be briefly indicated.

The ultimate criterion applied in classifying the different grades of triangulation is the actual error in the length of any line. This is indicated by the discrepancy between the measured length of a base line and its length as computed through the triangulation from the last preceding base. In precise triangulation such discrepancies must not exceed 1 part in 25,000, in primary triangulation 1 part in 10,000, and in secondary triangulation 1 part in 5,000. These are the discrepancies which remain after the side and angle equations have been satisfied by the least-squares adjustment. Consequently, in making the comparisons from the field computations, it will sometimes be found that these discrepancies will be exceeded by small amounts in work which is satisfactory, since the angle and side equations will, almost without exception, decrease the discrepancy. To secure the accuracy indicated above, certain standards are adopted for the field work, the most important one of which relates to the closing error of the triangles, which is the discrepancy between the sum of the measured angles in a triangle and 180° plus the spherical excess of the triangle. The shape of the figures in the triangulation scheme, the frequency of bases, the size of the instrument, and the number and kind of observations are all selected with due regard to the accuracy desired.

**Precise triangulation.**—Precise triangulation should be executed in belts about 100 miles apart, except under certain conditions, where precise traverse may be used in its place. The most modern methods and instruments should be used. Triangle closing errors should never exceed three seconds, and the average closing error should be generally less than one second.

**Primary triangulation.**—Primary triangulation (or traverse of corresponding accuracy) should be used to subdivide the areas not covered by the precise horizontal control in order that eventually no point in the United States will be farther than about 25 miles from stations of at least primary accuracy. The triangles of the primary triangulation should close with a maximum error of not over six seconds, and an average error seldom greater than three seconds. Closures in length, on lines in the precise net, on primary lines previoulsy adjusted, or on base lines should not exceed 1 part in 10,000.

**Secondary triangulation.**—Secondary triangulation (or secondary traverse) should be extended into the areas not covered by work of a higher grade, in order that no quadrangle, or area of equal size, may contain less than three stations of secondary or higher accuracy. The term "quadrangle," as herein used, refers to the area 15 minutes of arc square, covered by a single topographic sheet of the U. S. Geological Survey. The triangles of secondary grade should close with a maximum error of 10 seconds and an average error seldom exceeding 5 seconds. Closures in length on lines in the precise or primary net, on lines of secondary triangulation previously adjusted, or on base lines should not exceed 1 part in 5,000.

**Tertiary triangulation.**—Triangulation of tertiary grade is solely for the control of mapping operations in a region controlled but not covered by triangulation of a higher order. It should start from control of a higher grade and should never be carried for more than a few figures without being connected again to a control station of a higher order of accuracy. It may be performed with a plane-table, transit, or sextant. There should always be at least three well-distributed triangulation or traverse stations of a higher order than tertiary in each quadrangle or equivalent area—two to serve as a base and the third to check upon. The sole requirement of accuracy in tertiary triangulation is that positions must be located without errors that will be appreciable on the resulting map.[1]

## SPECIFICATIONS FOR RECONNAISSANCE FOR PRECISE TRIANGULATION.

Below are given the reconnaissance specifications for precise triangulation which have been in use, with slight modifications, for several years and which have appeared in practically the same form in previous publications.

1. **Character of figures.**—The chain of triangulation between base nets shall be made up of completed quadrilaterals and of central-point figures, with all stations occupied. It must not be allowed to degenerate even for a single figure to single triangles. There must be two ways of computing the lengths through each figure. On the other hand, there must be no overlapping of figures and no excess of observed lines beyond those necessary to secure a double determination of every length, except as follows: In a four-sided central-point figure one of the diagonals may be observed; a figure used in expanding from a base often requires the observation of additional lines; and a net work of triangulation over a city or other wide area may very properly contain a few overlapping figures to meet special conditions.

2. **Strength of figures.**—In the chain of triangulation between base nets the value of the quantity $R=\left(\frac{D-C}{D}\right)\Sigma[\delta_A^2+\delta_A\delta_B+\delta_B^2]$ for any one figure must not in the selected best chain (call it $R_1$) exceed 25, nor in the second best (call it $R_2$) exceed 80, in units of the sixth place of logarithms. These are extreme limits never to be exceeded. Keep the quantities $R_1$ and $R_2$ down to the limits 15 and 50 for the best and second best chains, respectively, whenever the estimated total cost does not exceed that for a chain barely within the extreme limits by more than 25 per cent. The values of $R$ may be readily obtained by the use of the "Table for determining relative strength of figures in triangulation," on page 5.

In the above formula the two terms $\frac{D-C}{D}$ and $\Sigma[\delta_A^2+\delta_A\delta_B+\delta_B^2]$ depend entirely upon the figures chosen and are independent of the accuracy with which the angles are measured. The product of these two terms is therefore a measure of the strength of the figures with respect to length, in so far as the strength depends upon the selection of stations and of lines to be observed over. The method of computing the strength of figure is explained on page 4.

3. **Lengths of lines.**—It is best that no line of the precise triangulation outside of the base nets be less than 5 kilometers in length. So far as accuracy of observations is concerned, there is little advantage in having the lines longer than this. Above this minimum length two main considerations affect the size of the scheme: First, the combined cost per mile of progress of reconnaissance, building, and observing; and, second, the number and accessibility of the points determined. When these two factors are opposed, the compromise scheme selected should have the stations close enough together to be used by engineers without special instruments and signal lamps. In general, lines of the main scheme in precise triangulation should not exceed 50 miles in length.

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[1] Detailed instructions for precise triangulation are given in U. S. Coast and Geodetic Survey Special Publication No. 19, and for secondary triangulation in Special Publication No. 26. Specifications for primary triangulation are also given in Special Publication No. 26.

4. **Frequency of bases.**—If the character of the country is such that a base site can be found near any desired location, $\Sigma R_1$ between base lines should be made about 100. This will be found to correspond to a chain of from 10 to 25 triangles, according to the strength of the figures secured. With strong figures but few base lines will be needed, and a corresponding saving will be made on this part of the work. If topographic conditions make it difficult to secure a base site at the desired location, $\Sigma R_1$ may be allowed to approach but not exceed 130. There will be danger when this larger limit is used that an intervening base may be necessary, for if in any case the discrepancy between adjacent bases is found to exceed 1 part in 25,000 an intervening base must be measured.

5. **Base sites and base nets.**—In selecting base sites keep in mind that a base can be measured with the required degree of accuracy on any site where the grade on any 50-meter tape length does not exceed 10 per cent, and that narrow valleys or ravines less than 50 meters wide in the direction of the base are not obstacles to measurement. The length of each base is to be not less than 4 kilometers. In each base net great care should be taken to secure as good geometrical conditions as possible. There should be no hesitancy in placing the base on rough ground, provided the roughness is not greater than that indicated above, if by doing so the geometrical conditions in the base net are improved. Each base net should not be longer than two ordinary figures of the main chain between bases. The base net may also be strengthened by observing over as many lines between stations of the net as can be made intervisible without excessive cost for building or cutting. Caution is necessary in thus strengthening a base net by observing extra lines to avoid making the figure so complicated as to be excessively difficult and costly to adjust.

## COMPUTATION OF STRENGTH OF FIGURE.

In the following table the values tabulated are $\Sigma\,[\delta_A^2+\delta_A\delta_B+\delta_B^2]$. The unit is one in the sixth place of logarithms. The two arguments of the table are the distance angles in degrees, the smaller distance angle being given at the top of the table. The distance angles are the angles in each triangle opposite the known side and the side required. $\delta_A$ and $\delta_B$ are the logarithmic differences corresponding to one second for the distance angles $A$ and $B$ of a triangle.

*Table for determining relative strength of figures in triangulation.*

| ° | 10° | 12° | 14° | 16° | 18° | 20° | 22° | 24° | 26° | 28° | 30° | 35° | 40° | 45° | 50° | 55° | 60° | 65° | 70° | 75° | 80° | 85° | 90° |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 10 | 428 | 359 | | | | | | | | | | | | | | | | | | | | | |
| 12 | 359 | 295 | 253 | | | | | | | | | | | | | | | | | | | | |
| 14 | 315 | 253 | 214 | 187 | | | | | | | | | | | | | | | | | | | |
| 16 | 284 | 225 | 187 | 162 | 143 | | | | | | | | | | | | | | | | | | |
| 18 | 262 | 204 | 168 | 143 | 126 | 113 | | | | | | | | | | | | | | | | | |
| 20 | 245 | 189 | 153 | 130 | 113 | 100 | 91 | | | | | | | | | | | | | | | | |
| 22 | 232 | 177 | 142 | 119 | 103 | 91 | 81 | 74 | | | | | | | | | | | | | | | |
| 24 | 221 | 167 | 134 | 111 | 95 | 83 | 74 | 67 | 61 | | | | | | | | | | | | | | |
| 26 | 213 | 160 | 126 | 104 | 89 | 77 | 68 | 61 | 56 | 51 | | | | | | | | | | | | | |
| 28 | 206 | 153 | 120 | 99 | 83 | 72 | 63 | 57 | 51 | 47 | 43 | | | | | | | | | | | | |
| 30 | 199 | 148 | 115 | 94 | 79 | 68 | 59 | 53 | 48 | 43 | 40 | 33 | | | | | | | | | | | |
| 35 | 188 | 137 | 106 | 85 | 71 | 60 | 52 | 46 | 41 | 37 | 33 | 27 | 23 | | | | | | | | | | |
| 40 | 179 | 129 | 99 | 79 | 65 | 54 | 47 | 41 | 36 | 32 | 29 | 23 | 19 | 16 | | | | | | | | | |
| 45 | 172 | 124 | 93 | 74 | 60 | 50 | 43 | 37 | 32 | 28 | 25 | 20 | 16 | 13 | 11 | | | | | | | | |
| 50 | 167 | 119 | 89 | 70 | 57 | 47 | 39 | 34 | 29 | 26 | 23 | 18 | 14 | 11 | 9 | 8 | | | | | | | |
| 55 | 162 | 115 | 86 | 67 | 54 | 44 | 37 | 32 | 27 | 24 | 21 | 16 | 12 | 10 | 8 | 7 | 5 | | | | | | |
| 60 | 159 | 112 | 83 | 64 | 51 | 42 | 35 | 30 | 25 | 22 | 19 | 14 | 11 | 9 | 7 | 5 | 4 | 4 | | | | | |
| 65 | 155 | 109 | 80 | 62 | 49 | 40 | 33 | 28 | 24 | 21 | 18 | 13 | 10 | 7 | 6 | 5 | 4 | 3 | 2 | | | | |
| 70 | 152 | 106 | 78 | 60 | 48 | 38 | 32 | 27 | 23 | 19 | 17 | 12 | 9 | 7 | 5 | 4 | 3 | 2 | 2 | 1 | | | |
| 75 | 150 | 104 | 76 | 58 | 46 | 37 | 30 | 25 | 21 | 18 | 16 | 11 | 8 | 6 | 4 | 3 | 2 | 2 | 1 | 1 | 1 | | |
| 80 | 147 | 102 | 74 | 57 | 45 | 36 | 29 | 24 | 20 | 17 | 15 | 10 | 7 | 5 | 4 | 3 | 2 | 1 | 1 | 1 | 0 | 0 | |
| 85 | 145 | 100 | 73 | 55 | 43 | 34 | 28 | 23 | 19 | 16 | 14 | 10 | 7 | 5 | 3 | 2 | 2 | 1 | 1 | 0 | 0 | 0 | 0 |
| 90 | 143 | 98 | 71 | 54 | 42 | 33 | 27 | 22 | 19 | 16 | 13 | 9 | 6 | 4 | 3 | 2 | 1 | 1 | 1 | 0 | 0 | 0 | 0 |
| 95 | 140 | 96 | 70 | 53 | 41 | 32 | 26 | 22 | 18 | 15 | 13 | 9 | 6 | 4 | 3 | 2 | 1 | 1 | 0 | 0 | 0 | 0 | |
| 100 | 138 | 95 | 68 | 51 | 40 | 31 | 25 | 21 | 17 | 14 | 12 | 8 | 6 | 4 | 3 | 2 | 1 | 1 | 0 | 0 | 0 | | |
| 105 | 136 | 93 | 67 | 50 | 39 | 30 | 25 | 20 | 17 | 14 | 12 | 8 | 5 | 4 | 2 | 2 | 1 | 1 | 0 | 0 | | | |
| 110 | 134 | 91 | 65 | 49 | 38 | 30 | 24 | 19 | 16 | 13 | 11 | 7 | 5 | 3 | 2 | 2 | 1 | 1 | 1 | | | | |
| 115 | 132 | 89 | 64 | 48 | 37 | 29 | 23 | 19 | 15 | 13 | 11 | 7 | 5 | 3 | 2 | 2 | 1 | 1 | | | | | |
| 120 | 129 | 88 | 62 | 46 | 36 | 28 | 22 | 18 | 15 | 12 | 10 | 7 | 5 | 3 | 2 | 2 | 1 | | | | | | |
| 125 | 127 | 86 | 61 | 45 | 35 | 27 | 22 | 18 | 14 | 12 | 10 | 7 | 5 | 4 | 3 | 2 | | | | | | | |
| 130 | 125 | 84 | 59 | 44 | 34 | 26 | 21 | 17 | 14 | 12 | 10 | 7 | 5 | 4 | 3 | | | | | | | | |
| 135 | 122 | 82 | 58 | 43 | 33 | 26 | 21 | 17 | 14 | 12 | 10 | 7 | 5 | 4 | | | | | | | | | |
| 140 | 119 | 80 | 56 | 42 | 32 | 25 | 20 | 17 | 14 | 12 | 10 | 8 | 6 | | | | | | | | | | |
| 145 | 116 | 77 | 55 | 41 | 32 | 25 | 21 | 17 | 15 | 13 | 11 | 9 | | | | | | | | | | | |
| 150 | 112 | 75 | 54 | 40 | 32 | 26 | 21 | 18 | 16 | 15 | 13 | | | | | | | | | | | | |
| 152 | 111 | 75 | 53 | 40 | 32 | 26 | 22 | 19 | 17 | 16 | | | | | | | | | | | | | |
| 154 | 110 | 74 | 53 | 41 | 33 | 27 | 23 | 21 | 19 | | | | | | | | | | | | | | |
| 156 | 108 | 74 | 54 | 42 | 34 | 28 | 25 | 22 | | | | | | | | | | | | | | | |
| 158 | 107 | 74 | 54 | 43 | 35 | 30 | 27 | | | | | | | | | | | | | | | | |
| 160 | 107 | 74 | 56 | 45 | 38 | 33 | | | | | | | | | | | | | | | | | |
| 162 | 107 | 76 | 59 | 48 | 42 | | | | | | | | | | | | | | | | | | |
| 164 | 109 | 79 | 63 | 54 | | | | | | | | | | | | | | | | | | | |
| 166 | 113 | 86 | 71 | | | | | | | | | | | | | | | | | | | | |
| 168 | 122 | 98 | | | | | | | | | | | | | | | | | | | | | |
| 170 | 143 | | | | | | | | | | | | | | | | | | | | | | |

## HOW TO USE THE TABLE.

To compare two alternative figures, either quadrilaterals or central point figures, for example, with each other in so far as the strength with which the length is carried is concerned, proceed as follows:

(*a*) For each figure take out the distance angles, to the nearest degree if possible, for the best and second best chains of triangles through the figure. These chains are to be selected at first by estimation, and the estimate is to be checked later by the results of comparison.

(*b*) For each triangle in each chain enter the table with the distance angles as the two arguments and take out the tabular value.

(*c*) For each chain, the best and second best, through each figure, take the sum of the tabular values.

(*d*) Multiply each sum by the factor $\frac{D-C}{D}$ for that figure. The quantity so obtained, namely, $\frac{D-C}{D}\Sigma[\delta_A^2+\delta_A\delta_B+\delta_B^2]$, will for convenience be called $R_1$ and $R_2$ for the best and second best chains, respectively.

(*e*) The strength of the figure is dependent mainly upon the strength of the best chain through it, hence the smaller $R_1$ the greater the strength of the figure. The second best chain contributes somewhat to the total strength, and the other weaker and progressively less independent chains contribute still smaller amounts. In deciding between figures they should be classed according to their best chains, unless said best chains are very nearly of equal strength and their second best chains differ greatly.

SOME VALUES OF THE QUANTITY $\frac{D-C}{D}$.

The starting line is supposed to be completely fixed.

For a single triangle, $\frac{4-1}{4}=0.75$.

For a completed quadrilateral, $\frac{10-4}{10}=0.60$.

For a quadrilateral with one station on the fixed line unoccupied, $\frac{8-2}{8}=0.75$.

For a quadrilateral with one station not on the fixed line unoccupied, $\frac{7-2}{7}=0.71$.

For a three-sided, central-point figure, $\frac{10-4}{10}=0.60$.

For a three-sided, central-point figure with one station on the fixed line unoccupied, $\frac{8-2}{8}=0.75$.

For a three-sided, central-point figure, with one station not on the fixed line unoccupied, $\frac{7-2}{7}=0.71$.

For a four-sided, central-point figure, $\frac{14-5}{14}=0.64$.

For a four-sided, central-point figure with one corner station on the fixed line unoccupied, $\frac{12-3}{12}=0.75$.

For a four-sided, central-point figure with one corner station not on the fixed line unoccupied, $\frac{11-3}{11}=0.73$.

For a four-sided, central-point figure with the central station not on the fixed line unoccupied, $\frac{10-2}{10}=0.80$.

For a four-sided, central-point figure with one diagonal also observed, $\frac{16-7}{16}=0.56$.

For a four-sided, central-point figure with the central station not on the fixed line unoccupied and one diagonal observed, $\frac{12-4}{12}=0.67$.

For a five-sided, central-point figure, $\frac{18-6}{18}=0.67$.

For a five-sided, central-point figure with a station on a fixed outside line unoccupied, $\frac{16-4}{16}=0.75$.

For a five-sided, central-point figure with an outside station not on the fixed line unoccupied, $\frac{15-4}{15}=0.73$.

For a five-sided, central-point figure with the central station not on the fixed line unoccupied, $\frac{13-2}{13}=0.85$.

For a six-sided, central-point figure, $\frac{22-7}{22}=0.68$.

For a six-sided, central-point figure with one outside station on the fixed line unoccupied, $\frac{20-5}{20}=0.75$.

For a six-sided, central-point figure with one outside station not on the fixed line unoccupied, $\frac{19-5}{19}=0.74$.

For a six-sided, central-point figure with the central station not on the fixed line unoccupied, $\frac{16-2}{16}=0.88$.

To illustrate the application of the preceding strength table the $R_1$ and $R_2$ for Figure 14, page 12, will be considered. Let it be assumed that the direction of progress is from the bottom line toward the top line. It will be found that the smallest $R$, called $R_1$, for this figure will be obtained by computing through the three best shaped triangles around the central point. The next best $R$, called $R_2$, will be obtained by computing through the two triangles formed by the diagonal. The $R_2$ is easily computed as follows: From the known side to the diagonal the distance angles are 89° and 27°. Using these angles as arguments in the preceding strength table, the factor 17.5 is obtained. Similarly, from the diagonal to the top line the distance angles are 91° and 26° and the corresponding factor is 18.8. The sum of the two factors is 36.3. If the central point of the figure is an occupied station, $\frac{D-C}{D}=0.56$ (see p. 6) and $R_2=36.3\times 0.56=20$. If the central point is unoccupied, as shown in Figure 14, $\frac{D-C}{D}=0.67$ (see above) and $R_2=36.3\times 0.67=24$, as given opposite the figure.

The $R_1$ may be computed in a similar manner by using the distance angles in the three best-shaped triangles around the central point.

## EXAMPLES OF VARIOUS TRIANGULATION FIGURES.

The following 14 figures are given to illustrate some of the principles involved in the selection of the strong figures and to illustrate the use of the preceding Strength Table.

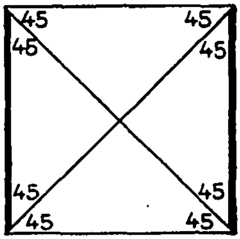



FIG. 1.—All stations occupied. $R_1=5$ $R_2=5$

Same, any one station not occupied. $R_1=6$ $R_2=6$

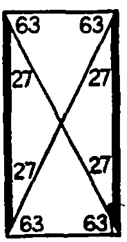



FIG. 2.—All stations occupied. $R_1=1$ $R_2=1$

Same, any one station not occupied. $R_1=2$ $R_2=2$

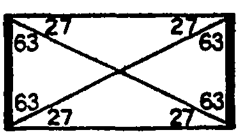



FIG. 3.—All stations occupied. $R_1=22$ $R_2=22$

Same, one station on fixed line not occupied $R_1=27$ $R_2=27$

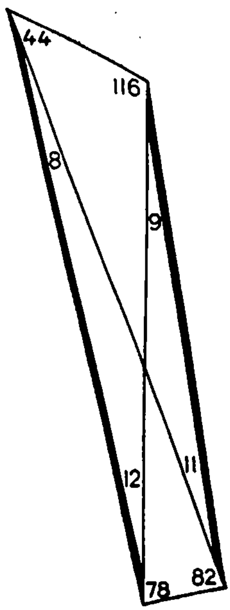



FIG. 4.—All stations occupied. $R_1 = 1$ $R_2 = 2$

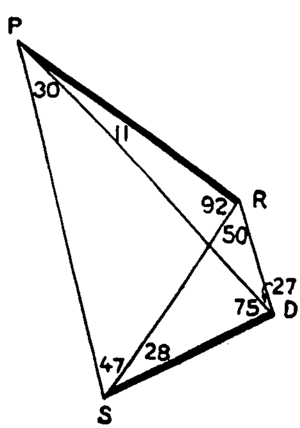



FIG. 5.—All stations occupied. $R_1 = 10$ $R_2 = 12$

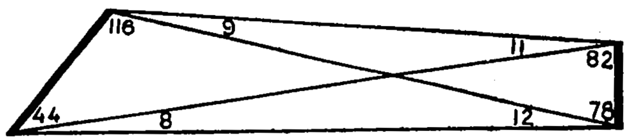



FIG. 6.—All stations occupied. $R_1=164$ (approx.) $R_2=176$ (approx.)

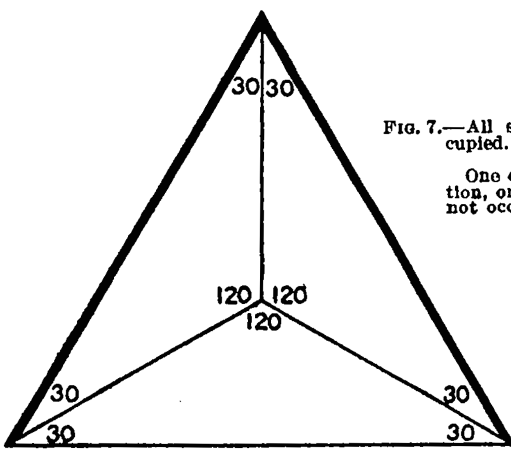



FIG. 7.—All stations occupied. $R_1= 2$ $R_2=12$

One outside station, on fixed line, not occupied. $R_1= 3$ $R_2=15$

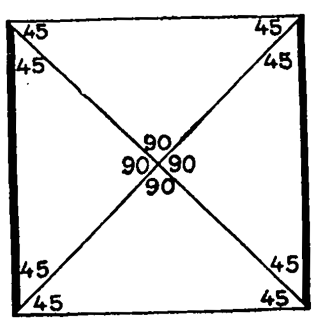



FIG. 8.—All stations occupied. $R_1=13$ $R_2=13$

Same, one corner station not occupied. $R_1=16$ $R_2=16$

Same, central station not occupied. $R_1=17$ $R_2=17$

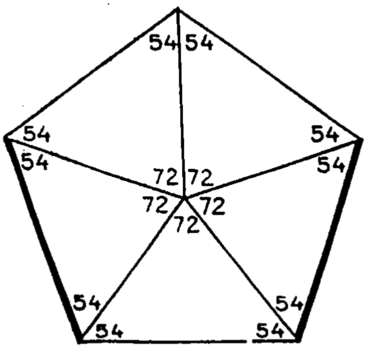



FIG. 9.—All stations occupied. $R_1=10$ $R_2=15$

Same, any one outside station not occupied. $R_1=11$ $R_2=16$

Same, central station not occupied. $R_1=13$ $R_2=19$

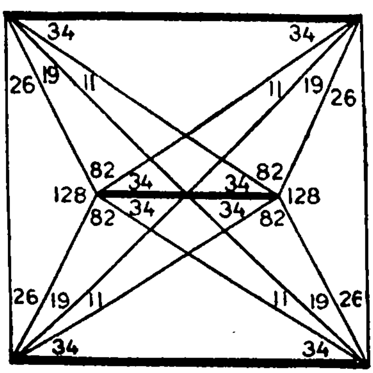



FIG. 10.—All stations occupied. $R_1=5$ $R_2=5$

$$\frac{D-C}{D}=\frac{28-16}{28}=0.43$$

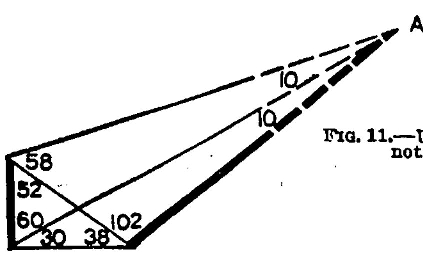



FIG. 11.—Unoccupied station not on fixed line. $R_1=36$ $R_2=102$

21198°—23——2

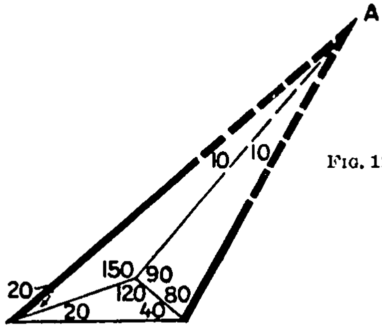



FIG. 12.—Unoccupied station at intersection of fixed line and line to be determined. $R_1 = 4$ $R_2 = 20$

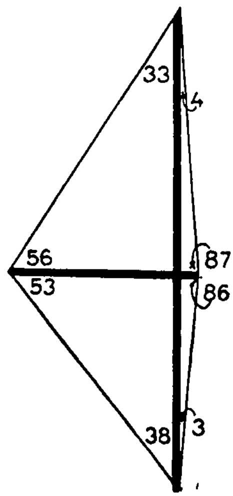



FIG. 13.—All stations occupied. $R_1 = 9$

(A strong and quick expansion figure.) $R_2 = 9$

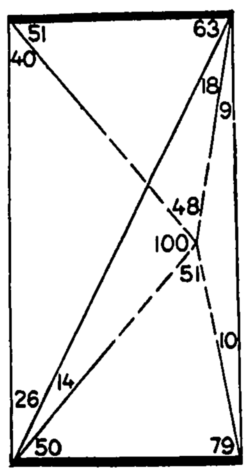



FIG. 14.—Central station not occupied. $R_1 = 18$ $R_2 = 24$

In every figure the line which is supposed to be fixed in length and the line of which the length is required are represented by heavy lines. Either of these two heavy lines may be considered to be the fixed line and the other the required line. Opposite each figure $R_1$ and $R_2$, as given by the Strength Table, are shown. The smaller the value of $R_1$ the greater the strength of the figure. $R_2$ need not be considered in comparing two figures unless the two values of $R_1$ are equal, or nearly so.

Compare Figures 1, 2, and 3. Figure 1 is a square quadrilateral; Figure 2 is a rectangular quadrilateral which is one-half as long in the direction of progress as it is wide; Figure 3 is a rectangular quadrilateral twice as long in the direction of progress as it is wide. The comparison of the values of $R_1$ in Figures 1 and 2 shows that shortening a rectangular quadrilateral in the direction of progress increases its strength. A comparison of Figures 1 and 3 shows that extending a rectangular quadrilateral in the direction of progress weakens it.

Figure 4, like Figure 2, is short in the direction of progress. Such short quadrilaterals are in general very strong, even though badly distorted from the rectangular shape, but they are not economical as progress with them is slow.

Figure 5 is badly distorted from a rectangular shape, but is still a moderately strong figure. The best pair of triangles for carrying the length through this figure are $D\ S\ R$ and $R\ S\ P$. As a rule, one diagonal of the quadrilateral is common to the two triangles forming the best pair, and the other diagonal is common to the second best pair. In the unusual case illustrated in Figure 5 a side line of the quadrilateral is common to the second best pair of triangles.

Figure 6 is an example of a quadrilateral so much elongated, and therefore so weak, that it is not allowable in any class of triangulation.

Figure 7 is the regular three-sided, central-point figure. It is extremely strong.

Figure 8 is the regular four-sided, central-point figure. It is very much weaker than Figure 1, the corresponding quadrilateral.

Figure 9 is the regular five-sided, central-point figure. Note that it is much weaker than any of the quadrilaterals shown in Figures 1, 2, or 4.

Figure 10 is a good example of a strong, quick expansion from a base. The expansion is in the ratio of 1 to 2.

Figures 11 and 12 are given as a suggestion of the manner in which, in secondary and tertiary triangulation, a point (A), difficult or impossible to occupy, may be used as a concluded point common to several figures.

Many of the figures given on the preceding pages are too weak to be used on precise triangulation, but for convenience of reference and to illustrate the principles involved they are included with the figures which it is permissible to use.

## SPECIFICATIONS FOR RECONNAISSANCE FOR PRIMARY AND SECONDARY TRIANGULATION.

The reconnaissance specifications for precise triangulation given above apply also in principle to primary and secondary triangulation. The chief difference lies in the limiting values of $R$. On both primary and secondary triangulation $R_1$ and $R_2$ in any one figure must never exceed 40 and 120, respectively, in units of the sixth place of logarithms, and should be kept down to 25 and 80 for a single figure whenever the estimated total cost is not increased by more than 25 per cent. One station in each figure may be left unoccupied whenever to do so does not increase the values of $R$ beyond the specified limits.

In any class of triangulation a number of stations of somewhat inferior accuracy are always determined, in addition to the main scheme, for local use in connection with detailed surveys. These are called supplemental stations and may be either occupied or intersection stations, provided there is a check on the determination.

The value of $R$ should not be greater than 50 for any triangle used in connecting a supplemental station to the main scheme unless the triangle is used as an identification check only upon the position of the point.

**Frequency of bases on primary and secondary triangulation.**—If the character of the country is such that a base site can be found near any desired location, $\Sigma R_1$ between base lines, or between a base line and a line of precise or primary triangulation used as a base, should be made about 130. This will be found to correspond to a chain of from 10 to 35 triangles, according to the strength of the figures secured. With strong figures but few base lines will be needed, and a corresponding saving will be made on this part of the work. If topographic conditions make it difficult to secure a base site at the desired location, $\Sigma R_1$ may be allowed to approach but not exceed 200. There will be danger when this larger limit is used that an intervening base will be necessary, for the reason stated in the next sentence. If in any case the discrepancy between adjacent bases (either measured bases or lines of precise or primary triangulation used as bases) is found to exceed 1 part in 10,000 for primary or 1 part in 5,000 for secondary an intervening base must be measured or the intervening triangulation strengthened.

Certain general principles can be applied to reconnaissance, but skill in selecting a scheme which will give the greatest strength compatible with economy and the configuration of the country can only be acquired by experience and a close study of the various figures permitted by the geometric conditions to be met. These figures are shown on pages 8-12 and are fully explained in the text relating to strength of figures.

## INTERVISIBILITY OF STATIONS.

Reconnaissance for triangulation can be executed by either of two general methods, or by a combination of them. In the first method, which can be used in hilly or mountainous country, the intervisibility of the stations is tested by visiting each station. In the second method, reliance is placed upon obtaining the elevations of the stations and of the intervening country from maps or other sources and determining the intervisibility of points and the heights of towers from those data. This method is necessary in flat country. In actual practice a combination of the two methods is generally used.

Before going to the field copies of Government, commercial, and road maps should be procured, as well as all available data relating to previous surveys in or near the area to be covered by the reconnaissance. A careful examination of the maps and other data will indicate the most practical route, and a provisional scheme may be plotted on one of the maps to be used as the work sheet. This will serve as a useful guide as the detailed work is carried forward.

In testing this tentative scheme too much reliance must not be placed upon the accuracy of maps if the visibility of a line of sight is questionable. If the intervisibility of two stations can not be tested visually because of flat or wooded country, then maps must be resorted to. In testing a line the elevations of the two stations, and of any probable intervening obstructions, should be obtained from the map, and the intervisibility of the two stations should be tested by computing the effect of the curvature of the earth and the refraction or bending of a ray of light in passing through the atmosphere. Two or three solutions of problems will be given later. (See p. 20.)

The difference between the apparent and true difference in elevation of two points is affected by two factors—the curvature of the earth's surface and the refraction of light by the earth's atmosphere. These factors are of opposite sign and of an approximately fixed relation to each other, so that the combined effect can be applied as a single factor. The effect of refraction is about one-seventh as much as the curvature. The formulas for the separate effect of each can be found in various works on geodetic surveying, but the formulas below give the approximate resultant:

$$h \text{ (in feet)} = K^2 \text{ (in miles) times } 0.574,$$

or

$$K \text{ (in miles)} = \sqrt{h \text{ (in feet)}} \text{ times } 1.32.$$

Below is a table, condensed from the one given in Appendix 9, Report for 1882, which gives the distance $K$ (in statute miles) at which a line from the height $h$ (in feet) will touch the horizon, taking into account terrestrial refraction with a mean assumed coefficient of 0.070.

*Correction for earth's curvature and refraction.*

| Distance. | Correction. | Distance. | Correction. | Distance. | Correction. | Distance. | Correction. |
|---|---|---|---|---|---|---|---|
| *Miles.* | *Feet.* | *Miles.* | *Feet.* | *Miles.* | *Feet.* | *Miles.* | *Feet.* |
| 1 | 0.6 | 16 | 146.9 | 31 | 551.4 | 46 | 1214.2 |
| 2 | 2.3 | 17 | 165.8 | 32 | 587.6 | 47 | 1267.7 |
| 3 | 5.2 | 18 | 185.9 | 33 | 624.9 | 48 | 1322.1 |
| 4 | 9.2 | 19 | 207.2 | 34 | 663.3 | 49 | 1377.7 |
| 5 | 14.4 | 20 | 229.5 | 35 | 703.0 | 50 | 1434.6 |
| 6 | 20.6 | 21 | 253.1 | 36 | 743.7 | 51 | 1492.5 |
| 7 | 28.1 | 22 | 277.7 | 37 | 785.6 | 52 | 1551.6 |
| 8 | 36.7 | 23 | 303.6 | 38 | 828.6 | 53 | 1611.9 |
| 9 | 46.4 | 24 | 330.5 | 39 | 872.8 | 54 | 1673.3 |
| 10 | 57.4 | 25 | 358.6 | 40 | 918.1 | 55 | 1735.8 |
| 11 | 69.4 | 26 | 388.0 | 41 | 964.7 | 56 | 1799.6 |
| 12 | 82.7 | 27 | 418.3 | 42 | 1012.2 | 57 | 1864.4 |
| 13 | 97.0 | 28 | 449.9 | 43 | 1061.0 | 58 | 1930.4 |
| 14 | 112.5 | 29 | 482.6 | 44 | 1111.0 | 59 | 1997.5 |
| 15 | 129.1 | 30 | 516.4 | 45 | 1162.0 | 60 | 2065.8 |

To determine how much the line of sight between two stations will clear or fail to clear an intervening hill, either the table above may be used or the following formula employed:

$$h = h_1 + (h_2 - h_1)\frac{d_1}{d_1 + d_2} - 0.5736 d_1 d_2,$$

where

$h$ = height of line at obstruction,
$h_1$ = height of lower station,
$h_2$ = height of higher station,
$d_1$ = distance from lower station to intervening obstruction,
$d_2$ = distance from intervening obstruction to higher station.

This formula is also based on a mean assumed coefficient of refraction of 0.070.

## DISCUSSION OF RECONNAISSANCE METHODS.

Prior to the years 1898–1900 reconnaissance for precise triangulation was a very expensive operation. The best method was considered to be that of an approximate secondary triangulation. Horizontal and vertical angles were observed starting from some known base and assumed elevation, and either a rough computation of triangle sides was made or the approximate distances were scaled from a sketch. This was kept up as the work progressed. From the observations of vertical angles elevations were computed to decide the height necessary to build at the main scheme stations to see over intervening ridges and also to ascertain the location of the crest of each ridge. It was therefore necessary to introduce many supplemental points within the area of the main scheme and to erect poles with flags or targets at many of the points. While this method involved time, labor, and expense, and the progress was exceedingly slow, it was by no means accurate. The conditions under which the observations for horizontal and vertical angles were made introduced large errors, which resulted in many obstructed lines and added much to the cost of the final field operations. Under this method the average cost of reconnaissance for precise triangulation was about $40 per mile of progress.

The present method of reconnaissance for precise triangulation, with some modifications, has been in use since 1898. During that period more than 8,000 miles of reconnaissance has been executed in all parts of the United States and under all conditions. The corresponding triangulation has been practically completed, and it has been found that the reconnaissance has satisfied all requirements for which it is intended. The average cost during the last two decades has been about $3.90 per mile of progress.

Briefly, the present method consists in first obtaining a general knowledge of the country by a close study of all available maps. A provisional scheme can then be mapped out and revised later by an examination on the ground. No horizontal or vertical angles are observed. Instead, magnetic bearings are taken to prominent objects, to locate them approximately, and to assist in distinguishing them from similar objects in that vicinity.

In the actual examination of the country and selection of the points for the scheme the object is to make a mental topographic survey of the regions over which the projects extend. A careful study of the maps will indicate the general lay of the country, the direction of drainage, the approximate location of the highest points, and the route which apparently offers the least resistance. In the actual examination of a region it is only necessary to consider the topographic features that may come within range of the work in hand, such as the crests of the highest ridges, hills, and peaks, which may serve as observation points in laying out the scheme.

When visiting one of these commanding points, the first step is to locate its approximate position on the map or sketch. This can be done by plotting the point with reference to adjacent topographic features and can be checked by magnetic compass bearings on any objects shown on the map, such as water tanks, church spires, prominent hills, peaks, or mountains. The next step is to study closely with the aid of binoculars the prominent objects that may come within the area of the scheme for the purpose of fixing them in the memory and estimating their appearance from other directions. The positions of objects observed may be closely determined by magnetic compass bearings and by estimating the distances. These should be recorded for each object observed, as should also the designation of the object, such as "flat top hill," "sharp peak," "clump of trees on ridge," etc. Any distinctive features of the objects observed which will assist in identifying them when seen from other points should be kept in mind. To the experienced eye every hill, ridge, peak, and mountain will present some distinctive feature which distinguishes it from all others. Each point observed should be plotted on the work sheet or map in the position fixed by the bearings and estimated distances. This will assist in identifying it when seen from other places as the work progresses, and its position can then be checked and corrected if necessary. Bearings and distances should be observed at all selected points of the main scheme and at a sufficient number of intermediate points to identify all prominent features and to fix them well in mind.

When traveling across the country between objective points, it is important to note the prominent features of the region and also the apparent differences in elevation of ridges, hills, and peaks. As the points are viewed from different positions, the general locations and relative elevations of the most prominent points become fixed in mind. It should be remembered that only the higher places are utilized for triangulation, and in any locality these are comparatively few in number. The observer should, therefore, focus his attention on the prominent objects which must be considered in the selection of the scheme. This may be illustrated by comparison with a large city having thousands of buildings of various heights and kinds. There are only a few of these buildings that tower above all others near by. The lower buildings are not suitable for stations, and so it is only necessary to examine closely the few most prominent buildings and note their distinctive features, general locations, and relative elevations. When this has been done from several different directions, the characteristics of each become firmly fixed in mind.

It requires experience and careful study of natural features to estimate distances closely. Atmospheric conditions must be considered, as the object observed will appear differently in sunlight than when shaded by clouds. Usually some distant hills or ridges may be seen to which the distances are known, and these may be used for comparison in estimating the distances to other points by noting the various color effects. Where the air is clear, the difference in color is the only guide in estimating the distance to far mountains. With a little experience, distances can be estimated with an error of not more than 15 per cent.

Since precise triangulation is laid out in different forms and under different topographic conditions, the observer should consider carefully the methods to be pursued and the objects to be attained. Trained powers of observation and a habit, natural or acquired, of self-orientation—by which is meant the faculty of knowing at any point visited for the first time just where to look for other points requisite to the work in hand—will best help the observer to secure a full knowledge of the country and will suggest the best method of laying out the work.

## SELECTING SITES FOR TRIANGULATION STATIONS.

Triangulation stations, as far as practicable, should be placed on the crests of ridges and on the highest points of hills and mountains. In a mountainous country it is not necessary to place the stations on the highest peaks, but each one should be on the highest point of the peak selected, and this peak should be the highest one in the immediate vicinity in order that there may be an unobstructed view in all directions.

In making a choice between a high peak and a lower one many factors must be taken into account, part of which relate to the cost of the immediate project in hand and others to the usefulness of the triangulation itself. The elements which affect the cost of the reconnaissance and triangulation will be considered first.

The cost of the reconnaissance per mile of progress measured along the axis of the scheme of triangulation will be practically the same in any region where two schemes are possible, whether a large or a small scheme is used, and whether the points selected are on the highest peaks or on lower ones. The use of the highest points usually results in large figures in the scheme of triangulation, though not necessarily so. It is usually easier to secure strong figures when the highest peaks are used as main scheme points.

Where weather conditions are not more than ordinarily unfavorable, the rate of progress and the cost of the observing will be the same whether the average line is 10 or 50 miles in length. It is only when weather conditions are unfavorable that a disparity in cost per mile of progress becomes noticeable, as the observing may then become greatly retarded over long lines, although on the smaller scheme it would proceed at almost the normal rate.

Delays to the observing party in reaching the high peaks must also be considered, for two-thirds of the cost of the observing is due to salaries which go on whether progress is being made or not. Transportation of both reconnaissance and observing parties is now almost exclusively by motor truck. Years ago, when wagon teams were used, pack animals were at hand to pack the instruments, camp equipage, and food of the observing party to the tops of the high peaks, but with the absence of pack animals from the party and the growing dearth of them throughout the western part of the

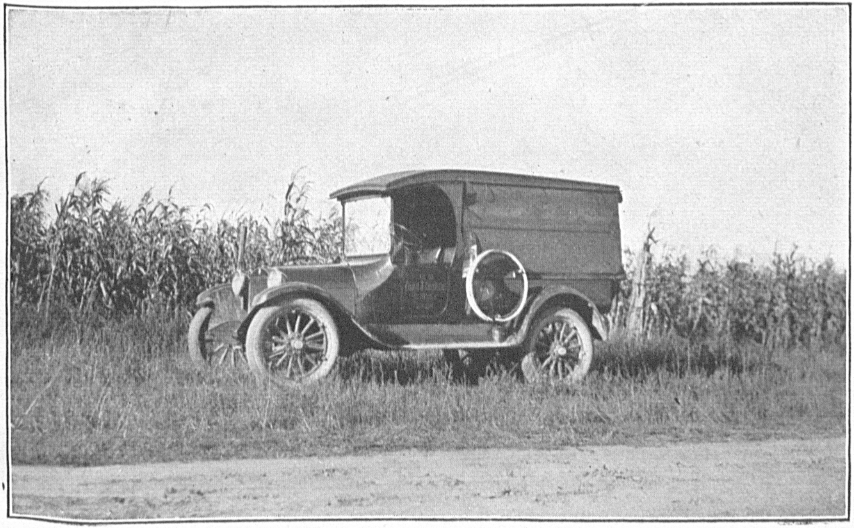


FIG. 15.—MOTOR TRUCK USED FOR GEODETIC WORK.

country this method of transporting the outfit means expensive delays. If trucks can be driven within 2 or 3 miles of a station, the observing party can back pack the instruments and observing outfit to the station, return each night to a camp at the trucks to sleep, and back pack the outfit down the night they finish. This limit of 2 to 3 miles should be given due consideration in selecting stations, though it can be extended to 4 or 5 miles in case of necessity.

Another disadvantage attending the use of the large triangulation figures and stations difficult of access is the lack of supervision of the observer over the light keepers. With inexperienced men, or men of poor quality, this makes rapid progress difficult.

The cost factor, however, is not the only one to be considered. The usefulness of precise triangulation, aside from its function of extending geodetic control over the country, depends upon the easy accessibility of the stations and their distribution over the area covered, and also upon the lines being sufficiently short for engineers and surveyors to extend local triangulation from them without using special instruments and methods.

In a large scheme the principal stations, located on the highest peaks, are favorably placed to extend the triangulation in any direction. The disadvantage of the large scheme is that the great distances between stations make it almost impossible to locate extra points by intersection, and light keepers must be used at the supplemental stations.

In a smaller scheme, where the distances between stations average not more than 25 miles, many intersection points can be located without posting lights, and the distances between stations will be small enough that the distances and azimuths as well as the positions can be used readily by engineers for their detailed surveys. The stations are also apt to be on the lower peaks, and, therefore, more accessible. Where it is necessary to place a supplemental station on a high peak, this can usually be done by observing on it from three stations without the necessity of the observing party occupying it.

Another thing to be considered in the reconnaissance is the degree of certainty as to the intervisibility of stations. To specify that there must be absolute certainty in that respect would make the reconnaissance unduly costly. A better plan is to compare the cost of thoroughly testing each line of the reconnaissance with the additional cost of the observing and building when an occasional obstructed line is found and it becomes necessary for the observing party to increase the heights of the signals at the ends of the line or else select a new station, shift the light keeper, and perhaps build a new signal.

The purpose of the preceding discussion is to summarize the various factors governing the selection of stations. It is not practicable to lay down rigid rules, but the success of the one doing reconnaissance will be measured by his ability to balance these various opposing elements and select the most desirable scheme.

One other factor which should be carefully considered in the choice of a site for a triangulation station is the permanence of the mark. Precise triangulation stations are seldom established for immediate use, but rather to furnish precise control for future surveys. Topographic features may change with increase of population and with industrial development, and new maps will be wanted and surveys for improvements needed. Both may be quickly and readily supplied if the precise triangulation stations, or a large part of them, can be recovered. The importance of selecting a place for the station where the mark will be least exposed to disturbance is evident.

## COMPUTATION OF THE INTERVISIBILITY OF STATIONS.

Triangulation must be executed under widely varying conditions which involve a large range of difficult problems, depending largely upon the character of the country it traverses. It will be sufficient to discuss briefly the effect upon triangulation reconnaissance of five classes of terrain, viz: Water surfaces, such as bays or lakes; open country nearly level, as prairie; comparatively level farming country, partly wooded; hilly wooded country with parallel ridges of nearly

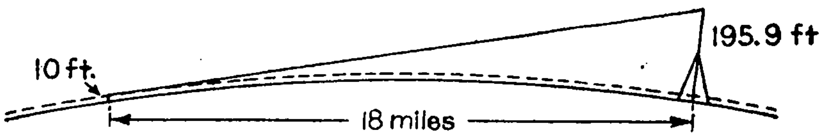



FIG. 16.—Intervisibility of stations across water, case 1.

the same elevation; and, lastly, hilly or mountainous country with elevations of irregular height. These are taken up below in the order named.

**Water surfaces.**—The length of line which may be observed across a body of water depends upon the elevation of the land on each side or the height of signal which it is feasible to build in overcoming curvature and refraction. Experience has shown that the accuracy of angle measurements is much affected if the line of sight across water approaches the surface nearer than 10 feet. There is apt to be a disturbed stratum of air near the surface which will cause lateral refraction. Besides, the air just above the surface is very difficult to see through.

Where the distance between two stations is approximately known, and also their respective elevations above the water surface which


FIG. 17.—Intervisibility of stations across water, case 2.

lies between them, the question of their intervisibility may be quickly solved by reference to the table on page 15, "Correction for earth's curvature and refraction." The following example illustrates the application of the table:

**Example.**—Two stations are at the water's level on opposite shores of a bay 18 miles wide. The line of sight in no case should approach the water nearer than 10 feet.

(*a*) How high above the water must the instrument be at station *A* with the instrument at station *B* 10 feet above the surface?

(*b*) How high must the towers be, supposing them to be of equal height at the two stations?

*Solution of* (*a*).—From the table for refraction and curvature, page 15, the instrument must be at an elevation of 185.9 feet for the line of sight, to be tangent to the earth's surface at a distance of 18 miles. Since it must not approach the water surface nearer than 10 feet at station *B*, the instrument at *A* must be 195.9 feet above the water surface. (See fig. 16.)

*Solution of* (*b*).—Since the towers are to be of equal height, the line of sight will approach the water the nearest at a point midway between the two stations. From the table the instrument must be elevated 46.4 feet to see the water surface 9 miles distant. Since the line of sight must clear the surface by 10 feet, the instrument must be elevated 56.4 feet at each station. (See fig. 17.) Or, by the formula

$$h \text{ (in feet)} = K^2 \text{ (in miles)} \times 0.574,$$
$$h = 81 \times 0.574 = 46.49 \text{ feet},$$
$$46.49 + 10 = 56.49 \text{ feet}.$$

**Open, level country.**—In open prairie country, nearly level, where no artificial objects interfere, the triangulation may be laid out with reference to that height of signal which may be the most economical to build. In a country of this character tripod and scaffold signals of from 50 to 75 feet in height, with superstructures where necessary, will be found the most economical and will be sufficient for quadrilaterals of an average length of side of 12 to 15 miles. In prairie country the surface is seldom a flat level plane, but instead has ridges resembling the waves on the ocean. The crest of the higher ridges may be from 1 to 5 miles apart, with many intervening smaller ridges. If a map is available, the drainage system shown on it will generally indicate the approximate location of the crest of the highest ridge in each locality. These highest ridges will usually be found to be of nearly the same general elevation or at least on the same general slope. Which of the high points should be selected for the stations will depend largely upon the ease with which trucks may be driven to them.

**Rolling cultivated region.**—In a comparatively level and partly wooded farming country, where there are numerous buildings and groves of trees, the methods employed in the selection of points will be similar to those used on an open level prairie, except that it is more difficult to detect by observation the highest ridges, and it is necessary that the line of sight avoid buildings or clumps of tall trees on the high ridges. At each proposed station bearings should be taken to all such obstructions near the lines of sight and precautions taken to avoid them whenever practicable. As it is usually necessary to have the stations rather close together in a partially wooded country, it is comparatively easy to detect possible obstructions on the line if proper care is taken.

Since it is not advisable to elevate the instrument more than 65 or 70 feet above the ground because of the wind effect upon its supporting tripod, the tall superstructure can be used economically where the country is partly wooded.

**Wooded, rolling country.**—This kind of terrain presents the hardest problems to one doing reconnaissance. Part of northern Alabama is a region of this type, with rough heavily wooded ridges and poor roads. When such a region is not mapped, the reconnaissance can be executed by following the trend of the drainage and slopes of the ridges until some high ridge is reached. Thick underbrush will frequently make it difficult to find the highest point in even a limited area, but recourse can be had to climbing trees in order to secure the desired lookout.

The closest attention must be paid to the features under observation, for at first glance a wooded, rolling country will appear to have no distinctive features. It is necessary to learn the "lay of the land" so thoroughly that routes can be planned to examine the most prominent points. The area of the country over which the scheme extends should be completely covered and examined, so the observer may have all hills, ridges, and other prominent objects well fixed in mind.

High superstructure can be resorted to for elevating the line of sight above intervening ridges, as stated in the preceding case. At all points selected for the main scheme special attention should be given to possible forward lines; bearings should be observed on all low gaps on intervening ridges as well as on the high points. Distant points seen through low gaps in intervening ridges should be carefully studied, so they may be identified later. Every prominent point will present some special feature by which it may be identified, such as a prominent tree. Two trees identical in appearance are rarely found, and usually a tree can be distinguished from all others by some distinctive feature. Therefore, it is not necessary to erect poles with targets for the purpose of identifying points if the proper time and mental effort is spent in memorizing the prominent features.

In any character of country the pole and target method for the purpose of identifying points is harmful to the observer, as it has a tendency to destroy the faculty of identifying such natural features

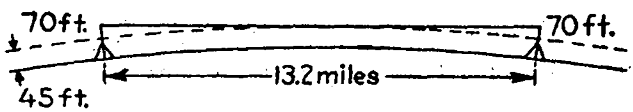



FIG. 18.—Intervisibility of stations across wooded plain, case 1.

as are essential, and without this faculty no person should attempt to do reconnaissance.

So far as applying the table or the formula for curvature and refraction is concerned, the last three preceding types of terrain may be considered together. The following example will serve to illustrate the method of application:

**Example.**—A level plain is wooded with trees 35 feet high. It is desirable that the line of sight clear the trees by 10 feet at least.

(*a*) With towers 70 feet high, without superstructure—that is, with lamp and theodolite mounted at same height—what is the maximum length of line?

(*b*) Under the same conditions of terrain, what is the maximum length of line when the theodolite is at a height of 70 feet and the lamp at a height of 90 feet above the ground?

*Solution of* (*a*).—Since the line of sight must not approach nearer than 45 feet to the surface of the plain or 10 feet above the tree tops, and the towers are 70 feet high, the problem is the same as if the towers were 70–45 feet high and the line of sight could be tangent to the surface of a level plain. From the table it is seen that the line of sight from a tower 25 feet high would be tangent to the surface of the sphere at a distance between 6 and 7 miles.

Applying the formula

$$h \text{ (in feet)} = K^2 \text{ (in miles)} \times 0.574$$

$$K^2 = \frac{25}{0.574}$$

or

$$K = 6.6 \text{ miles.}$$

The stations could, therefore, be 13.2 miles apart. (See fig. 18.)

*Solution of (b).*—From the previous example the line of sight from a tower 70 feet high is tangent to the spherical surface 45 feet above the station at a distance of 6.6 miles. The distance at which the line of sight from the 90-foot tower will be tangent to the 45-foot surface is found from the formula in a similar manner, as follows:

$$(90-45)=h=K^2\times 0.574$$

$$K^2=\frac{45}{0.574}$$

or

$$K=8.9 \text{ miles.}$$

Therefore, the maximum distance between stations would be 6.6+8.9=15.5 miles. (See fig. 19.)

**Hilly or mountainous country.**—Over a hilly or mountainous country the reconnaissance is less difficult. It is seldom necessary to build high observing towers to elevate the instrument, and it is only necessary to select prominent intervisible points that satisfy the requirment of a strong scheme which will give proper control over the area covered.

In this form of reconnaissance it is important to keep a very careful watch on the different aspects presented by the principal elevations as seen from different places when traveling through the region covered by the triangulation in order that the same point may be

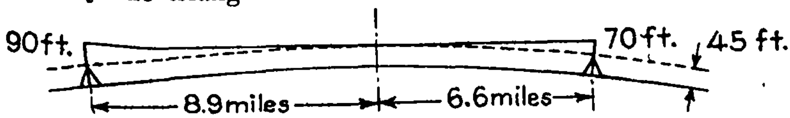



FIG. 19.—Intervisibility of stations across wooded plain, case 2.

identified from different directions. This general examination will help in acquiring a habit of self-orientation, by which on reaching a mountain or summit the eye will at once recognize and correctly locate salient features of the landscape.

A country of this character should be well scrutinized and bearings taken to all prominent points. It often happens that a scheme may be carried forward several figures before it is discovered that an alternate line of stations must be selected, beginning at some critical line to the rear. Therefore, if a thorough reconnaissance has been made, the revision may be made without going over the ground the second time. It is practicable and sometimes preferable in a mountainous country to extend one side of the scheme several hundred miles, then on the return fill in stations on the other side. This method has been adopted where there are roads approximately parallel to each side of the scheme but very few crossroads, as was the case on the El Reno, Okla., Needles, Calif., project, between Albuquerque, N. Mex., and Needles, Calif., a distance of 400 miles. The north side of the scheme was completed from Albuquerque to Needles, and on the return trip points were selected to the southward to complete the scheme.

Another notable case where this method was used is the Texas-California arc from the one hundred and fourth meridian to the Pacific coast. This case is more remarkable, due to the fact that the reconnaissance was made by two observers working independently and on opposite sides of the scheme. The work was done in three sections. The first section extended from near the one hundred and fourth meridian to El Paso, Tex., a distance of 170 miles; the second section from El Paso to Tucson, Ariz., 240 miles; and the third section from Tucson to a connection with the Pacific coast triangulation, 360 miles. Before starting each section a general program was mapped out and the scheme, if practicable, was to be kept within a certain limited area. Starting from the one hundred and fourth meridian, one observer selected points on the north side of the scheme and the other observer on the south side. There

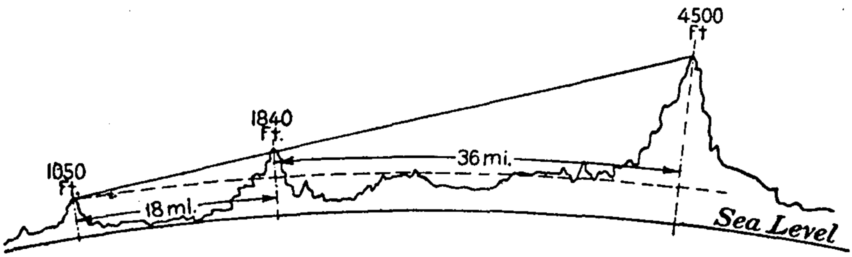



FIG. 20.—Intervisibility of stations in mountain country.

was no communication between the two observers until each had completed his work to El Paso. There they met and compared notes and decided on the most practicable points.

The second and third sections were carried on in like manner. There was no communication between the two parties during the progress of the work except at El Paso, Tucson, and Yuma, after the work on the corresponding section was completed in each case. On the 770 miles of progress it was not found necessary to go back and revise any part of the work, and when observations for horizontal directions were made there was not an obstructed line found

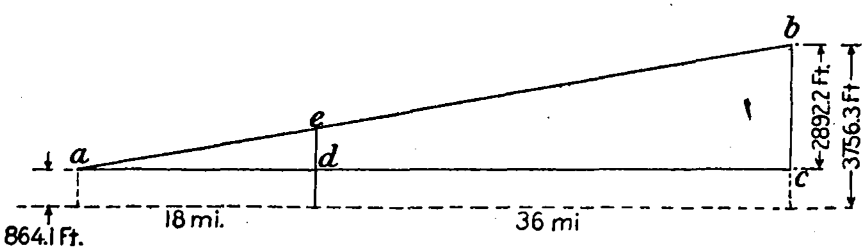



FIG. 21.—Intervisibility of stations in mountain country, solution 1.

on the scheme due to the reconnaissance. This reconnaissance was made by William Bowie and the writer.

When maps of a hilly or mountainous country are available, they are of great assistance in reconnaissance. When laying out a scheme from a map the most frequent problem is to determine if a certain ridge or mountain between two stations will cut the line of sight, and if so, if it will be practicable to build at either station and thus make the stations intervisible. Such a problem may be solved either by the formula on page 16 or by the table for curvature and refraction. A solution of such a problem by each method is given below.

**Example.**—Two stations, A and B, are 54 miles apart and at an elevation above sea level of 1,050 and 4,500 feet, respectively. At $X$ on the line between $A$ and $B$ and at a distance of 18 miles from $A$ is a ridge 1,840 feet high. (See fig. 20.)

(*a*) How much below the crest of the ridge does the line between stations strike?

(*b*) Supposing a tower is to be built at only one station, what height would be necessary at each station for the line of sight to barely clear the ridge?

(c) If towers of equal height are to be built at the two stations, what height must they have for the line of sight to barely clear the ridge?

*Solution of* (*a*). (See fig. 21).—At 18 miles, curvature and refraction=185.9 feet. At 36 miles, curvature and refraction=743.7 feet.

For the purpose of obtaining the difference in elevation at $X$ between the crest of the ridge and the straight line from station A to station B, we can consider $A$ and $B$ as being reduced in height by 185.9 feet and 743.7 feet, respectively, those amounts being the correction for curvature and refraction from $A$ and $B$ to $X$. The three points $A$, $B$, and $X$ can now be considered to be on a plane surface but with elevations corrected for curvature and refraction.

Let $h_A$, $h_X$ and $h_B$ be the revised elevations of the straight line from $A$ to $B$ at $A$, $X$, and $B$, respectively.

Given $h_A=1,050-185.9=864.1$ feet, $h_B=4,500-743.7=3,756.3$ feet. To find $h_X$:

In the triangle $a\ b\ c$, Figure 21,

$$cd : bc :: ad : ac,$$
$$cd=h_X-h_A,$$
$$bc=h_B-h_A,$$

or

$$h_X-h_A : h_B-h_A :: ad : ac,$$
$$h_X-864.1 : 3,756.3-864.1 :: 18 : 54,$$
$$3\ h_X=5,484.5,$$
$$h_X=1,828.$$

Therefore, the line from $A$ to $B$ cuts the ridge 12 feet below its crest.

Another method for obtaining the elevation at $X$ of the straight line between the two stations is by the formula given on page 16,

$$h=h_1+(h_2-h_1)\frac{d_1}{d_1+d_2}-0.5736\ d_1\ d_2.$$

In which for the example given above

$$h_1=1,050,\ h_2=4,500,\ d_1=18,\ d_2=36.$$

Substituting these values

$$h=1,050+(4,500-1,050)\frac{18}{18+36}-0.5736\times18\times36=1,828.$$

Therefore, the line between $A$ and $B$ is 12 feet below the top of the ridge.

There may be times in the field when the observer will not have a book at hand from which to obtain the formula for the second method and he may not be able to recall the formula. He may use the first method, however, if he merely remembers that the correction in feet for curvature and refraction is the square of the distance in miles times 0.574. The second method may be a little easier as regards the numerical operations.

*Solution of* (*b*).—Accepting 1,828 feet as the elevation at $X$ of the line from $A$ to $B$, the line strikes 12 feet below the crest of the ridge. If the station at $A$ is to be elevated the necessary height can be computed by means of a triangle, as shown in Figure 22. The line from $A$ to $B$ has already been corrected for curvature and refraction.

Let $AA'$ be the height by which $A$ is to be increased. From similar triangles,

$$AA' : XX' :: AB : XB,$$

or

$$AA' : 12 :: 54 : 36.$$

Therefore,

$$AA'=18 \text{ feet.}$$

If the station at $B$ is to be elevated a similar method may be used as shown in Figure 23.

$$BB' : 12' :: 54 : 18.$$

Therefore, $BB' = 36$ feet.

These two solutions show that, other things being equal, it is always more economical to build at the station nearest the obstruction, for the height necessary to clear the obstruction increases in direct proportion to the distance from it.

*Solution of* (c).—Since the line from $A$ to $B$ has been corrected for curvature and refraction in obtaining the difference of 12 feet between the line and the crest of the

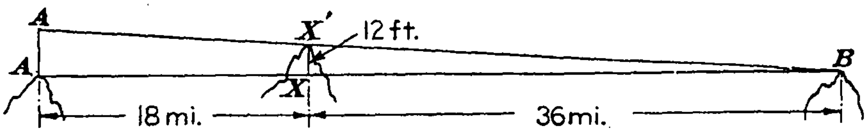



FIG. 22.—Intervisibility of stations in mountain country, solution 2.

ridge at $X$, it is evident that if both $A$ and $B$ are elevated 12 feet the line between them will just graze the crest of the ridge.

## GRAPHICAL METHOD.

The correction for curvature and refraction can also be applied graphically and the intervisibility of two points determined with an accuracy often equal to that of the elevations used for the points to be investigated, provided the vertical scale of the graph is properly proportioned to the scale of the distance between the points. On a scale suitable for the length of lines of the reconnaissance scheme plot a curve whose coordinates are the distance in miles and the

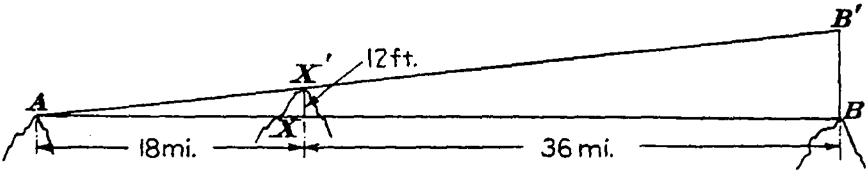



FIG. 23.—Intervisibility of stations in mountain country, solution 3.

corresponding correction for curvature and refraction. Curves of this kind are shown in Figures 24 and 25.

The application of this graphical method is illustrated by the following example: Two hills on opposite sides of a bay are 50 miles apart. One of them is 350 feet above the bay. How high must the other be to be barely visible from the first?

Plot a point $b$ 350 feet above the curve at $B$. Draw a straight line through $b$ tangent to the curve. Plot a point $a$ on this line 50 miles from point $b$ and scale the vertical distance, $a\ A$, to the curve. It is desirable that the point $B$ should be taken at such a point on the curve that the line tangent to the curve will be nearly horizontal. If considerable accuracy is desired, the formula or table on page 15 should be used. By the formula $a$ should be 367.4 feet above $A$. The elevation scaled from the curve agrees closely with this computed value.

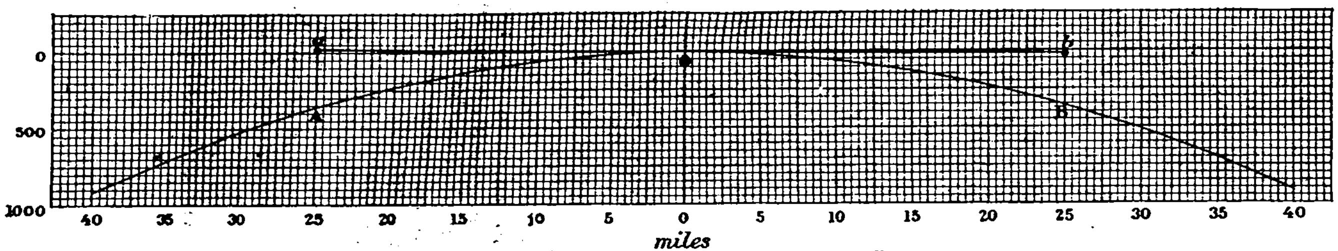



FIG. 24.—Intervisibility of stations, graphical solution for long lines

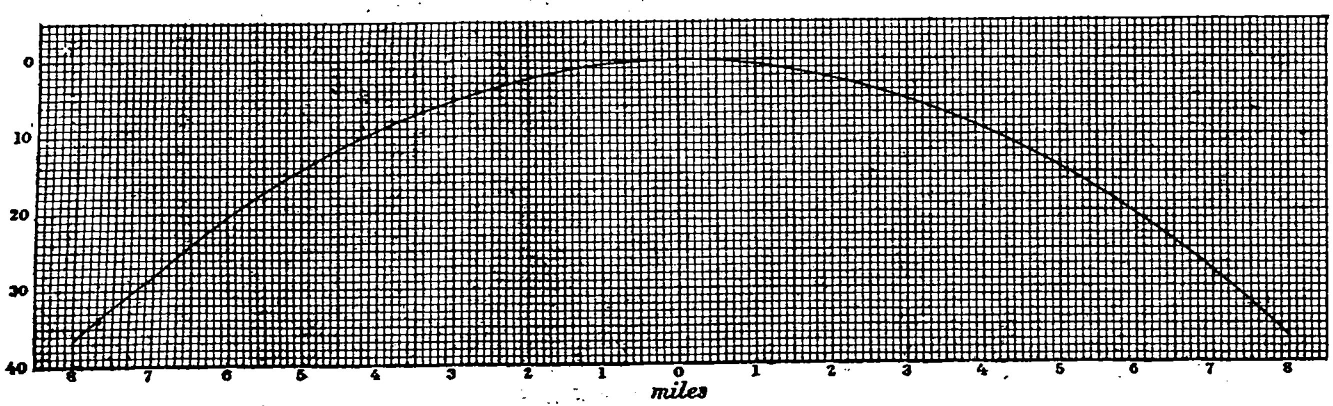



FIG. 25.—Intervisibility of stations, graphical solution for short lines

21198°—23——3

## SELECTION OF BASE SITES.

The measurement of a base is an operation requiring much less time and money than formerly and can be made over fairly rough ground. While the slope of the 50-meter tape should not exceed 10 per cent, steeper slopes can be measured if necessary by taking special precautions and at the expense of some extra time. Topographic conditions may make it necessary sometimes to go outside the main scheme one or two figures to find a suitable site. This should be avoided if possible, for it is the $\Sigma R_1$ which governs the frequency of bases, and additional figures in the base net will increase the $\Sigma R_1$ and shorten the distance between bases.

Time and money can often be saved by measuring a base along a railroad tangent, using the rail as a support for the tape as in precise traverse. The base may be measured on one or more tangents provided the two ends of the base are intervisible. Also, the base may be measured partly on the railroad and partly on stakes on the prolongation of the tangent.

In measuring a base along a railroad three things should be kept in mind. First, if a broken base is used the strength of the computed line joining the end stations will decrease in proportion to the extent the base departs from a straight line; that is, a base with a slight bend at the middle station is much stronger than one broken at an angle approaching 90°. Second, if both ends of the base are along a tangent of the railroad extreme care must be taken to project the length measured along the rail onto the line between stations. This requires that the stations be as near as possible to the rail and that special precautions be taken in measuring the projection angles if a high tower is used.

The third factor to be considered is the effect of the friction between the tape and the rail upon the length indicated by the tape. The tape is standardized supported throughout, but under very favorable conditions. It is known that moisture on the rail will cause the tape to adhere to the rail to such a degree that the tension is not transmitted through the tape. It is probable that on a dry, smooth, highly polished rail a measure can be made of sufficient precision, but that if the rail is rough, rusty, or oily the resulting measured length will be affected by an appreciable amount. Two precise bases have been measured by the U. S. Coast and Geodetic Survey partly on railroad rails. One of these bases seems to be satisfactory, but the measured length of the other is too long, a result to be expected if there were an unusual amount of adhesion of the tape to the rail.

## RECONNAISSANCE DESCRIPTIONS OF STATIONS.

The reconnaissance descriptions should be typewritten on paper without watermark and of medium thickness, with the carbon faced to the back of the paper in order that they may be blue-printed directly for use by the observing party.

These descriptions should furnish all information which will be of value to the building and observing parties. Each station must be so clearly described that it can be easily and definitely identified, and special attention must be given to finding and describing the best approach to the station. The height of tower and kind of station mark needed must be stated in the description in order that the building party may know what materials will be necessary. Sample reconnaissance descriptions of a station and of a base line follow:

**Alma** (J. S. Bilby, 1913).—In Hill County, Mont., about 30 miles north of Joplin, a town on the Great Northern Railroad, 9 miles northeast of Alma post office, 3 miles south of the Canadian boundary, in the northwest corner of section 20, township 37 north, range 8 east. The station is on a small knoll about 200 meters southeast of the northwest corner of section 20, and is marked with a barrel partly filled with rock and with rock piled around the outside of it, forming a cairn. The section corner referred to above is marked with an iron pipe bearing a cap, on which the number of the section, township, and range is stamped. The station can be reached by wagon from any direction over good roads. To reach the station from Joplin, go due north 23 miles to Sage Creek, then bear northeast about 1 mile and follow the road leading to the coal mine on Canada Coulee. The station is 1¼ miles east of this road. The station is reached from Chester by way of Alma, then east 2 miles to the Joplin Road. Joplin, the nearest railroad town, has lumber and supplies. Alma is the nearest post office and has a small store. A stand for the instrument and a station mark are required. Station mark as described in notes 1 and 7.[a]

**Artesia base line.**—(E. H. Pagenhart, 1916).—In Chaves and Eddy Counties, N. Mex., approximately 4 miles west of the railroad between the towns of Artesia and Lake Arthur. The line extends from triangulation station Artesia to triangulation station Arthur, two stations of the main scheme, a distance of 11 miles, 176° magnetic in direction. The entire distance is across flat or gently rolling prairie with a maximum grade at either end of not more than 5 per cent. The base line crosses the Eddy-Chaves county line road a short distance west of Dunwalter's place. Wagon crossing over Walnut Creek, a rocky dry run, is found on the line, and at Cottonwood Creek there is a shallow ford 200 meters below the line and near Mat Green's place. There are no cultivated fields, and vehicles may be driven along the line by lowering 10 three or four wire fences. No clearing is necessary. Wagon road follows within one-half mile of line. Convenient middle-of-line camp at Mat Green's place on Cottonwood Creek, about 1 mile northwest from the lower Cottonwood schoolhouse. Base ends are intervisible. Mail, express, telegraph, lumber, and supplies at Artesia.

## PROGRESS SKETCH AND REPORT.

The stations are plotted on a progress sketch as the work progresses. Usually this sketch is made on the best map available for the area covered. When the field work is completed, a smooth tracing of this sketch, including only the essential details, is made and submitted with the season's report.

In the reconnaissance report information and suggestions should be given to assist the parties that follow with the building and observing. The descriptions of stations are intended to cover the immediate locality of each station, but the report should give also a descriptive outline of the entire region over which the scheme of triangulation extends. Suggestions may also be made as to the organization and transportation of the building and observing parties. The report should contain information in regard to the possibility of the roads at different seasons of the year, prevalence of forest fires, and weather conditions. The report should invariably give a statement of progress and costs covering the items tabulated below.

[a] This means there is deep soil at the station, and concrete posts, with subsurface mark, will be needed.

*Statement of progress and costs.*

| | |
|---|---|
| Length of main scheme of reconnaissance in statute miles | |
| Area in square statute miles | |
| Number of new points selected | |
| Number of stations prepared and marked | |
| Number of months engaged on work | |
| Total cost of work[3] | |
| Cost per mile of progress | |
| Cost per square mile | |
| Cost per point selected | |

*Truck transportation costs.*

| | |
|---|---|
| (a) Depreciation | $ |
| (b) Repairs | |
| (c) Gasoline, oil, and grease | |
| (d) Tires | |
| Total | |
| Total miles run by truck | |
| Cost per mile | |

## ORGANIZATION AND OUTFIT OF PARTY.

The progress and cost of reconnaissance depend very largely on the means of transportation. In nearly all parts of the United States the motor truck is the most rapid, economical, and satisfactory means of travel for the reconnaissance party. The type of half-ton commercial delivery truck (shown in fig. 15) has been used extensively and is best adapted for reconnaissance.

In some sections of the country the officer in charge of the work should be assisted by one man. The outfit should consist of one 9 by 9 foot center-pole tent, a cot and bed roll for each person, a small cooking outfit, and the following tools: 1 ax, 1 hatchet, 1 handsaw, 1 claw hammer, 1 pair wire pliers, and the usual kit of tools for the truck. The instruments needed are binoculars, draw telescope, azimuth compasses, half-circle protractor, and set of drawing instruments.

## PRECISE TRAVERSE.

Precise traverse is done in those sections of the country where the topographic conditions make precise triangulation unduly expensive. The condition which makes it desirable to carry on precise traverse in preference to precise triangulation is flatness of the land combined with the presence of timber. When precise triangulation is carried on under this condition, the lines are necessarily short and high scaffold signals are required to make the stations intervisible. In some regions of the country the topographic conditions make it desirable to extend precise triangulation over certain portions and precise traverse over others.

As an illustration, the arc of horizontal control between Huntsville, Ala., and the ninety-eighth meridian by way of Memphis, Tenn., and Little Rock, Ark., may be cited. On this arc precise triangulation was extended from Huntsville to Memphis, precise traverse from

[3] To include transportation to and from field, salaries for time spent in office preparing for field and making out reports and to cover accrued leave, and storage on outfit until next season.

Memphis to Little Rock, and precise triangulation from Little Rock to the ninety-eighth meridian in Oklahoma.

The region between Memphis and Little Rock is traversed by a railroad. It is flat swamp land, heavily timbered, and with very few roads. These conditions are very unfavorable for triangulation. In a country of this character the cost per mile of progress for precise traverse is less than one-half the cost of triangulation.

Since the stations when traverse is used are along a railroad track where they are readily available for control of local surveys, they are of greater value for future use than triangulation stations which are necessarily located in places very difficult of access. The two principal factors to be considered in choosing between triangulation and traverse are the total cost of each class of work and the value of the work for control of local surveys. It is not desirable to change from precise triangulation to traverse for only short sections, even though the cost of triangulation for those sections may be considerably greater. Where the cost is about the same, triangulation should always be chosen, since there are better checks on the accuracy of triangulation than of traverse.

## LOCATION OF TRAVERSE STATIONS.

In general, traverse will be run along a railroad track. The stations should preferably be at the intersection of contiguous tangents of the railroad. If a tangent is particularly long and the profile of the road makes it difficult to get a clear line between the ends of the tangent, one or more intermediate stations should be placed at the side of the road. The profile of the road will be the deciding factor in the location of these intermediate stations, but where the ground is practically level the stations should be located near a crossroad if convenient. The stations along a tangent should never be more than 4 or 5 miles apart, as delays caused by observing longer lines will more than offset the time gained by having fewer observations, and the stations will have greater value for public and private surveys if placed fairly close together.

A station should be placed near each railroad crossing or point where a branch line makes off from the line followed by the traverse. A station should also be located at or very near each town along the route of traverse, and when at all practicable a second station should be located within 2 miles of the town in order to make an azimuth available for local engineers and surveyors.

Where curves are numerous and the tangents very short, it will be well to lay out comparatively long lines extending over several curves in order that the azimuth may be carried forward with greater strength than if it had to be carried through a number of short lines. The distance between the ends of such long lines can be computed from the measured distances and angles observed at supplementary stations along the track. Care must be taken that each end of such a long line is carefully tied into the scheme running along the railroad between its ends.

Other specifications governing the selection of traverse stations are given in U. S. Coast and Geodetic Survey Special Publication No. 58, Instructions for Precise and Secondary Traverse.

## MARKS FOR HORIZONTAL CONTROL STATIONS.

The essential parts of the specifications for station and reference marks now in use are given below:

**Metal tablets.**—Each station which has been located with precise, primary, or secondary accuracy, as defined in U. S. Coast and Geodetic Survey Circular No. 30, should be marked by a standard tablet of copper alloy, so fastened in the rock or concrete as to effectively resist extraction, change of elevation, or rotation. (See fig. 26.) The name of the station and the year established should be stamped upon the mark, preferably before it is set in the rock or concrete.

**Setting of tablets.**—Stations for horizontal control must often be located where the permanent marking of them is difficult, and for that reason a great variety of settings for the tablets must be permitted. The location of the station, depth of soil, or presence of rock ledges, and the availability of materials will usually control the choice of the mark to be used. The precautions to be taken in establishing each kind of mark are briefly stated below.

(1) *In rock outcrop.*—Care should be taken that the rock in which a mark is set is hard and is part of the main ledge, not a detached fragment. The tablet should be countersunk and well cemented in.

(2) *In bowlders.*—When a tablet is set in a bowlder, the latter should be of durable material and of cross section, area, and depth below the surface not less than the standard concrete mark as described below.

(3) *In rock ledges below surface.*—When the ledge is only slightly below the surface, a tablet set in the usual manner in the ledge will be sufficient, provided two reference marks are established. Where the ledge is so far below the surface that a surface mark is required, a tablet or copper bolt should be set in the ledge, the ledge carefully brushed or washed off for a space at least 18 inches in diameter, and a concrete surface mark placed above the subsurface mark. A tablet should be set in the surface mark directly over the subsurface tablet or bolt. If the rock ledge in which the subsurface mark is set is very smooth, it should be furrowed with a chisel to afford better anchorage for the concrete.

(4) *In concrete.*—(*a*) *Shape.*—The mark should be either a frustum of a cone or a pyramid or have the form of a post with an enlarged base. If of pyramidal form, the sides should have a batter of at least 1 inch to 1 foot. When a post with an enlarged base is used, the base should be 4 inches larger in least horizontal dimension than the post proper and have a vertical thickness of at least 6 inches. If the concrete is cast in place, the enlarged base can easily be provided for by enlarging the bottom of the hole at the sides with the digger. Extreme care should be used to avoid making the mark with a mushroom top or with projecting corners near the surface which would provide leverage points for frost action and would make easier the malicious destruction of the mark.

(*b*) *Size and depth.*—The concrete post should extend to a depth of from 30 to 36 inches, depending upon the kind of soil. It should be not less than 14 inches in diameter, except that the upper 12 inches may be in the shape of a frustum of a cone or pyramid with the upper surface not less than 12 inches in diameter. Where the mark is not in the path of traffic or in soil subject to cultivation, it should

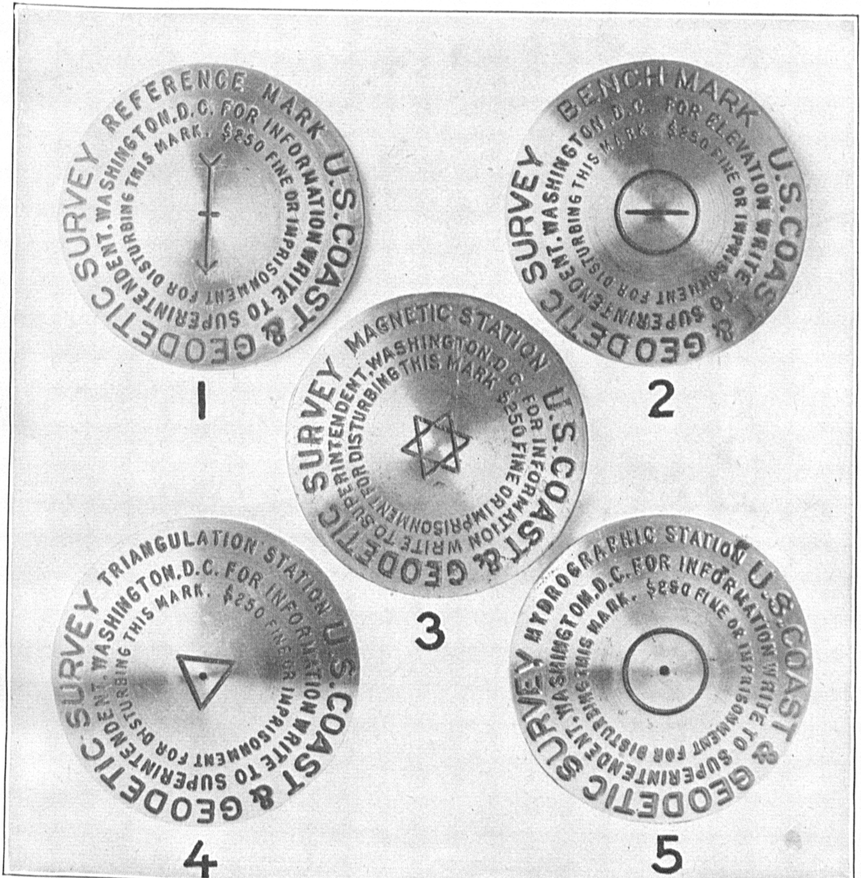



FIG. 26.—STANDARD MARKS OF THE U. S. COAST AND GEODETIC SURVEY.

1. Reference mark.
2. Bench mark.
3. Magnetic station mark.
4. Triangulation station mark.
5. Hydrographic station mark.

extend from 2 to 4 inches above the surface. When located where traffic passes over it, the top of the mark should be slightly below the surface.

The procedure in making the standard concrete mark is as follows: A hole is dug to a depth of 3½ feet or more. It should be 16 inches in diameter for the top 2½ feet, and 10 inches in diameter at the lower end. Concrete made of good cement, sand, and gravel or broken rock is placed in the lower part of the hole to a depth of 6 inches. A standard tablet station mark (fig. 16) is then set in the concrete, with the top of the tablet slightly depressed. This completes the underground mark. A layer of from 4 to 6 inches of sand or dirt is then put into the hole. The hole is then enlarged about 2 inches in radius near the bottom in order that the lower end of the block of concrete for the surface mark will be mushroomed, and then the hole is filled with concrete to within 9 inches of the surface of the ground. Next a mold or frame 12 inches on a side at the top, 13 inches at the bottom, and 12 inches in depth is set in the hole on top of the concrete and filled in around the outside with dirt tamped firmly. The frame is then filled with concrete level with its top and a standard tablet station mark (fig. 16) is set in the center of the concrete, with the top of the tablet slightly depressed. The tablet must be centered exactly over the underground mark. The top of the concrete should be smoothed with a trowel and the frame should be left in place to protect the concrete until it becomes firmly set.

Care must be taken not to distrub the position of the tablet in the underground mark when placing the layer of sand or dirt and when pouring the concrete for the surface mark. A piece of thin board should be placed over the lower mark or other suitable means used to insure against any horizontal movement of the tablet due to the impact or pressure of the material above.

## SPECIAL CONDITIONS.

Under certain conditions special marks will often be required, and these should conform in size and durability to the marks described above.

(1) **Sand.**—In sand, which if used as a mold would spoil the concrete by absorbing the water from it, sewer tiles 8 inches in diameter and 30 inches long may be used, set with the bell end down, filled with concrete and with the base end set in concrete. A sheet-iron mold of the same dimensions filled with concrete may also be used. A metal tablet should be set in the center of the top.

(2) **Marsh.**—Where the surface of the ground is too soft to hold a mark of the usual type, a post of durable wood should be forced down vertically as far as it will go, its top cut off flush with the surface, and a sewer tile at least 6 inches in diameter set into the marsh around the top of the post. The tile should then be filled with concrete and a tablet set in the top. Where the marsh is very soft but dries out at certain seasons of the year, successive tiles can be forced down around the post, the post then can be withdrawn and the mud worked out from within the tiles, and the tiles then filled with a hydraulic cement mixture.

(3) **Land subject to cultivation.**—The subsurface or lower mark should be a tablet in a block of concrete 12 inches square or 12 inches

in diameter and 4 inches thick, set with its top 3 feet below the surface. The upper mark should be a tablet set in a block of concrete 15 inches in least horizontal cross-section dimension and 20 inches thick, with its top 12 inches below the surface of the ground. About 3 inches of dirt should be placed between the concrete blocks bearing the upper and lower marks.

All stations so marked should be referenced by two standard reference marks placed on property boundary lines, preferably along a well-established highway or quarter-section line in a location where there is little likelihood of their being disturbed. The directions to the reference marks should be such as to give a good angle of intersection at the station. The reference marks may be as much as a half mile from the station, if necessary, provided they can be seen from the station. The distance to each reference mark should be carefully measured. Other distances, such as those to the center of a highway, the corner of a building, or the center of a well, should be measured if feasible. Two or more such measurements will intersect so near the station that the concrete block will be easily found with a small prodding rod. When measurements are made to buildings or other objects, the directions must also be given. If measurements of this kind are made, the station may usually be easily recovered though the reference marks may both be destroyed. The measurements to a road should always be to the center of the road and not to the fence line. All distances must be carefully measured and not estimated. Care should be taken in placing reference marks along highways, for nearly all States are widening the highways.

## REFERENCE MARKS.

Each reference mark should consist of a metal tablet similar in material and shape to the station mark but bearing an arrow which points to the station. A reference mark should be stamped with the same designation as its station mark, and where there is more than one reference mark they should be numbered serially in a clockwise direction, the number to be stamped upon each one. Each should be set under the same conditions as specified for the station mark, except that the concrete post in which it is set may be 2 inches smaller in diameter and 6 inches shorter than for the station mark.

Each station mark must have at least one reference mark and should preferably have two. If the station mark, due to surface conditions, is entirely beneath the surface, there should be two reference marks, unless there are permanent witness marks, such as road crossings, etc., which will serve to locate the station without an excessive amount of digging. If the station mark is on ground liable to be disturbed or washed away, two reference marks should invariably be established. These should be so located as to avoid the probability of both being disturbed by the same cause. They should also preferably be so located as to give a good angle of intersection at the station, or else be placed in range with the station.

**Material.**—The main considerations in making concrete are to have clean materials, mix them well before adding water, have the mixture not too wet, and tamp well into the form. Each streak of dirt in concrete means a line of cleavage. Where rough aggregate is available, the proportions may very well vary from 1–2–4 to 1–3–5, but the top 12 inches of the mark should be of considerably richer mixture. Where only cement and sand are available, the lower part of the mark should be proportioned 1 part of cement to 3 parts of sand and the upper part should be 1 part of cement to 2 parts of sand. With a mark of the proper size it will not be necessary to reinforce the concrete with metal rods or wire. To avoid cracking of the concrete, due to rapid drying, it should be covered with paper or cloth and then with earth or other material for a period of at least 48 hours.

### TRAVERSE STATIONS.

The size and character of the mark at traverse stations should be the same as for triangulation stations, except that certain stations may be left without permanent marks when several are close together. The following rules will apply to the distribution of permanent marks on precise traverse.

In general, there should be a permanently marked station at least every 3 miles along the traverse, except when a section of traverse along a tangent is more than 3 miles in length. A traverse station should always be permanently marked if either of the lines leading from it is a mile or more in length. When a station is marked in a permanent manner, one of the adjacent stations must be permanently marked in order that a line of known length and direction may be recoverable. Traverse stations which are not marked permanently should be marked by a stake of some durable wood in order that it may be recoverable for at least a few years.

Special care must be used in selecting sites for reference marks on traverse to insure that they will not be subject to the same hazard as the station mark. Two reference marks should always be established, preferably on opposite sides of the railroad track and near the fence lines at the edges of the right of way. Whenever a horizontal control mark is to serve also as a bench mark it should correspond in depth below the surface to the requirements for bench marks.

### COURTESY TO PROPERTY OWNERS AND OTHERS.

The reconnaissance party is the advance agent for the other parties. Stations must be established on public property and on property owned by individuals and corporations, and it will be necessary in the process of the work to enter on property to investigate lines, make observations, and select points for the scheme. The rights of property owners should be respected, and any controversy that may cause future trouble should be avoided. It must be remembered that the reconnaissance is only preliminary to the work that follows, and it may be necessary for successive parties to enter upon the same property. Therefore, the good will and cooperation of property owners or their agents are very essential, and if this is obtained by the reconnaissance party it will have a lasting effect and will smooth the way for the parties that follow.

# PART II—SIGNAL BUILDING.

## GENERAL DIRECTIONS.

In many regions it is not possible to select stations for a scheme of triangulation and have all the stations intervisible from the ground. In such regions signal towers must be built over the station marks to elevate the observer, light keeper, and instruments. Plans and specifications for various types of signals and illustrations showing the operations of construction are given in the following pages. For each type of signal the working drawing shows one side of the signal, with dimensions of timbers used. It is not always practicable to get timber of the specified dimensions at the local lumberyards. In such cases other dimensions must be substituted and the necessary sizes built up by spiking together two or more timbers. This will prevent loss of time, and the signal will be sufficiently rigid for all purposes. The great majority of tall signals built in recent years have had the legs built up by spiking together 2 by 6 inch or 2 by 4 inch timbers.

A triangulation signal is a combination of two independent structures, one having three legs and called the inner tower or tripod and the other having four legs and called the outer tower or scaffold. These two towers must not touch or be fastened together at any point. The service required of a signal when used by two observing parties working at different stations in the same figure is, briefly, that the outer tower must support the observer and the tent which protects him and his instrument from the sun and wind and must, at the same time and without interference with the observer or his work, support a light keeper and the lamp or heliotrope. The inner tower must support the instrument with such stability that, except in a strong wind, its motion in azimuth will never be so rapid or so irregular as to affect seriously the accuracy of the measurement of angles, and that its disturbance in level will never be so rapid or so great as to inconvenience the observer by making frequent adjustments necessary. It is not practicable to build the tripod so rigid that observations can be made in a high wind, but its vibration due to light or moderate winds must not be so great as to interfere seriously with accurate pointing. Signals must be strong enough to stand without injury in all ordinary winds and in most storms. It is not good economy to build them so heavy and strong as to withstand the most violent storms.

## CONSTRUCTION OF 60-FOOT SIGNAL.

A completed signal 60 feet high to the instrument is shown in Figure 27. The various steps in the process of framing and erecting such a signal are given in the following general directions in approximate order of time, it being understood that two or more processes may sometimes be carried on simultaneously.

### FRAMING THE TRIPOD.

The first step is the framing of the tripod legs and of one side of the tripod with all the material lying on the ground. In Figure 28 it is assumed that timbers of the dimensions specified are to be used and

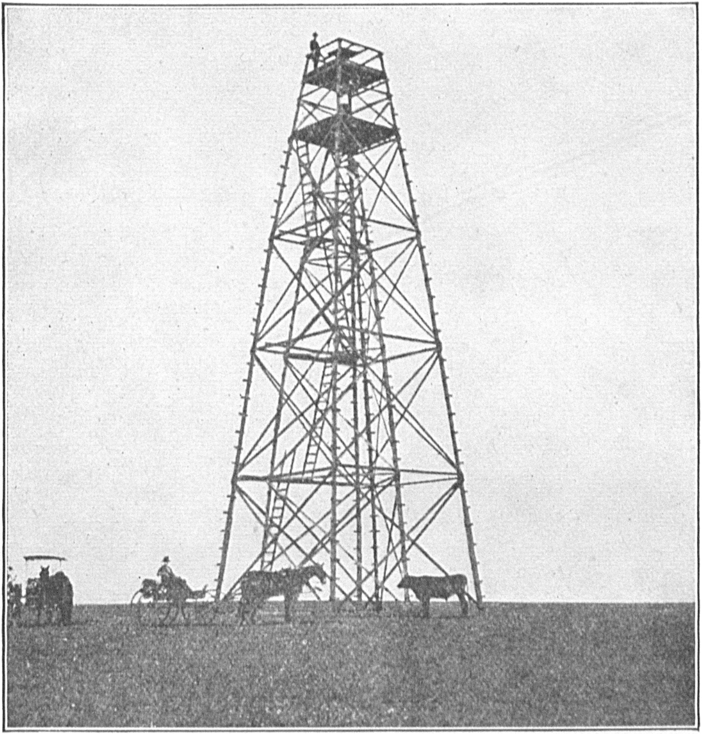


FIG. 27.—COMPLETED 60-FOOT SIGNAL.

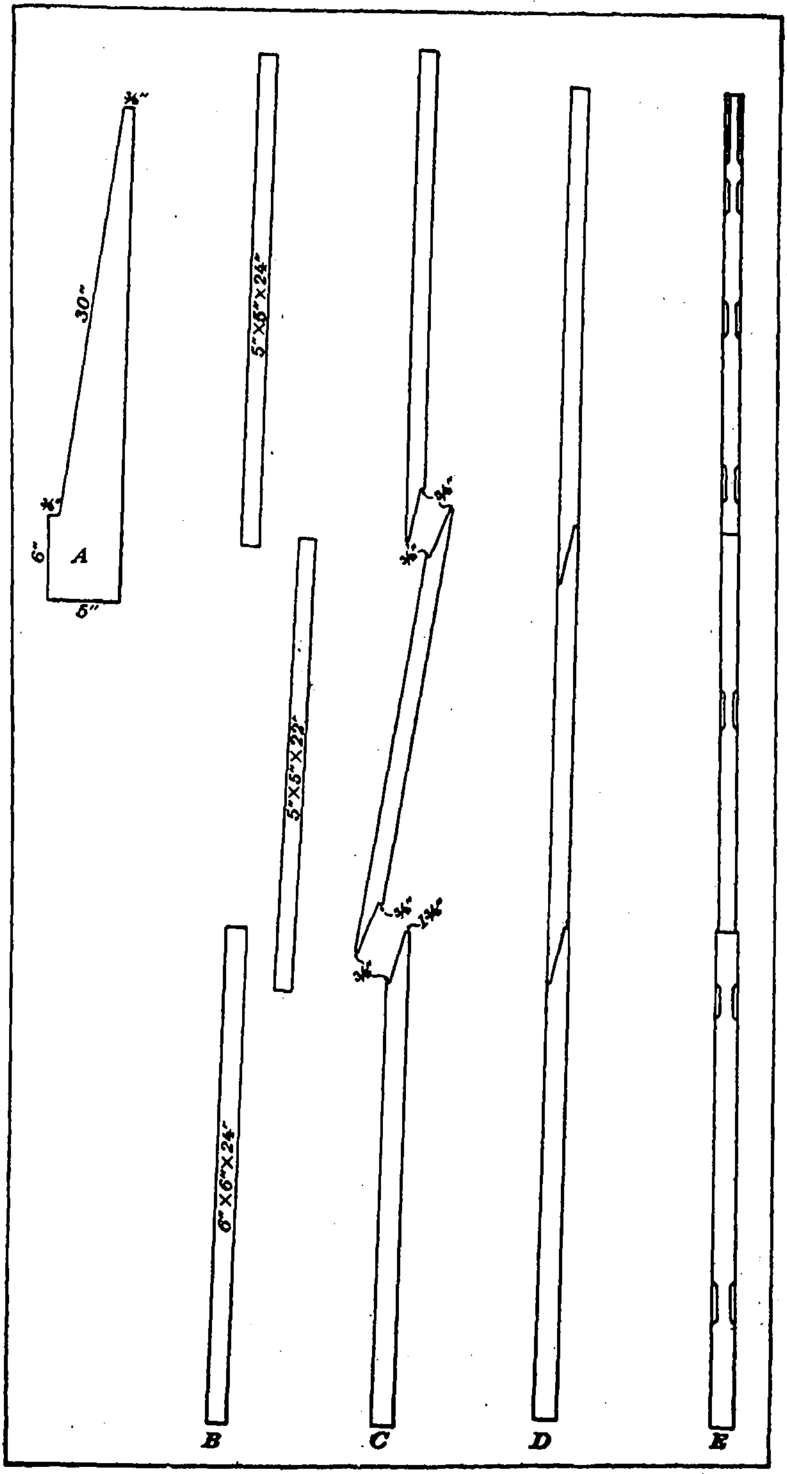



FIG. 28.—Scarf pattern and framed legs of signal.

that they are not to be built up by splicing. *A* is a pattern used in making the scarfs, *B* shows the positions in which the timbers are laid before the work of framing begins, *C* shows the scarfs cut, *D* shows the parts of one leg nailed together, and *E* shows the leg chamfered ready for framing. All scarfs are nailed together except

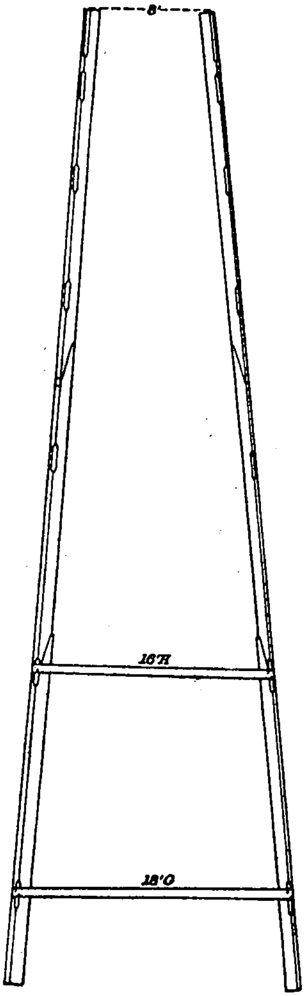



FIG. 29.—Side of tripod for 60-foot signal partly framed.

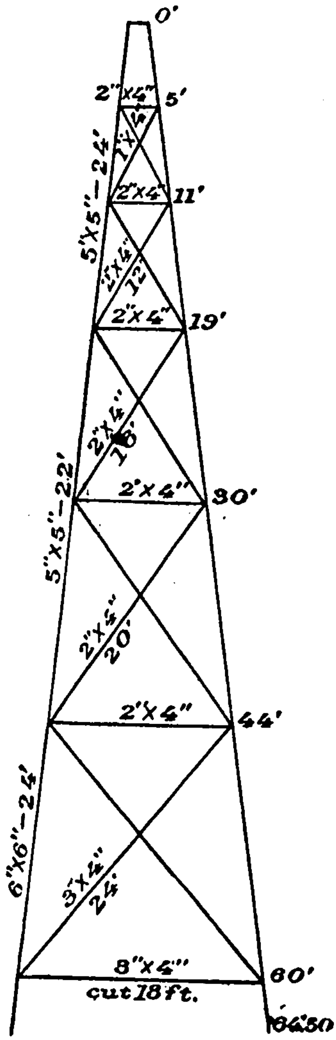



FIG. 30.—Working drawing of side of tripod for 60-foot signal.

on unusually tall signals. (See pp. 51–53.) Figure 29 shows tripod legs Nos. 1 and 2 with two of the horizontal ties in place, the legs being in such a position that the chamfers which form a bearing surface for the ties and diagonals are horizontal. The chamfers as seen in this position are 2 feet long, cut 1 inch back from the corner on the top and

2 inches on a side. They are marked for cutting with chamfer patterns made of two pieces of board 2 feet long nailed together to make a form which fits over the corner of the leg. It is recommended that, in general, the legs of the tower be built up of 2 by 6 inch or 2 by 4 inch timbers, for such timbers are more easily handled, and they can be spiked together more quickly than the scarfs can be cut on the large timbers. By properly breaking joints, as indicated on pages 49 and 50, there is little loss in rigidity or strength.

In framing the first side of the tripod cut the bottom horizontal tie to the length given in Figure 30 if the height of the tower is to be 60 feet. For other heights of towers consult the table on page 45. Place the two legs to be framed in the position shown in Figure 29 and nail on the first and second ties, *G* and *H*. The length of the horizontal tie *H* is such that for a 60-foot tripod the legs when straight will be about 8 feet apart at the top, as shown in Figure 29. For tripods of other heights the distance apart at the top when the legs are straight will vary with the height and is to be fixed by the judgment of the builder as to the amount of curvature to be put into the legs. After nailing the first two ties draw the upper ends of the two legs toward each other, thus putting a bend into each one of them, and nail on the successive ties, beginning at the bottom. The lengths of all the ties above *G* are to be such as to give the legs the desired bend, the tops of the legs being brought a little closer together as each successive horizontal tie is nailed on. When the tie 5 feet from the top is nailed on, the tops of the two legs should meet, as shown in Figure 30. The distance along the legs to each horizontal tie is given in Figure 30, reckoned from zero at the top. The ends of the ties should be cut off with the same slant as the leg, leaving 1½ inches overhang. Each panel must then be squared by using a steel tape to make the two diagonals of the panel equal in length. Time should not be spent in cutting the diagonals of the panels to measure. Instead, they should be laid in place and sawed off, each end parallel with the horizontal tie, and nailed fast, the panel having already been sprung to its proper position. The portions of the ends of the diagonals which project beyond the end of the horizontal tie should then be sawed off. Use two nails in each end of the horizontal ties and diagonal and one nail where each pair of diagonals intersect. Use sixtypenny nails for all 3 by 4 inch pieces and fortypenny nails for all 2 by 4 inch pieces. The dimensions for each part of a side of a 60-foot tripod are given in Figure 30.

Call the side of the tripod framed first No. 1. Cut the horizontal ties and diagonals for sides Nos. 2 and 3 by laying each piece on the corresponding piece of side No. 1 and cut to match, thus avoiding any necessity for measurements with a tape or square. Mark a cross with a pencil on the top end of each diagonal. Lay out in order each piece for sides Nos. 2 and 3 in a convenient location ready to send aloft, the nails all being started. When picking each timber up to lay it out in its proper position, face the top of side No. 1, and when laying it down face the triangulation station. This will bring each piece right end to when it is picked up and sent aloft.

FOUNDATION HOLES.

A stake with a nail in the top may be used for a temporary station mark. The holes for the foundation are laid off and staked according to the ground plan shown in Figure 31, all measurements being made from the temporary station mark. For locating the holes it is convenient to use a small theodolite (fig. 32) and a steel tape. The angles shown on Figure 31 are counted from zero at the foot of tripod

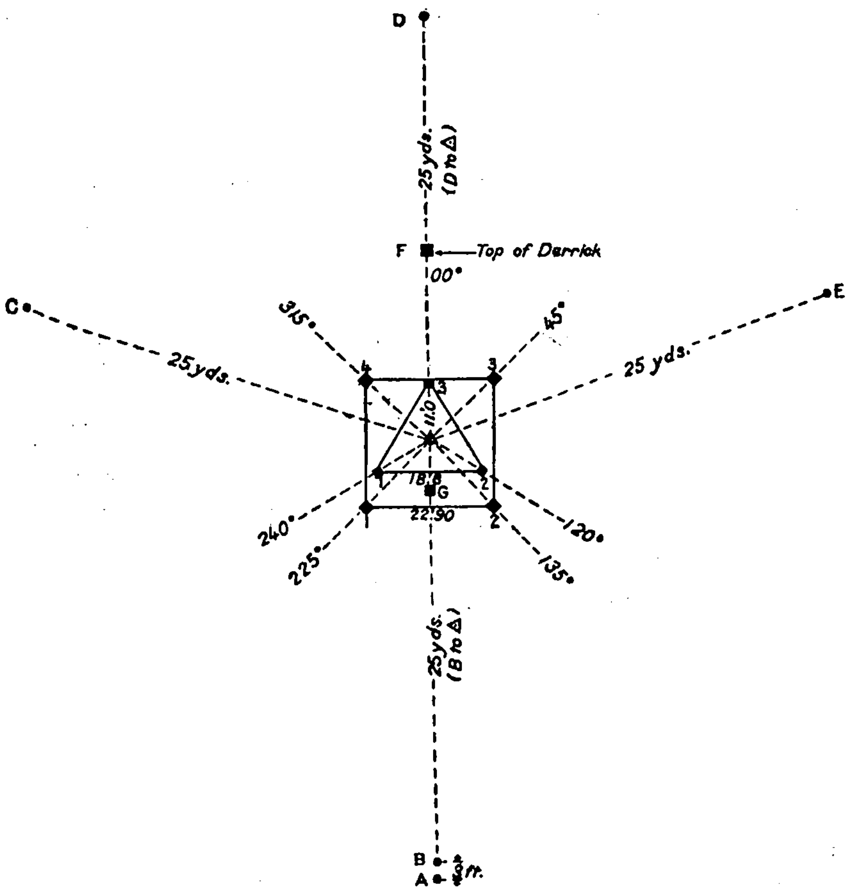



FIG. 31.—Ground plan for 60-foot signal.

leg No. 3. If possible, the orientation of the signal should be such that no line of sight from the head of the tripod will be obstructed by a scaffold leg. The holes for the tripod legs and the scaffold legs are all made 3 feet wide, 3½ feet long, and 3½ to 4 feet deep.

Spend no time in bringing the bottoms of all the holes accurately to the same level, but after they are dug and the tripod footplates set take a round of levels, either with a carpenter's level or with the small theodolite (fig. 32) used as a leveling instrument, using footplate No. 3 as a bench mark. Then cut legs Nos. 1 and 2 to correspond with the differences found, No. 3 having already been cut to the exact

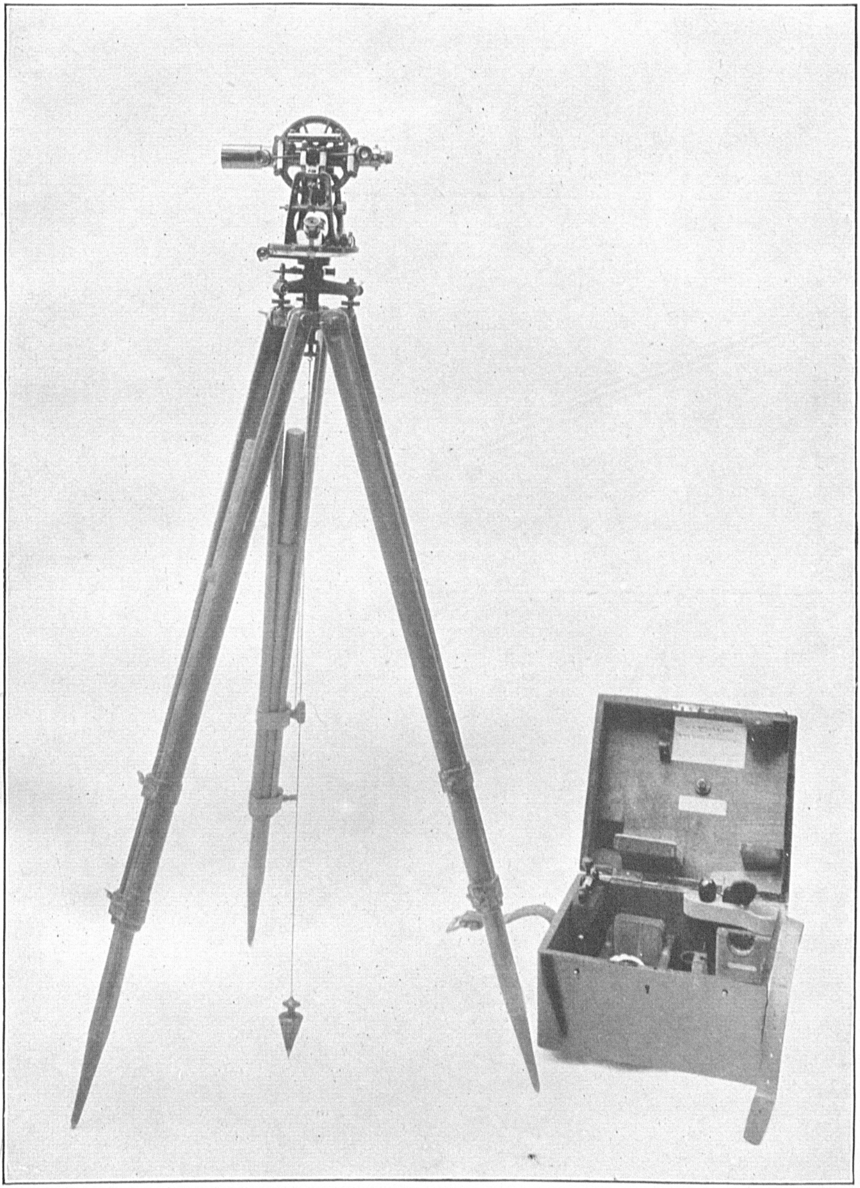


FIG. 32.—FOUR-INCH THEODOLITE.

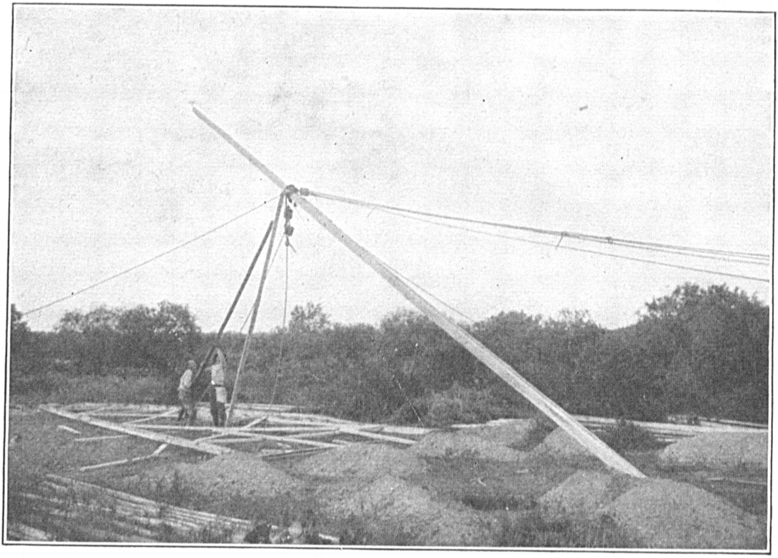


FIG. 33.—RAISING THE DERRICK.

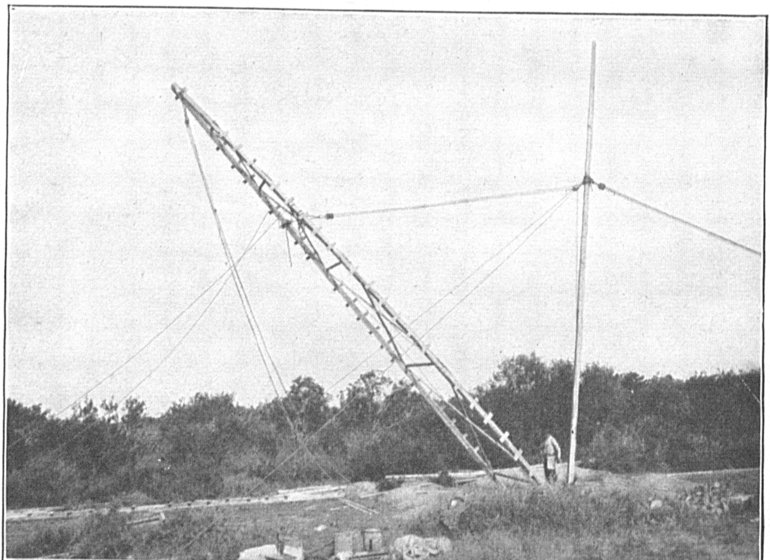


FIG. 34.—RAISING ONE SIDE OF TRIPOD FOR 60-FOOT SIGNAL.

length shown in Figure 30. The holes for the tripod legs should be dug first. Do not delay raising the tripod while waiting for the holes for the scaffold legs, as they can be dug after the tripod is raised. After the scaffold footplates have been set, take a round of levels on them, using the lower horizontal tie at the No. 3 tripod leg for a bench mark, it being exactly 4½ feet above its footplate. Cut off each scaffold leg as much above or below the 4½ footmark already on it as the corresponding footplate is above or below No. 3 tripod footplate as shown by the levels. It is necessary to keep the correct relation in height between the ties on the scaffold and those on the tripod in order to make the observing floor come at the right height in relation to the top of the tripod.

The footplates are 2 by 12 inches and 3 feet long. The bottom of each hole should be carefully smoothed, so that the footplate will have a firm bearing on the ground, and the plate should be placed in such a position that the leg will rest on it near the center.

### RAISING TRIPOD SIDE.

One or more sections of a leg of the scaffold may be used as a derrick for raising side No. 1 of the tripod. The derrick should be about two-thirds the height of the tripod. Posts for attaching guys should be set as shown in Figure 31, *A* and *B* being the positions of the posts for the back guys, *C* and *E* for the side guys, and *D* for the forward guy. *F* represents the position of the top of the derrick when laid out ready for raising and *G* the foot of the derrick. Before raising the derrick put on the side guys and make them fast to the posts at *C* and *E*, leaving about 2 feet of slack. A double-fall or winch tackle should be used for the back guy to *B*. Before beginning to raise the derrick put on the hoisting tackle, so that it will be ready for use when the derrick is up. One set of guys will do for a derrick 40 feet high, but a second set of guys, placed about halfway up, should be added for a higher derrick to prevent buckling when the side of the tripod is being raised.

The posts for guys should be 4 inches square, or an equivalent size of round timber. For high signals, where there is a heavy strain on the back guy and post or in any case in which the holding power of a guy post is uncertain on account of soft ground, an auxiliary guy post should be used. The second post should be placed beyond the first, and the two posts should be connected by a short guy attached to the top of the main guy post, 2 feet or more above the ground, to prevent it from being drawn forward, and attached to the auxiliary guy post as near the surface of the ground as possible.

Start the derrick up by using props (fig. 33) and then raise with the back guy fall. When raised, the derrick should rake back about 4 feet, so that when the heavy strain comes in raising the side of the tripod it will stand about vertical, as shown in Figure 34.

Before raising the tripod cleat the legs, using strips 1 by 4 by 16 inches spaced about 16 inches. Drag side No. 1 of the tripod back with the hoisting fall of the derrick, using handspikes to assist if necessary, until the feet come to the edge of the tripod holes Nos. 1 and 2, as shown on the ground plan (fig. 31). Put on a bridle rope about one-third the distance down from the top of the tripod. Near the point where the bridle rope is attached attach four guys—two to lead backward and two forward. Put a footrope on each leg 1 foot from the bottom, lead it to guy post *D* (fig. 31), and after pulling it taut take two complete turns. Attach a hoisting line on each tripod leg near the top before commencing to hoist the side. These hoisting lines are light ropes passing through single blocks and are used in hoisting the ties and diagonals while framing up the tripod. Hook the block of the hoisting tackle in the bridle mentioned above, run the loose end of the fall through a snatch block made fast to the foot of the derrick, and take it to the rear end of the motor truck or the wagon, as the case may be. By using a double fall a truck or good pair of horses will raise one side of any signal up to 90 feet in height. Figure 34 shows side No. 1 of a 60-foot tripod being raised to position.

When side No. 1 of the tripod is in a standing position and the backward and forward guys have been made fast to the posts *B* and *D*, the hoisting tackle should be taken off side No. 1, overhauled, and used in raising the third leg of the tripod, as shown in Figure 35. For the third leg three guys are required, one to each of the posts *C*, *D*, and *E*, as shown on the ground plan (fig. 31). A hoisting line is made fast near the top and the leg raised to its final position, as shown in Figure 36. The horizontal ties and diagonals are then nailed on sides Nos. 2 and 3 of the tripod, beginning at the bottom, two men working aloft while two men below send the timbers up in their proper order, using the hoisting lines. The tie at the top of each panel should be put on ahead of the diagonals. To make the pieces fit in place, it will be necessary for a man on the ground to spring the legs into position by means of the guys and hoisting lines. The tripod head is to be made very rigid at the top by planking up solid the top 3 feet of the tripod with 2 by 12 inch plank.

## LEG ANCHORS.

When the tripod is completed, nail the feet to the footplates and put on the anchors. To construct an anchor, take two 2 by 4 inch pieces 3 feet long and spike them on opposite sides of the foot of the leg parallel to each other. Fill in with earth to a level with the top of these pieces, then nail two more pieces of the same size on opposite sides of the leg at right angles to the first two. Lay boards or any other pieces 2 or 3 feet long across the top of the lower pieces, and after filling in earth level with the second set of anchor pieces lay shorter blocks or boards across them, too. This construction makes an anchor platform about 3 feet square. Fill the hole to the top, keeping the earth well tamped. All the legs of both the tripod and scaffold are to be anchored in this manner.

When the tripod has been anchored, cast loose the backfall and guy of the derrick and let it tip in against the tripod. Shift the hoisting falls to the tripod head, one on the side toward the derrick and the other on the opposite side. The derrick is then lowered with the fall on that side.

## FRAMING THE SCAFFOLD.

Begin the scaffold by scarfing and splicing the legs or building them up in the same manner as described above for the tripod. Mark the lines for the horizontal ties as shown in Figure 37. Lay out legs Nos. 3 and 4 on the forward side of the tripod and legs Nos. 1 and 2 on the rear side. The bottom horizontal tie and the top floor tie are to be cut to the lengths given on the working plan (fig. 37) and nailed in their places as there indicated. As the intermediate horizontal ties are nailed on, force each leg out so as to give it the desired bend. The foreman, standing at one end of the side being framed and directing the men as they nail on the ties, may determine the amount of bowing or bending by estimation. After the ties are nailed in position they should be sawed off even with the outer side of the legs. Next square each panel, commencing at the bottom, by making its two diagonals of equal length, using a steel tape, and nail the diagonals in position. It should be noticed that none of the horizontal ties, except the ones at the top and bottom, are cut to measure, and no measurements are necessary to fix the lengths of the diagonals. When the framing of the first side of the scaffold has been completed, cut the horizontal ties and diagonals for the other three sides by using this first side as a pattern. Side No. 3, as well as side No. 1, may be framed fully before raising, except for signals more than 90 feet in height, which must be raised in two or more sections, as explained on page 51. All four legs of the scaffold should be cleated. (See p. 41.)

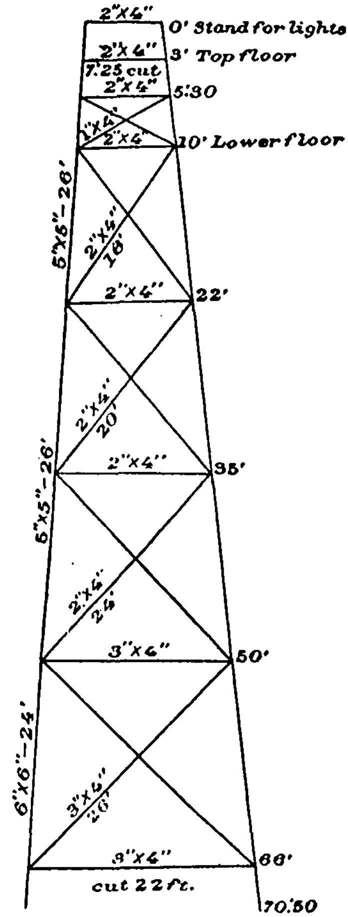


FIG. 37.—Working drawing of side of scaffold for 60-foot signal.

RAISING THE SCAFFOLD.

First make the bridle rope fast on one leg of the side to be raised, hook the hoisting tackle from the top of the tripod in it, and turn the side of the scaffold over, so that the ties and diagonals will be on the under side. Figure 38 shows this operation of turning over. Next make the bridle rope fast for raising and raise the side to a standing position, as shown in Figure 39. In a similar manner turn side No. 3 over, as shown in Figure 40, and raise it to a standing position, as shown in Figure 41. Next let two men go aloft and nail the ties and diagonals on sides Nos. 2 and 4, while two men below send up the timbers in order, as shown in Figure 42. It is best to complete one panel on one side and then shift to the other side, and so on to the top. The legs may now be anchored down and the necessary floors and ladders constructed to complete the scaffold, as shown in Figure 43.

The lower floor of the scaffold is at the height indicated in Figure 37, and the tripod can be cut off to the exact height required by the observer. The height of the observer and the height of the instrument telescope above the foot of its leveling screws will determine the height of the top of the tripod head above the floor. This must be known beforehand. The upper floor is placed 3 feet below the top of the scaffold in position to support the light keeper. A table 3 by 3 feet is constructed at the center of the top of the scaffold for supporting the lamps and heliotropes.

Two trapdoors should be made in the lower floor, one where the ladder comes up at leg No. 1 or No. 2 of the scaffold and the other in another corner of the floor, to be used in hoisting the instrument. The door for hoisting should be placed at leg No. 3 or No. 4 of the scaffold in order to obtain the best clearance of the tripod and the ladder timbers. The floor timbers must be spaced to give ample clearance for the instrument box.

The wall of the observing tent is a strip of canvas 4.6 feet wide reaching around the outside of the scaffold, with the two ends overlapping at one corner. The bottom of the wall is made fast to the lower floor by hooking the loops over nails driven in the floor. The top of the wall is made fast in the same manner to the horizontal tie on the scaffold 5.3 feet below its top. The roof of the tent is a tarpaulin which fits over the top floor and carries four canvas curtains which overlap at the four corners of the scaffold and also overlap the wall of the tent to which they may be tied. The space of 7 feet between the top and lower floors of the scaffold is thus inclosed, making a room with a floor 9 feet square for the observer. The tent requires no poles or extra timbers for its support.

## DESIGNS OF SIGNALS OF VARIOUS HEIGHTS.

In the case of an obstructed line, on which the obstruction is not discovered until the towers have been built, the difficulty may be overcome by building up a superstructure on the signal at each end of the line, such as was constructed on the top of a 60-foot signal at station Burson, shown in Figure 44. The lamps and heliotropes can then be posted at the top of the superstructures and a clear line obtained without increasing the height of the tripods. The superstructure shown in Figure 44 is of the same type as the scaffold for the first 24 feet. For the remaining 48 feet the superstructure is 2 feet square, and the legs are parallel. The horizontal ties are 4 feet apart. Two sides of the superstructure were framed on the ground in sections 12 feet long and hoisted to position with hoisting lines. The horizontal ties and diagonals for the other two sides were cut by using the first side as a pattern and were hoisted aloft with hoisting lines. Two sets of wire guys (No. 12 smooth wire) were put on the superstructure—one set at the top and the other set 24 feet lower. The guys were made fast to special posts set for the purpose. This type of superstructure proved to be sufficiently stable, and it could safely be built to a height of 150 feet above a scaffold. In posting his light the light keeper went up the inside of the superstructure and passed out to a seat constructed 2 feet below the table which was made for the lights and heliotropes at the top of the structure.

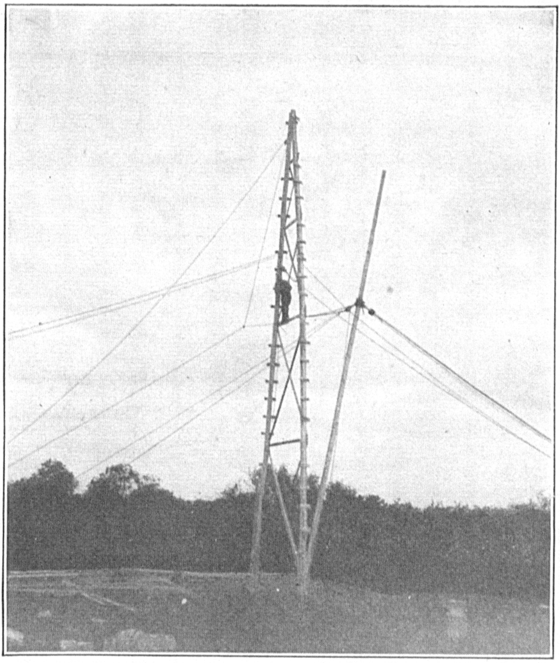


FIG. 35.—SHIFTING TACKLE BEFORE RAISING THIRD LEG OF TRIPOD.

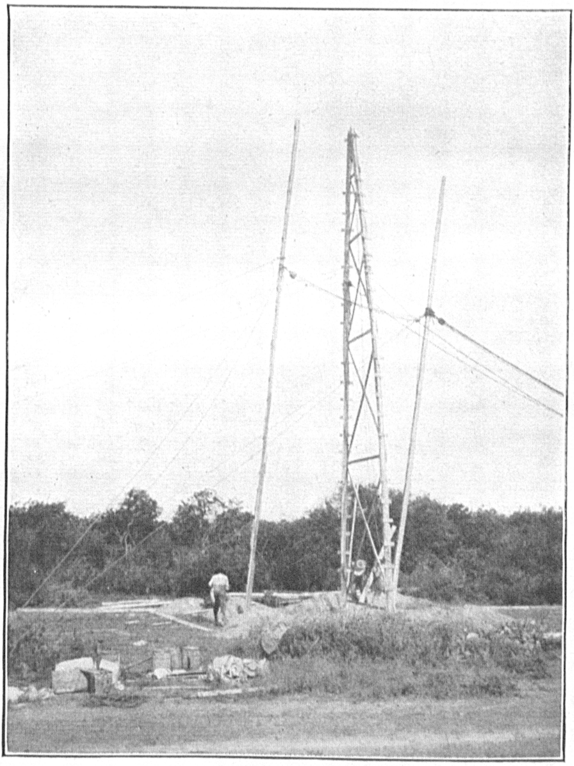


FIG. 36.—RAISING THIRD LEG OF TRIPOD FOR 60-FOOT SIGNAL.

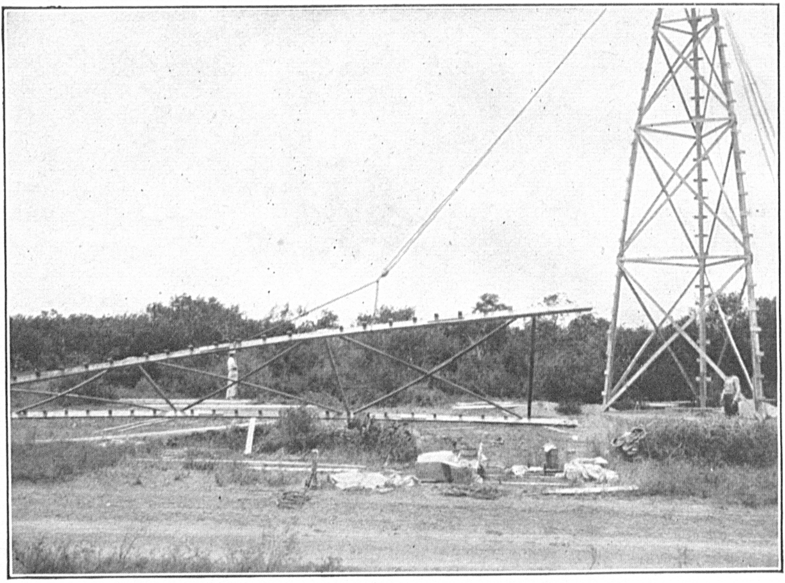


FIG. 38.—TURNING OVER FIRST SIDE OF SCAFFOLD.

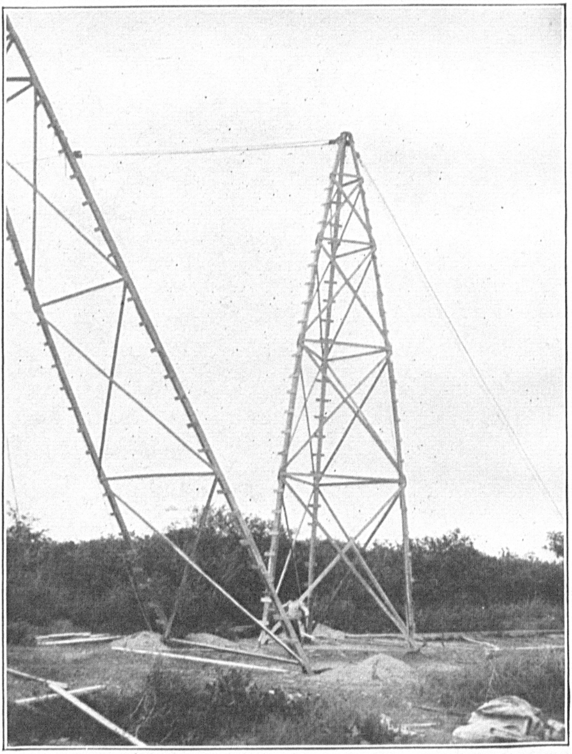


FIG. 39.—RAISING FIRST SIDE OF SCAFFOLD FOR 60-FOOT SIGNAL.

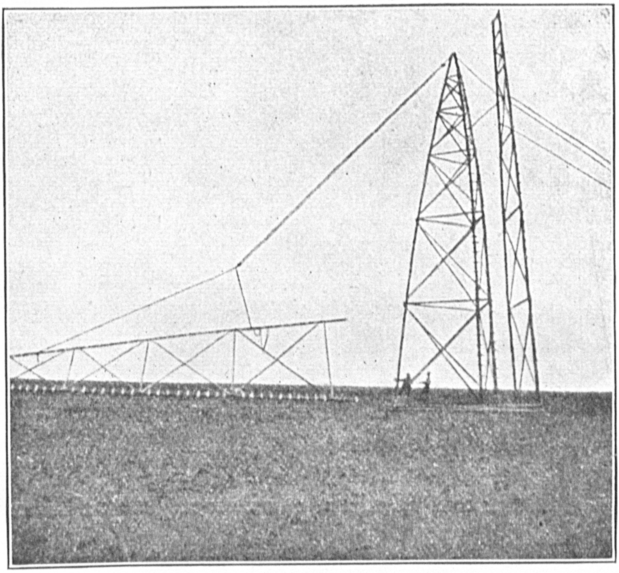


FIG. 40.—TURNING OVER SECOND SIDE OF SCAFFOLD.

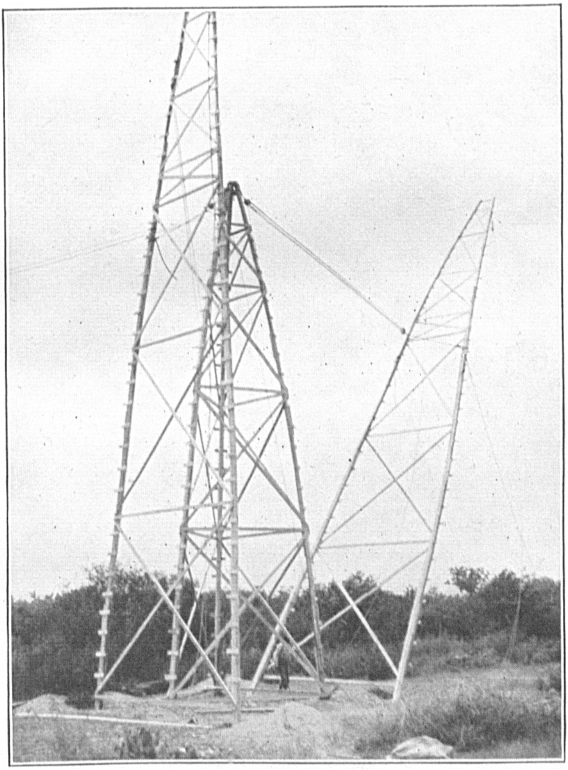


FIG. 41.—RAISING SECOND SIDE OF SCAFFOLD FOR 60-FOOT SIGNAL.

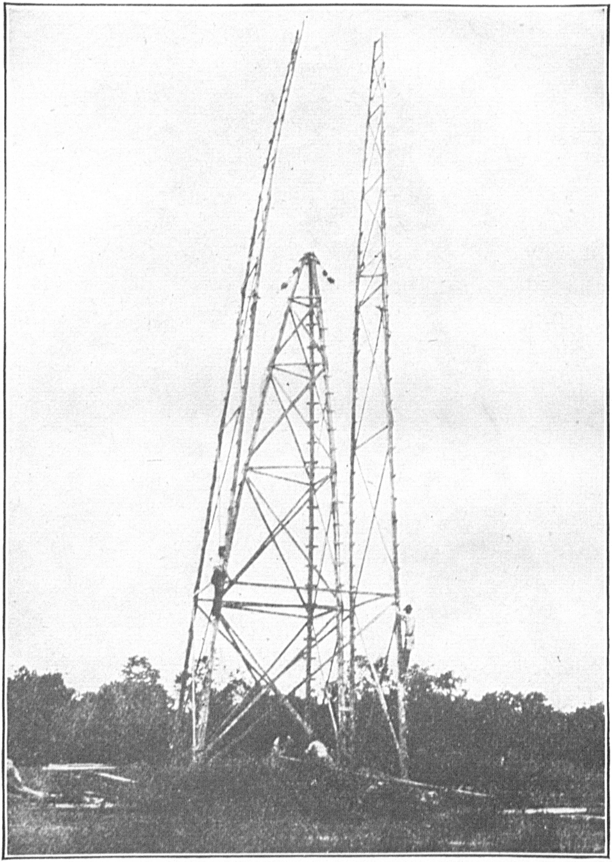


FIG. 42.—TWO SIDES OF SCAFFOLD FOR 60-FOOT SIGNAL IN STANDING POSITION.

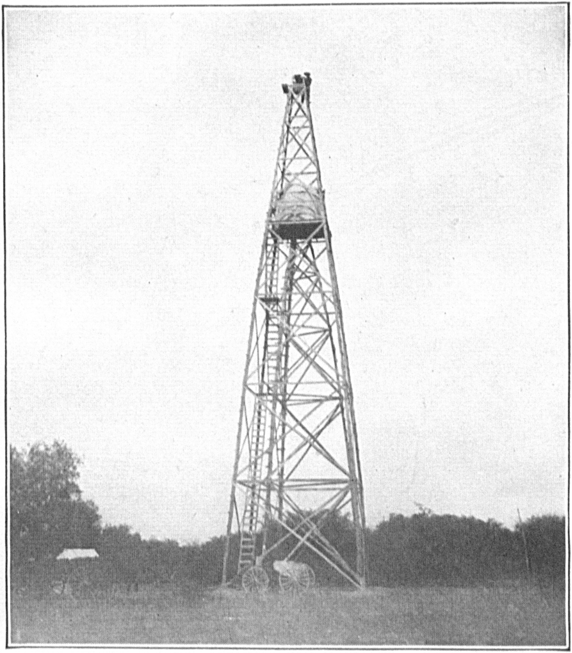


FIG. 43.—COMPLETED 60-FOOT SIGNAL WITH 20-FOOT SUPERSTRUCTURE.

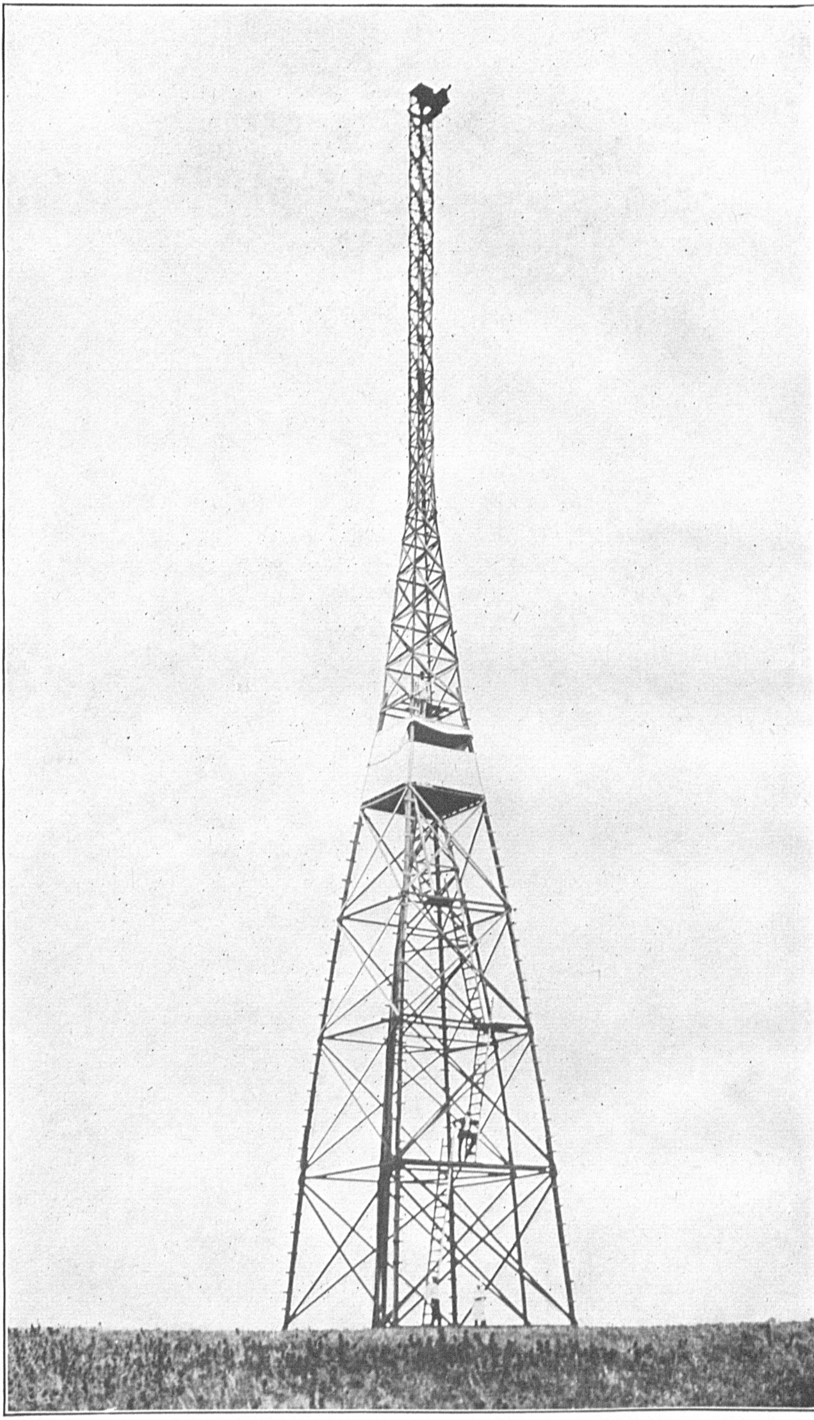


FIG. 44.—SIXTY-FOOT SIGNAL WITH HIGH SUPERSTRUCTURE.

For scaffolds of different heights the top portion of the signal down to a point 10 feet below the top is the same for all. The following table gives the lengths of the lower horizontal tie for tripods and scaffolds of different heights. The first column is the distance from the top of the tripod to the lower horizontal tie of the tripod as measured along the tripod leg.

| Length of tripod leg. | Length of lower horizontal tie of tripod. | Length of lower horizontal tie of scaffold. |
|---|---|---|
| *Feet.* | *Feet.* | *Feet.* |
| 10 | 6 | 10 |
| 15 | 7.5 | 11.5 |
| 25 | 10 | 13.5 |
| 45 | 14 | 17 |
| 60 | 18 | 22 |
| 75 | 19 | 23 |
| 100 | 20 | 25 |

The dimensions given in the table are fixed directly by measurement. The lengths of the intermediate horizontal ties and of all the diagonals are fixed as indicated in the preceding description of the process of framing and construction. The legs for the scaffolds are in each case 6 feet longer than the tripod legs, except for a signal for which no top platform is needed, in which case all the legs are of the same length. When a 10-foot tripod is used, the diagonals of the scaffold should reach from the bottom tie to the tie which is between the two floors, 5.3 feet below the top of the scaffold. In all other respects the scaffolds and tripods of different heights correspond in design to those shown in Figures 43 and 44, and any of them may be made with or without superstructure or light stand. The list of material required for any height of signal can be determined quickly by making working drawings to scale similar to those shown in Figures 30 and 37 and scaling off the lengths required for each side.

For signals higher than 75 feet the design shown may be extended by putting on other sections at the bottom somewhat heavier than the lower section of the 75-foot signal. Signals not greater than 90 feet in height may be framed and raised as just described, and no bolts need be used. If the signal is more than 90 feet, a section of a side 75 to 90 feet high may be raised as one piece, and the higher sections must than be framed separately, raised to position, and fastened with bolts to the top of the first section, as shown in Figure 45.

## ADVANTAGES OF THE SLENDER TYPE OF SIGNALS.

Some of the points of advantage claimed for the slender signals over those formerly used by the U. S. Coast and Geodetic Survey, and especially over the broad ones described in Appendix 10, Report for 1882, are given below.

There is only about one-half as much lumber per vertical foot in the slender signals as in the broad. This not only reduces greatly the cost of the material required for a signal of given height and the cost of hauling the material, but also considerably reduces the cost of construction.

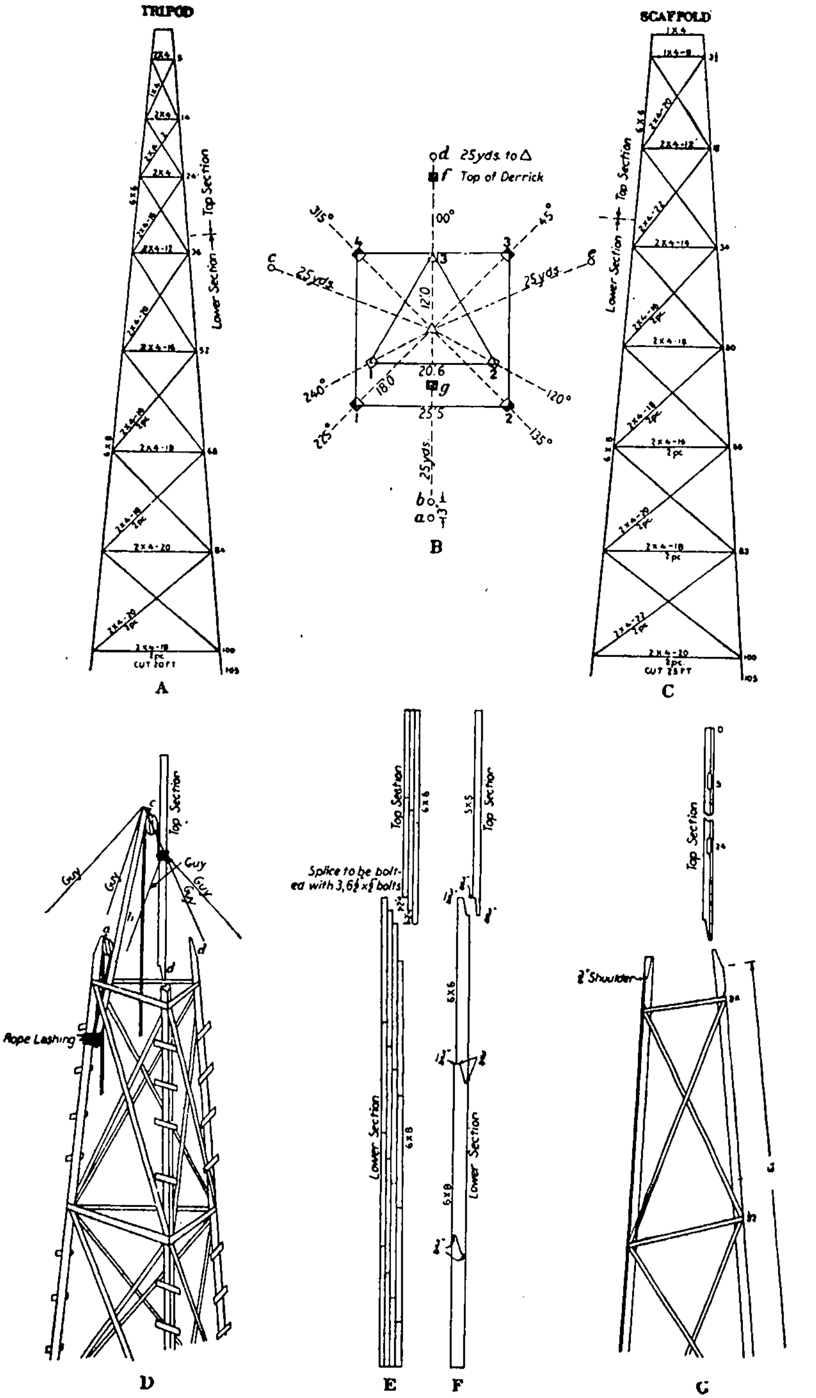



FIG. 45.—Working drawings for 100-foot signal showing arrangement of tackle for raising top section of tripod.

Much less area is exposed to wind pressure for a signal of given height in the slender signals than in the broad ones, and therefore much less strength is needed. More important than this, however, is the fact that the horizontal ties and diagonals, which are the relatively light pieces in the structure, are very much shorter in the slender than in the broad signals, and therefore the vibrations of these pieces due to wind are much less in the slender signal. These vibrations impart a tremor of short period and small amplitude to the instrument and also to the floor supporting the observer and are likely to prevent observations in a strong wind long before there are any other troublesome motions of the signal or any danger of collapse. Experience indicates that observations may be continued in a stronger wind without screens on a slender signal than on a broad one.

The bowing of the legs of the slender towers during construction puts the posts and horizontal ties under a moderate initial strain, which adds greatly to the stiffness of the structure and somewhat to its strength.

As the observing tent for the slender signal is supported on the outside of the tower, every part of the floor space is available for use, and it is possible to work as comfortably on a floor 9 feet square on the slender scaffolds as on a floor 12 feet square on the broad ones, where other styles of observing tent are used. This reduction in the size of the floor is important, as it allows a corresponding reduction in the size of the signal throughout its whole height.

The second or upper floor and the table for the light make it possible for the heliotroper or light keeper to show his light to a second observer on another station with the light or heliotrope mounted directly over the station instead of in an eccentric position and without the slightest interference with the observer below.

The slender signals, although they contain much less lumber than the broad ones and have a much smaller spread of base for a given height, are no more apt to collapse in a strong wind than the broad ones. Experience indicates that either type is sufficiently strong to make the losses by collapse very small.

When there is but one observing party, the upper floor is left off, and the tripod and scaffold legs are the same length.

## TOOLS AND TACKLE NEEDED TO ERECT A HIGH SIGNAL.

The following tools and tackle are necessary for a party of four or five men engaged in building tall signals not over 90 feet high:

*Tools.*

| | | | |
|---|---|---|---|
| Axes | 2 | Pick | 1 |
| Adz | 1 | Plane | 1 |
| Bevel | 1 | Plummet | 1 |
| Bits, assorted | 6 | Rules | 3 |
| Brace | 1 | Saw, compass | 1 |
| Chisel, cold | 1 | Screw driver | 1 |
| Chisel, wood | 1 | Set, saw | 1 |
| Digger, posthole | 1 | Shovels | 2 |
| Hammers, heavy | 3 | Spade | 1 |
| Hammers, claw | 1 | Spud | 1 |
| Handsaws | 4 | Square, 2-foot | 1 |
| Hatchets | 2 | Tape, steel, 50-foot | 1 |
| Level, carpenter's | 1 | Trowel | 1 |
| Mattock | 1 | Try-square | 1 |
| Oilstone | 1 | Wrench, monkey | 1 |

*Tackle.*

| | |
|---|---|
| Blocks: | |
| Double, 8-inch, with hook, patent bushed | 4 |
| Single, 6-inch, with hook, patent bushed | 4 |
| Snatch, 7-inch, with hook | 2 |
| Rope: | |
| ½-inch for hoisting lines, 200-foot pieces | 4 |
| ⅝-inch for guys, 110-foot pieces | 15 |
| Rope—Continued. | |
| ⅝-inch for slings, 2-foot pieces | 4 |
| ¾-inch for main tackles, 500-foot pieces | 2 |
| ¾-inch, 12-foot pieces | 4 |
| 1⅛-inch for bridles, 40-foot pieces | 2 |

## GENERAL OBSERVATIONS.

### RAISING THE SIGNAL.

Figures 33 to 45 illustrate the principal steps in raising the signal. These illustrations are intended to assist the inexperienced signal builder to make fast each guy and hoisting tackle in its proper place and to show the steps taken in raising each part of the signal. If the hoisting tackle is made fast too near the top of the part to be raised, the timbers will buckle and break. On the other hand, if the hoisting tackle is made fast too low down, it will have the same effect, only the buckling will be in an opposite direction. It is necessary to fasten the tackle on the part to be raised so it will be well balanced. A three-quarter ton motor truck will raise one side of any tripod or scaffold, with superstructure attached, up to 90 feet in height. Where a motor truck can not be used, the signal can be raised with a team of horses or by hand power with a winch or extra tackle.

### SUPERSTRUCTURE.

The superstructure is designed to elevate the heliotrope or lamp in order to raise the line of sight above an obstruction near the middle of the line between the two stations, and thus avoid the necessity for building higher tripods and scaffolds.

For example, a line may require a 50-foot signal at each end to clear obstructions near each station, but to overcome curvature and to clear an obstruction near the middle of the line would require a 75-foot signal at each end of the line. This would mean the addition of 25 feet to the bottom of the 50-foot tripod and scaffold and would nearly double the cost of material and labor. In such cases it is more economical to build a 50-foot superstructure on top of the 50-foot scaffold at each end of the line and mount the heliotrope or lamp at the top of the superstructure.

The superstructure is constructed by first extending the scaffold legs about 20 feet. (See fig. 43.) At this point the corner posts have approached within 2 feet of each other on a side. The superstructure is then extended 2 feet square to any desired height. (See fig. 44.) It can safely be built to a height of 150 feet above the tripod head. A set of four guys of No. 12 wire should be put on the upper superstructure about every 24 feet and secured to anchor posts set about 175 feet from the signal and on line with the diagonals of the ground plan of the signal. The top superstructure is identical with the superstructure on the hydrographic signal, of which detailed specifications are given on page 64. (See fig. 62.)

When it is known that a superstructure is needed, the part extending 20 feet above the top of the scaffold legs should be framed and raised with the scaffold, as shown in Figures 41, 42, and 43. Two men can then extend the superstructure to any required height at any convenient time after the signal has been erected. Figures 62, *B*, and 64 show the splice where the upper sections of the superstructure are joined to the lower or base section at a point 20 feet above the scaffold. The instructions for the special hydrographic signal on page 64 give in detail the method of framing and constructing the superstructure.

## USE OF YARD STOCK TIMBERS FOR 60-FOOT SIGNAL.

In a timbered country where there are local sawmills it is often convenient to place orders at the mill for the lumber required for a signal, and in such cases it may be advisable to specify the lengths and sizes of timbers called for in the preceding plans and specifications. In many regions, however, it may be difficult to procure timbers of the specified sizes and lengths, and the local lumber yards must be depended upon for the lumber needed. No time should be spent in attempting to find timbers of special lengths or dimensions. In general, the local yards carry a stock of 2 by 4 inch and 2 by 6 inch timbers ranging from 12 feet to 20 feet in length. Where the plans for a signal call for 6 by 6 inch timbers for the legs, the legs may be built up from 2 by 6 inch pieces. Any length may be used, but usually the 16-foot lengths are the most convenient to haul and are preferable to use, as is indicated below.

The legs for a 60-foot signal should be about 64 feet long and 6 inches square. They can be built up by using twelve 2 by 6 inch pieces 16 feet long for each leg. First lay four 2 by 6 inch pieces 16 feet long end to end and cut the ends to match. This can be done by sawing the end of one timber to match the end of the timber it joins, and it is not necessary to use a square. Next place four more 2 by 4 inch pieces 16 feet long end to end on top of the lower four pieces, starting 4 feet from one end. This breaks the joints 4 feet and gives a 4-foot overrun at one end, which is sawed off and used to fill in the 4-foot space at the opposite end. The upper set of timbers should be nailed temporarily to the lower set, using tenpenny nails near the center of the timber in width and 2 or 3 feet apart. The third set of timbers is next placed on in the same manner as the second set, but starting 8 feet from one end to give 4-foot lap on the joints of the second set. The 8-foot overrun can be sawed off and used to fill in the 8-foot space at the opposite end. The third set of timbers should be nailed temporarily with tenpenny nails in the same manner as the second set.

The tripod legs should next be marked for the ties and chamfers and should then be spiked with fortypenny nails. The nails should be spaced about 20 inches apart and should be staggered to come about 1 inch from alternate edges, except where chamfers are to be cut. Care should be taken to place the nails so they will not be hit with the tool used in cutting the chamfer. One or two spikes should be driven about 6 inches from the end of each 2 by 6 inch piece at the joints. This applies to the middle set of timbers as well as to the two outside sets. After spiking the top side as indicated above turn the leg top side down and drive spikes near each joint and at any intermediate place along the leg where necessary to draw it together.

To the bottom or lower portion of the legs of all signals 60 feet or more in height should be added a 2 by 6 inch piece 16 to 24 feet long, making this portion of the leg 6 by 8 inches. There should also be a 2 by 4 inch piece about 3 feet long spiked over each outer joint where the 2 by 6 inch timbers butt together.

In framing the scaffold lay the legs out in position for the ties and diagonals with the 2 by 6 inch timbers on edge. This gives the legs a greater strength and stiffness when raising. The cleats or steps are also nailed on with the legs in the same position and help to bind the 2 by 6 inch timbers together.

**Ties and braces.**—It is often necessary to build up or splice the ties and diagonal braces. A single piece of 2 by 4 inch timber up to 20 feet in length will usually give a sufficient strength and stiffness, but longer lengths should be partly doubled. For instance, if a diagonal 24 feet long is called for, take two 2 by 4 inch pieces 18 feet long and let them overlap 12 feet in spiking them together. This will make the brace 4 inches square on the overlap and by 2 by 4 inches for 6 feet at each end and will give the greatest strength and stiffness at the middle of the brace where it is needed.

It will be noted in the specifications on page 41 that the footplates called for are 2 by 12 inches and 3 feet long. The footplates can be made of two 2 by 6 inch pieces placed side by side with a 1 by 4 inch cleat nailed across each end to bind the two together. Lumber 2 by 6 inches can also be used in boxing up the head of the tripod where 2 by 12 inch pieces are called for.

## BUILDING THE LADDERS.

The side bars of the ladders are 2 by 4 inch pieces, and the steps are 1 by 4 inch pieces 2 feet long. The steps are spaced 14 inches center to center or top to top. Figures 43 and 44 show the ladders in position. It will be noted that the ladders are inside the scaffold on the side formed by legs Nos. 1 and 2, and that there is a landing at each tie of the scaffold. The length of each ladder section is the space between the ties on the scaffold for which it is made.

In making the ladders the 2 by 4 inch side bars are laid side by side on the ground and the spaces marked for the steps. The bottom ends of the side bars are cut to a miter of 1 in 6 to give the ladder the proper slant when it is set in position on the landing. In nailing, place the top edge of the step to the line and drive one nail in each end of the step about 1 inch from the lower edge. After the ladders are made the hoisting lines are rigged inside the scaffold frame on legs Nos. 1 and 2. The top landing and top ladder are set first and then the next lower one, and so on down to the bottom ladder, which is set last. There should be a clearance of 2 inches or more between the ladder timbers and the tripod. After the ladders have been set in place a second nail is driven in each end of all the steps.

## TRIPOD AND SCAFFOLD SIGNALS 100 FEET OR MORE IN HEIGHT.

The following directions are supplemental to the general directions on the preceding pages of this publication and are intended to supply the necessary additional information for framing and erecting signals 100 feet or more in height where it is necessary to raise them in two or more sections.

Figure 45 shows the complete working drawings of a tripod and scaffold signal 100 feet in height. *A* is one side of the tripod; *B*, the ground plan; *C*, one side of the scaffold; *D*, the lower section of the tripod erected; *E*, one leg of the signal built up of 2 by 6 inch timbers; *F*, one leg of the signal made of solid timbers scarfed and spliced; and *G* shows one side of the lower section of the tripod and one leg of the top section.

### HOLES FOR LEG ANCHORS.

The position of the holes for the leg anchors of the scaffold and tripod is shown in *B*, Figure 45. The holes should be about 3½ feet square and 4 feet deep. In some places it may not be practicable to dig the holes the required depth on account of rock. In such cases the holes should be made larger in cross section, longer anchors used, and a large cairn of rock built up over the anchors. Sometimes the signal must be built on a solid rock outcrop, where no holes can be made. In such cases long anchors are put on in the usual manner, and a large cairn of rock is built around each leg on top of the anchor. It should be remembered that the object of the anchors is to hold the legs down, and a sufficient volume of material should be placed on the anchors to accomplish this purpose.

### FRAMING THE TRIPOD.

The first step in building the signal is to frame the tripod legs. They may be made of solid timbers or built up by spiking together 2 by 6 inch pieces, as shown in *E* and *F*, Figure 45. In either case the legs must be made in two sections, the lower section about 75 feet long, and the two sections put together with ½-inch carriage bolts 6½ inches long.

The rest of the framing is done in accordance with the general directions for framing a 60-foot signal, as given on pages 36–50 of this publication, except that the horizontal ties and diagonal braces on the top section should only be nailed in place temporarily. Call the first side of the tripod framed No. 1 and cut the horizontal ties and diagonals for sides Nos. 2 and 3 by laying each piece to be cut on the corresponding piece on side No. 1 and cut to match.

Next remove the ties and diagonals from the top section of side No. 1 and lay them out ready to be sent aloft. Then unbolt the top section of the legs and proceed with raising the lower sections of side No. 1 and of the third leg in the same manner as in raising a 60 or 75 foot tripod. After putting the ties and diagonals on sides Nos. 2 and 3 of the lower section, attach the anchors and fill in the foundation holes.

### RAISING THE TOP SECTION OF THE TRIPOD.

To raise the top section of the tripod it is necessary to use a derrick, as shown in *D*, Figure 45. The top section of a tripod leg can be used for the derrick and may be placed on either leg No. 1 or leg No. 2 of the tripod, but the top section of the same leg as that on which it is placed should be used. After the top sections of the two other legs have been set in place, shift the hoisting block and rope to them and hoist to place the top section of the leg used as the derrick.

In *D* (fig. 45), *a* is the block and rope for hoisting the derrick, *b* is the derrick, *c* is the block and rope for hoisting the top section of the leg, and *d* and *d'* are the top and lower sections of the leg splice to be bolted. The derrick is hoisted aloft inside the tripod with the block and rope *a*. The rope is made fast to the lower end of the derrick, and a lashing is put around near the top of the derrick to fasten it to the standing rope, and thus keep the derrick upright while hoisting. When the top of the derrick is about at *a*, three guy ropes are put on and carried out to the guy posts *b*, *c*, *e*, as shown in the ground plan *B*, Figure 45, and the lashing around the top of the derrick is then removed. The block and hoisting rope *c* are then attached to the top of the derrick, and the derrick is hoisted to the necessary height for hoisting the top sections of the two other legs of the tripod. The foot of the derrick is lashed to the top of the leg, as shown in *D*, Figure 45.

The top sections of the two other legs can then be hoisted to place and bolted. As each top section is sent aloft two guy ropes are put on, as shown in *D*, Figure 45, and carried to guy posts. As soon as the top sections of all three legs have been bolted in place, the horizontal ties and diagonals for the top section are put on and the tripod completed.

### FRAMING THE SCAFFOLD.

The legs of the scaffold may be made of the solid timbers (*F*, fig. 45), or they may be built up (*E*, fig. 45), but in either case they must be framed for raising in two sections and be put together with bolts at a splice about 75 feet from the bottom. Lay out legs Nos. 3 and 4 on the forward side of the tripod and Nos. 1 and 2 on the rear side and proceed with the framing in accordance with the general directions given for a 60-foot signal, except that the diagonal braces for the panel where the lower and top sections are joined should be nailed only temporarily. All other diagonals and all the horizontal ties on the two framed sides can be nailed securely. The ties and diagonals for the other two sides should next be cut and laid out ready for sending aloft.

### RAISING THE SCAFFOLD.

Before starting to raise the scaffold remove the diagonals on the panel where the top and bottom sections are joined and take the bolts out of the leg splices. Carry the two top sections to the base of the tripod and lean them against the tripod in position to be sent aloft. The first section of the scaffold may then be raised by following the directions for raising the scaffold of a 60-foot signal. After completing the first section overhaul the hoisting tackle and attach the bridle ropes a few feet above the centers of the two framed sides of the upper section and hoist them aloft. As each of the two framed sides of the upper section is raised transfer the hoisting lines and guys from the lower section to it. The hoisting lines should be attached near the top and the guys near the bridle rope. When the two sides of the upper section have been raised to the required height, two men aloft can put the bolts in at the splices, and the scaffold can then be completed in accordance with the general directions for a 60-foot signal.

## PLUMBING SIGNALS AND MARKING STATIONS.

### VERTICAL COLLIMATOR.

A vertical collimator (shown in fig. 46) is used for centering a signal over a mark of a previously established station, for placing a mark under a new signal, or for centering the theodolite over the station mark. There must be an opening in the center of the cap block of the tripod head of the signal about 3 inches in diameter to permit the instrument to be used. The instrument consists of a telescope which fits in a vertical socket in the base and has a fixed level and adjustable cross wires. The axis of the level is at right angles to the line of sight of the telescope. The base of the instrument rests on three leveling screws.

The adjustment of the instrument is extremely simple. After having focused the eyepiece on the cross wires by pulling out or pushing in the eyepiece until the wires are plain and there is no apparent shifting of their intersection over a point on the ground as the eye is moved horizontally over the eyepiece, the intersection of the wires is adjusted to make it remain on a point as the telescope is revolved about its axis. This adjustment is made by shifting the diaphragm carrying the wires by means of the capstan-headed screws in the collar. At least three of the screws should be loosened when making the adjustment, and they should not be set up too tight. Finally, the level is adjusted to make the bubble remain in the center as the telescope is revolved.

With the instrument in perfect adjustment and the bubble brought to the center in two positions at right angles to each other, the line through the intersection of the wires or the line of collimation will be vertical. In actual use it is not essential that the instrument be in perfect adjustment, for if the bubble is brought to the same reading in each of four positions of the telescope about 90° apart four points may be determined on the ground, and the mean position will be in the vertical line through the telescope.

If a vertical collimator is not available, the centering can be done with a transit or theodolite. Have the theodolite in perfect adjustment. Make certain that there is no parallax in the eyepiece by adjusting it until there is no apparent movement in the intersection of the wires over an object on which it is pointed when the eye is moved back and forth in front of the eyepiece. Also see that the stride level is in perfect adjustment. Set up the theodolite at a distance from the tower about equal to its height and level it up by using the stride level. Point upon the center of the tripod with the slow-motion screw, plunge the telescope down to a point upon the ground under the tripod, and mark upon a horizontal board a line which coincides with the path determined by the intersection of the wires of the instrument. Move the theodolite to a point about 90° around the signal and repeat the process. The intersection of the two lines will be the point sought. If the mark is already established, the same process can be used to plumb up to the tripod head.

### PLUMBING OVER AN OLD STATION MARK.

When a signal is built over a previously established station mark, the opening between the three legs at *the top of the tripod* should be approximately centered over the station mark before the tripod legs are anchored. If the footplates are carefully leveled and measurements are made with reasonable care, the tripod head will seldom be more than 1 inch off center when erected. If necessary, however, the tripod can be shifted on the footplates or one leg wedged up to bring the center of the tripod head approximately over the station mark. Before nailing the cap block on the tripod head the 3-inch opening should be centered over the station mark with the vertical collimator. Set the collimator over the center of the opening in the cap block, level and adjust the instrument, and then move the cap block horizontally until the station mark is in a vertical line through the center of the telescope. Then nail the cap block securely to the tripod head.

### PLUMBING IN A NEW STATION MARK.

In general, the signal is built first and then the station mark is put in place. A small stake is used for the central point in laying out the ground plan of the signal. In this case no attempt is made to center the cap block over the stake, but after the cap block has been nailed securely to the tripod head the vertical collimator is used in centering the station mark. This is done most conveniently by first plumbing in a point on a bench or table a few inches above the ground. Place a 2 by 4 inch timber across the lower ties of the tripod, so it will be parallel to the tie connecting legs Nos. 1 and 2, and a few inches above the center stake. Then nail to this timber a piece of board about 12 inches square directly over the center stake. Drive a spike through one end of the timber into the tie on the tripod and at the other end drive a nail part way into the tie snug up on each side of the timber to prevent any horizontal movement. This end can then be lifted slightly and moved to one side when necessary and can be replaced exactly in its original position at any time.

With the bench in position, plumb down from the tripod head and locate a mark on the board, as follows: Have a man hold a square on the board and shift its position until the "vertical" wire in the vertical collimator coincides with one edge of the square. A line should then be drawn on the board along this edge of the square. Next turn the collimator 180° and repeat the operation. Then turn the collimator about 90° and 270° and locate two more lines on the board at right angles to the first two lines. This program gives a direct and reverse pointing in each of two directions, and the center of the small square formed by the four lines will be in the vertical line through the telescope of the vertical collimator. The point on

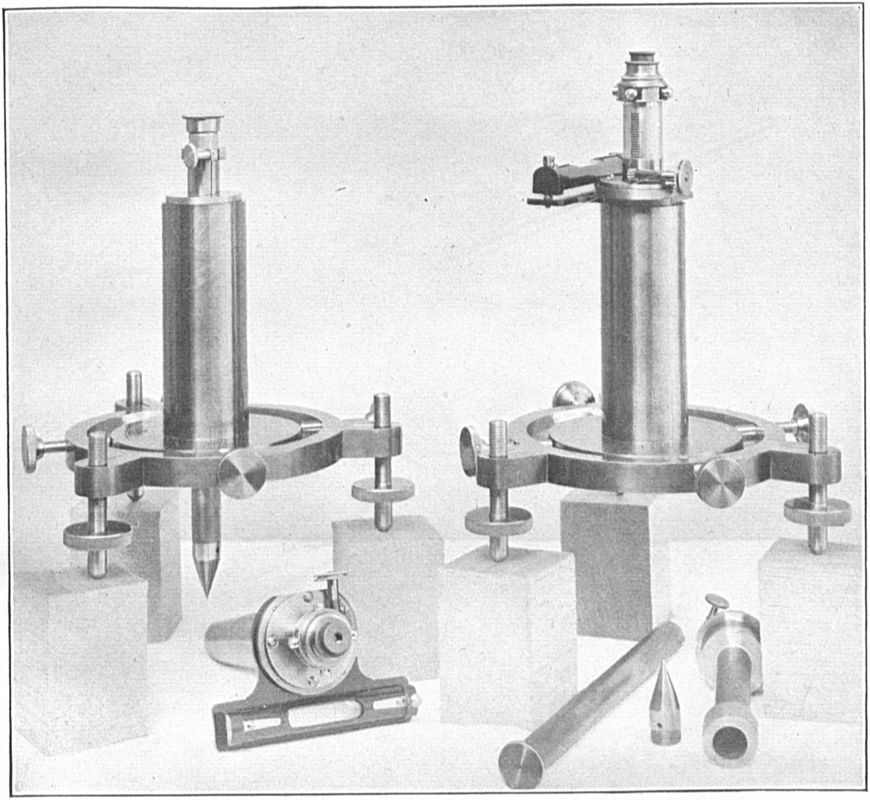


FIG. 46.—VERTICAL COLLIMATOR. TWO VIEWS.

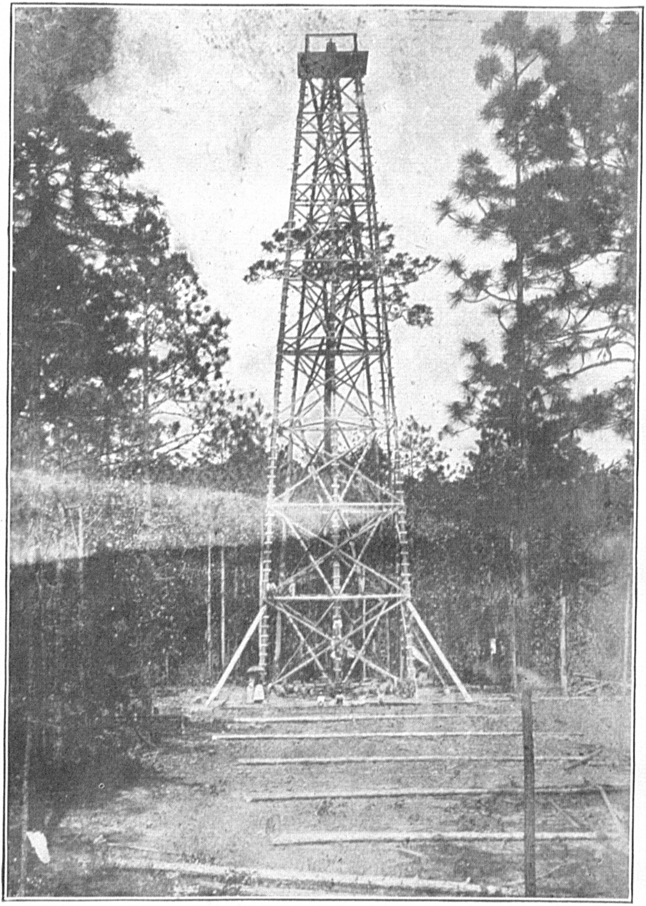


FIG. 47.—EXAMPLE OF 120-FOOT SIGNAL.

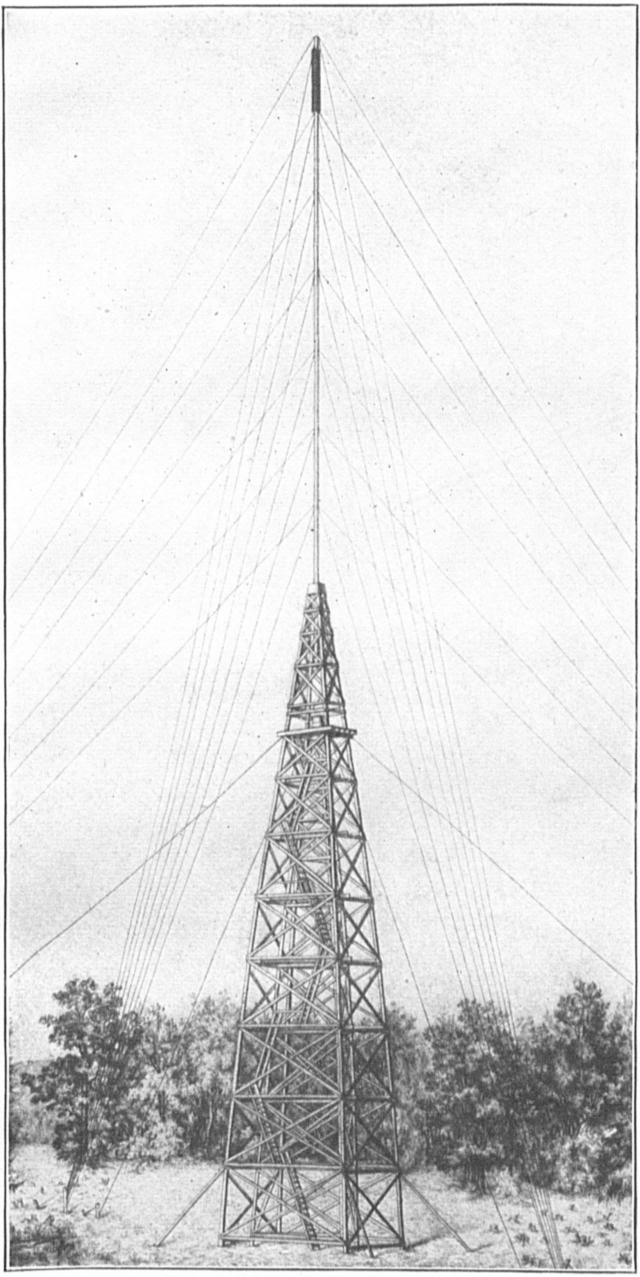


FIG. 48.—EXAMPLE OF 120-FOOT SIGNAL WITH SUPER-STRUCTURE AND POLE.

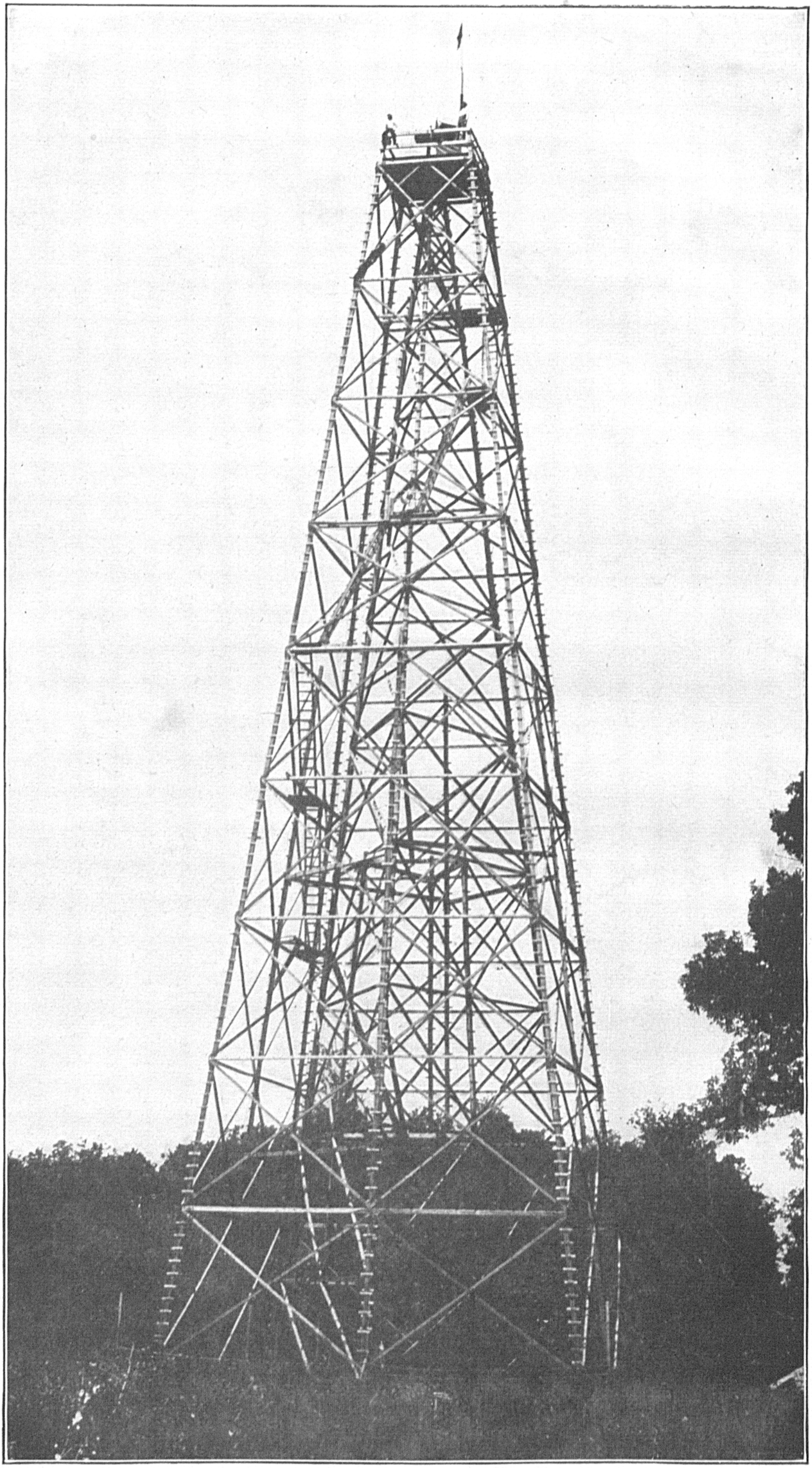


FIG. 49.—OLD TYPE OF SIGNAL.

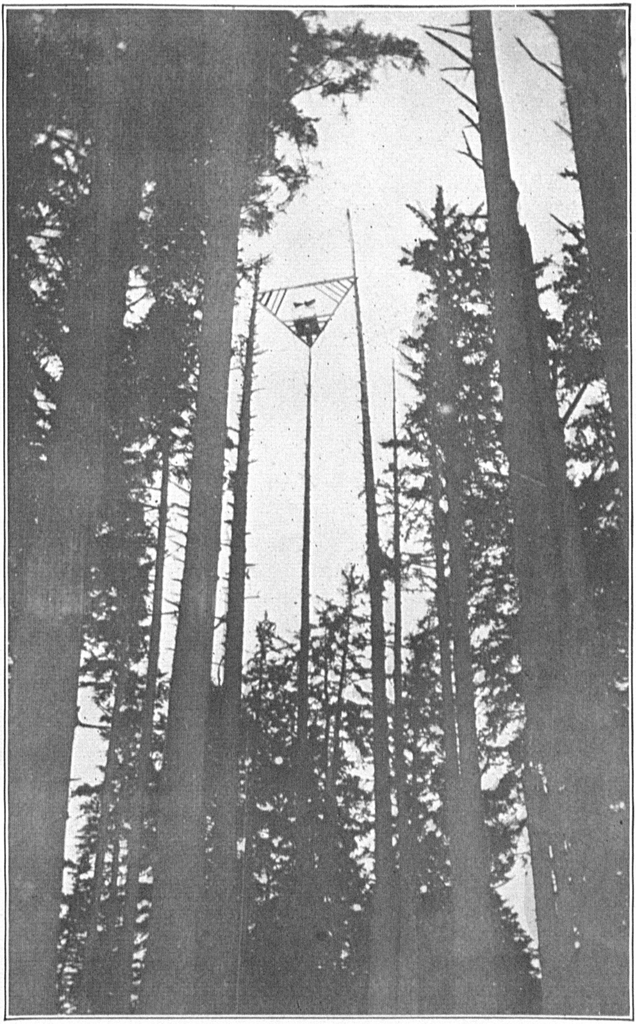


FIG. 50.—TRIPOD SIGNAL MADE OF THREE TREES.

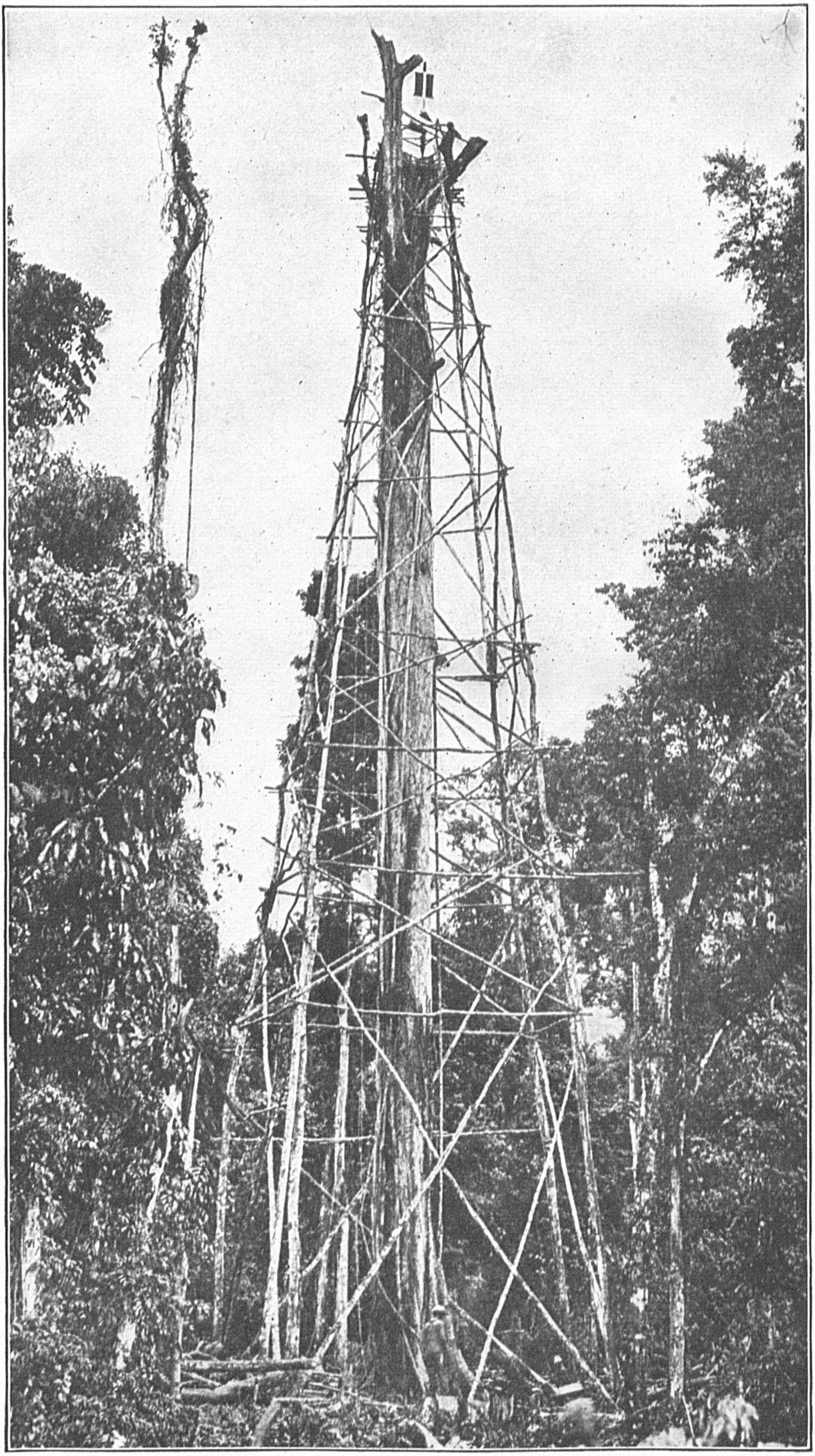


FIG. 51.—SIGNAL CONSISTING OF TREE IN PLACE OF TRIPOD AND OF SCAFFOLD MADE OF POLES.

the bench can then be used for setting the station mark by drilling a small hole through the board and using a plummet.

### PLUMBING IN BOARD ON LIGHT STAND.

On some signals the lamp (or heliotrope) is posted on the tripod head, but on others it is posted on a superstructure or light stand. In either case a board with a small hole in the center must be centered directly over the station mark by plumbing up. Place the board on the tripod head or light stand in its approximate position. Set the vertical collimator over the small hole in the board, and after leveling the instrument withdraw the telescope and insert the plunger. (See fig. 46.) Move the instrument until the point of the plunger is in center of the hole in the board; then withdraw the plunger and insert the telescope and move the board horizontally until the station mark is in the vertical line through the center of the telescope. Then nail the board securely to the light stand. Great care must be taken in adjusting the instrument and in keeping it leveled as the board is moved around. The instrument must be used in the usual four positions of the telescope, and after the board has been tacked temporarily in place the plumbing must be checked.

### PLUMBING IN SURFACE MARK OVER THE UNDERGROUND MARK.

When marking a station with both underground and surface marks, it is necessary to construct a bench over the point to hold a common center from which to plumb in the marks. The most practicable method is to drive two 1 by 4 inch stakes approximately on line with the station and about 1 foot from the edge of the hole for the concrete mark. The stakes should be firmly driven in the ground and project about 1 foot above the surface. Place a piece of 1 by 4 inch board across on top of the stakes and drive a nail through one end of the crosspiece into the top of the stake. At the other end drive a nail part way in the top of the stake alongside of the crosspiece and cut a fine notch on one edge of the crosspiece over the station point from which to suspend a plummet. The underground mark and surface mark can then be plumbed in from the point on the bench. When the bench is not in use, it can be turned around out of the way but can be replaced in exact position at any time if the stakes are not disturbed.

## VARIOUS TYPES OF SIGNALS.

### TRIPOD AND SCAFFOLD SIGNAL 120 FEET IN HEIGHT.

Figure 47 shows a 120-foot signal with a shore brace 6 inches square on each scaffold leg set at an angle of about 45°. The top end of each brace is notched to fit the corner of the scaffold leg and spiked fast just below the second tie, as shown in the figure. The lower end is set on a footplate and anchored in the same manner as the legs of the scaffold. The shore braces serve as additional anchorages and relieve the strain on the base of the scaffold legs in time of a heavy blow. Otherwise the signal is constructed in the same manner as the 100-foot signal. The signal shown in Figure 47 was raised in one section by using the tall tree directly back of the signal as a derrick.

## TALL SIGNAL WITH SUPERSTRUCTURE AND POLE.

Figure 48 shows a 120-foot signal with a 40-foot superstructure and 115-foot pole. The top of the pole is 275 feet above the station mark. The pole is made of timbers 4 inches square and 18 feet long spliced with a 2-foot scarf. The tripod and scaffold are the same as shown in Figure 37. The legs of the superstructure are 2 by 4 inch timbers and the bracing 1 by 4.

Before hoisting the pole an opening 4½ inches square was made in the cap block on the tripod head and the same size opening in the board on top of the superstructure, the center of each opening being directly over the station mark. The pole was hoisted inside the tripod. Sections were added to the bottom of the pole as it was hoisted aloft. When the top of the pole passed through the top of the superstructure, the targets and top guys were put on. The pole was then hoisted 16 feet higher, and the next set of guys were put on the pole just above the top of the superstructure. A set of guys was put on at each splice, or 16 feet apart, as the splice came above the top of the superstructure in hoisting. When the top of the pole was about 35 feet above the top of the superstructure, a turn was taken around the guy posts with each guy, leaving about 2 feet of slack in each guy. As the pole was raised the guys were slackened as needed. When the pole had been raised to the desired height, the bottom end was about 6 feet above the tripod head and was held in place by a guide made of two 2 by 4 inch pieces placed across the superstructure on opposite sides of the pole, with their ends spiked to ties of the superstructure. Two pieces of 1 by 4 inch boards were nailed at right angles to the guide timbers to hold the foot of the pole. At the top of the superstructure two 2 by 4 inch pieces were nailed to opposite sides of the pole to rest on crosspieces on top of the superstructure, and thus support the weight of the pole.

The pole was made about plumb and approximately the same strain taken on each guy. It was then carefully plumbed with a small theodolite or transit and all guys made fast securely. The two top sets of guys, which held that part of the pole to which the target was attached, were made fast to separate sets of posts, and not more than three guys altogether were made fast to any one post. The target shown on the top of the pole is a 7-inch stovepipe painted black. Other types of targets may be used on a signal of this kind.

## OLD TYPE SIGNAL.

Figure 49 shows a tripod and scaffold signal 152 feet high. This is the old-type signal with the large base. There is no bow in the legs, and on account of the large base it is necessary to have an additional leg extending part way up in the middle of each side of the scaffold and tripod. This type of signal requires about double the amount of lumber per vertical foot required for the type shown in Figure 47, and the cost is about double that of the slender type. It has a greater exposed surface to the wind and a greater vibration on account of the extra legs and the long ties and diagonals.

### TREE SIGNALS.

Figure 50 shows a signal made of three trees. The trees were trimmed up and sprung toward each other with rope tackles. Timbers were then spiked across to form a triangle, as shown in the illustration. These timbers supported the floor for the observer and also a stand on which the instrument was mounted. Since the observer and instrument were not on independent supports, the station was occupied with a repeating theodolite and the observer stood in one position while the pointings and readings were made. The height of the instrument was 187 feet above the station mark.

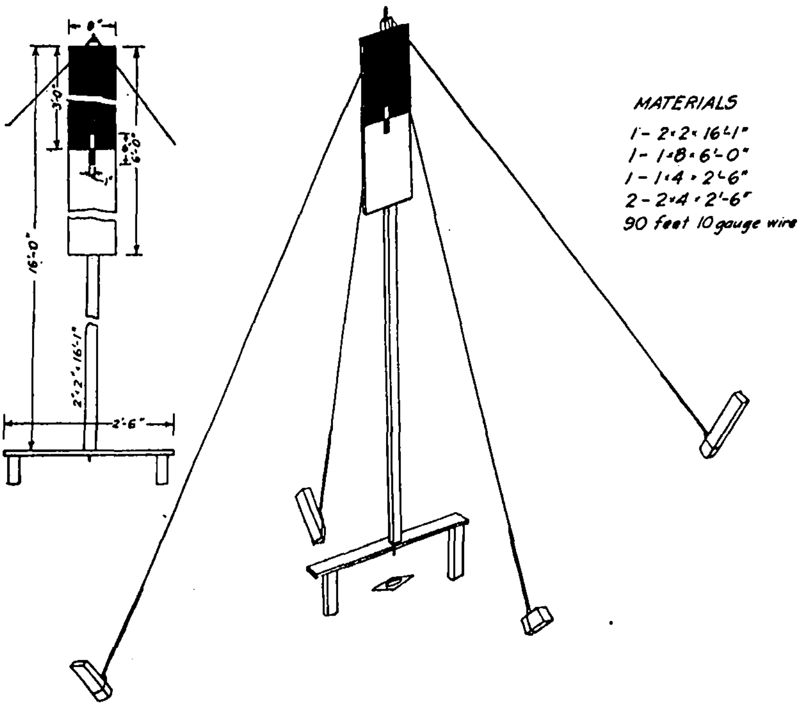



FIG. 52A.—Diagram of a pole signal.

Figure 51 shows a scaffold constructed of poles around a large tree. The tree was used in place of the tripod to support the instrument and the scaffold supported the observer. This type of signal was built because it was not practicable to get lumber to this station; neither was it practicable to clear the lines to make the stations intervisible from the ground. This illustrates one solution of one of the many problems that may be met in extending triangulation over a timbered country.

### POLE SIGNAL.

Figures 52A and 52B show two different types of pole signal each held in a vertical position by wire guys with the foot of the pole resting on a low bench. The bench may be made of two stakes driven in the ground on either side of the station mark, with a piece of scantling placed across on top and nailed to them. The foot of the pole should have a spike driven at its center projecting about an inch, and when the pole is erected this spike should be placed in a hole bored in the crosspiece of the bench directly over the station. Each set of guys should consist of four wires of No. 12 smooth galvanized wire. The number of sets depends upon the height of the pole. The pole is easily lowered when the station is occupied by loosening the guy or guys on only one side. The guys on the other three sides are not loosened from their anchors. To replace the pole it is only necessary to stand it up on the bench and fasten the loosened guy or guys on the one side. The centering of the pole or that part on which observations are made should be tested

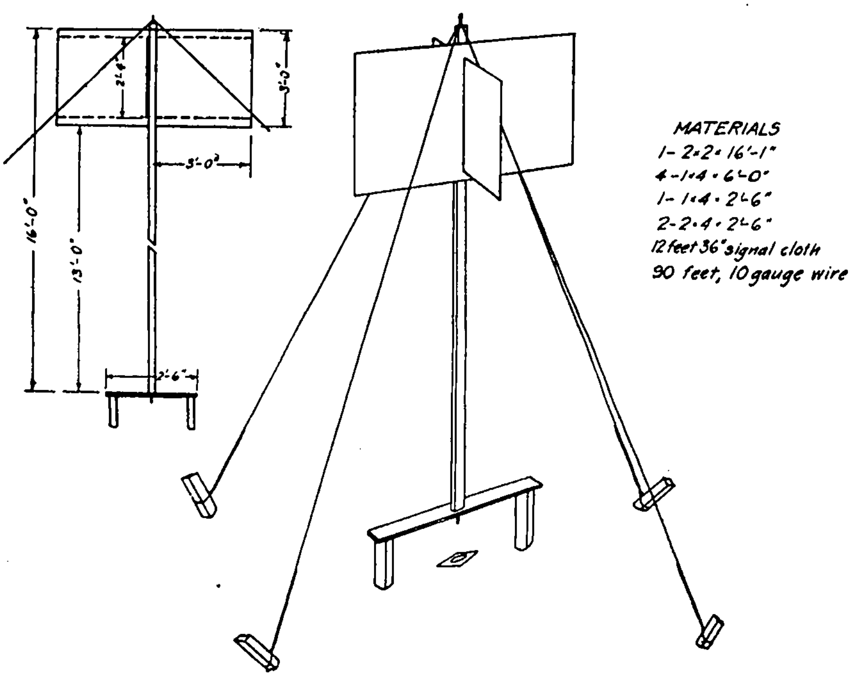



FIG. 52B.—Diagram of a pole signal (another type).

after the pole has thus been replaced, but it will usually be found that it has not been disturbed. A pole signal is a very satisfactory signal on secondary or primary triangulation when the station is to be occupied with a theodolite mounted on its own stand or when the station is not to be occupied.

### SIGNALS FOR PRECISE TRAVERSE.

On precise traverse it is seldom necessary or advisable to build high tripod and scaffold signals. The maximum height is about 40 feet, and the height most commonly used is from 4 to 16 feet for the tripod stand. All signals of this type are made of 2 by 4 inch timbers for the legs and 1 by 4 inch pieces for braces.

Figure 53 shows a tripod stand used at all stations where it is only necessary to elevate the instrument to the height of the observer's eye when he is standing on the ground. This type of tripod can be used at nearly all stations. If it is found necessary to elevate the instrument a few feet higher, it can be done easily by spiking on 2 by 4 inch pieces to lengthen the tripod legs and adding the necessary braces of 1 by 4 inch pieces to make the tripod rigid. A temporary observing platform (fig. 54) can then be built around the tripod.

Figures 55, 56, and 57 show other signals used on traverse work. Figure 58 shows the working drawing of a 30-foot signal.

**Targets.**—On precise traverse many of the lines are short and targets are used for day observations. Care must be taken in the use of targets to avoid phase and to have that part of the target on which observations are made directly over the station mark. It has been found by experience that the only target that will satisfy these conditions and requirements is a flat surface facing directly on the line to be observed, and the flat board target shown in Figure 59 has proved to be the most satisfactory. This target is a board ⅞ inch thick by 6 inches wide and projects about 6 feet above the tripod head. The top half is painted black and the lower half white. It is used on lines 1 mile or more in length. For shorter lines a 1 by 4 inch target projecting 4 feet above the tripod head is sufficient. The targets should be made of well-seasoned lumber of No. 1 grade and should be given two coats of good paint. A number of targets can be made in camp and painted ready for use.

**Portable tripod and scaffold signals.**—On precise traverse where the character of the country makes it necessary to erect tripod and scaffold signals of 16 to 20 feet in height at the majority of the stations time and money can be saved by the use of portable signals that can be moved from station to station. Any signal up to 20 feet in height can be easily transported on a motor truck or on a small trailer attached to a motor velocipede car, if such are used.

Figure 60 shows several tripod and scaffold signals nested on a trailer. The large tripod shown is 20 feet high when erected. Smaller tripods are nested inside the larger one. Two or more of the larger tripods may be nested if necessary.

Figure 61 shows the 20-foot portable signal, consisting of tripod and scaffold erected over the station. It will be noted that the signal is complete except for the floor to support the observer. The floor used for this purpose is 6 by 7 feet made of ⅞-inch boards in three sections. The floor is only needed while the observer is at work on the signal and so is moved with the observer. Six or more of the portable signals are necessary to keep the work moving. The building and observing parties work as a combined party.

The tripod of the signal shown in Figure 61 is nailed together and transported whole. In framing the scaffold sides Nos. 1 and 3 are framed, and the ties and diagonal braces are nailed in place. The ties and diagonals for sides Nos. 2 and 4 are framed and put on with bolts. Each piece is numbered on the ends and the same number placed on the leg of the scaffold at the place where the brace bolts on. When the signal is taken down to be moved forward, it is only necessary to remove the bolts from the ties and diagonals on sides

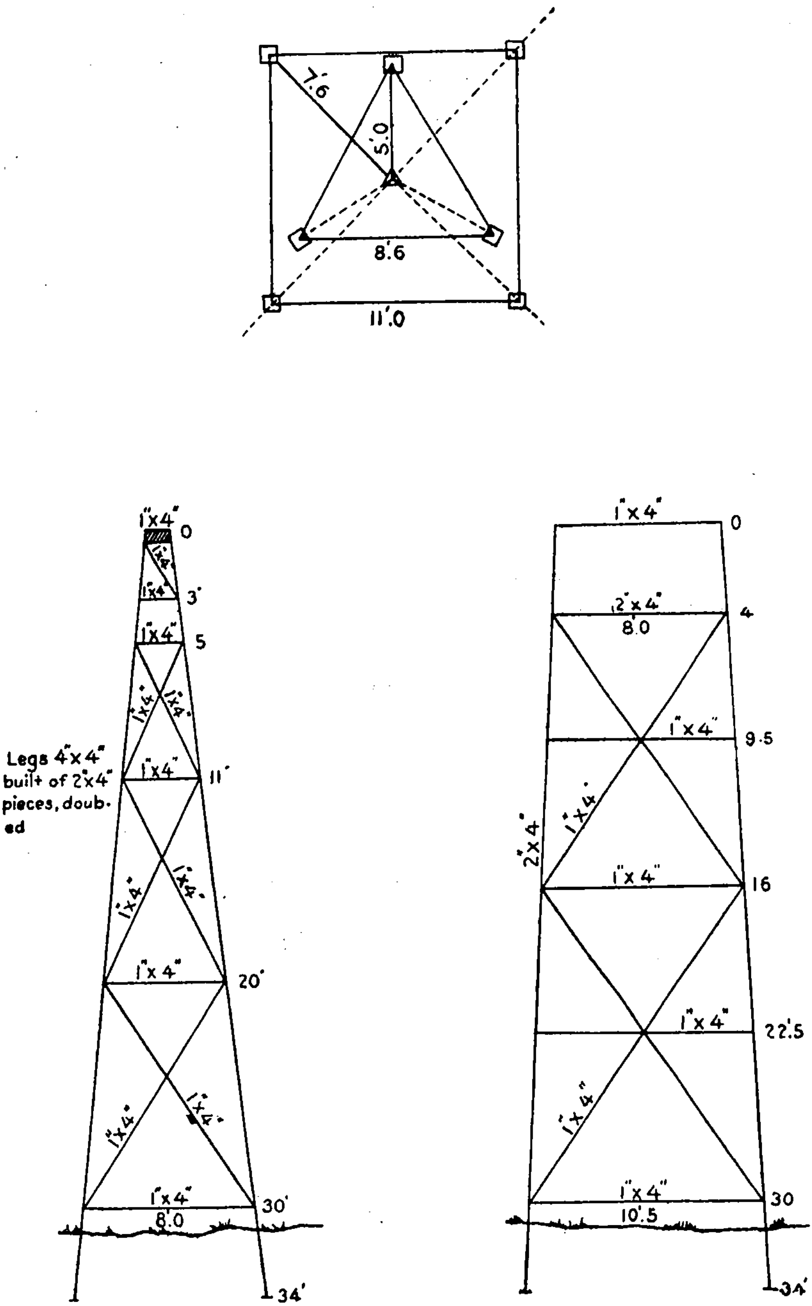



FIG. 58.—Working drawing of 30-foot traverse signal.

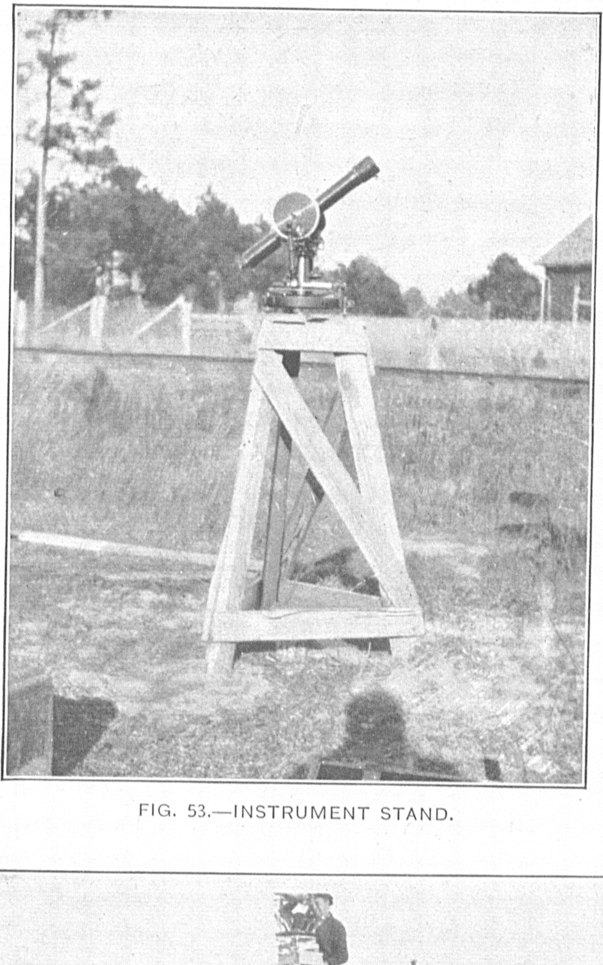


FIG. 53.—INSTRUMENT STAND.

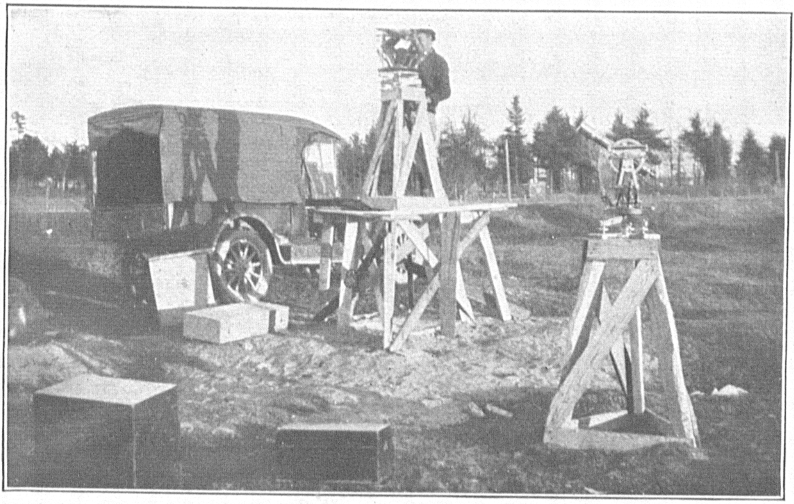


FIG. 54.—INSTRUMENT STAND AND PLATFORM FOR OBSERVER.

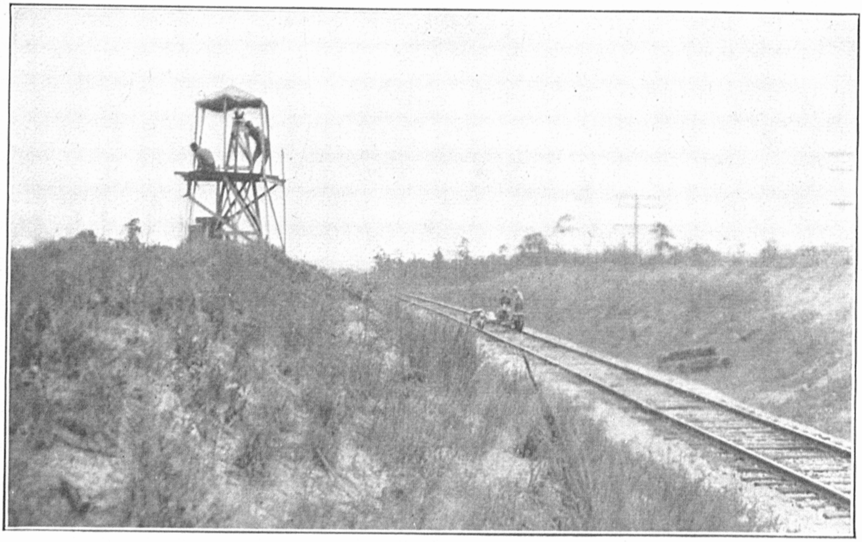


FIG. 55.—EXAMPLE OF SIGNAL USED ON TRAVERSE.

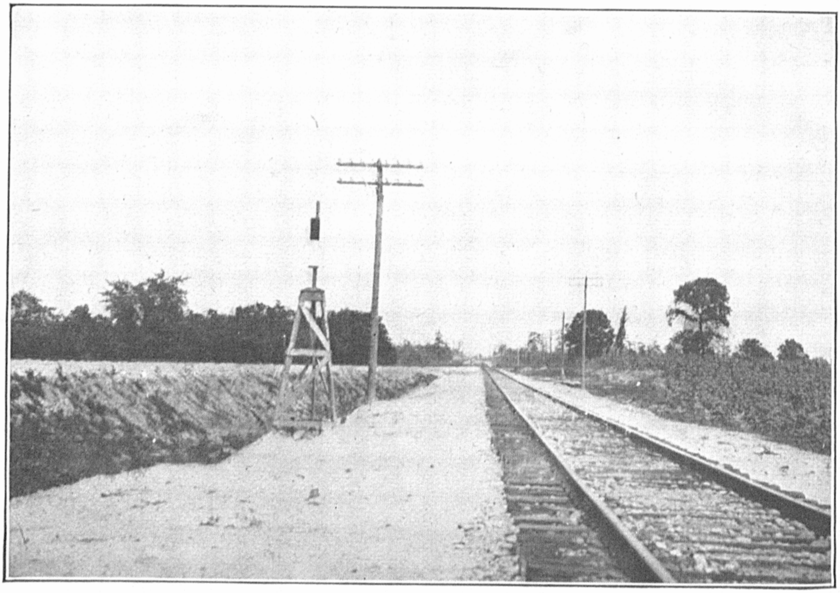


FIG. 56.—TRIPOD OF TRAVERSE SIGNAL WITH TARGET.

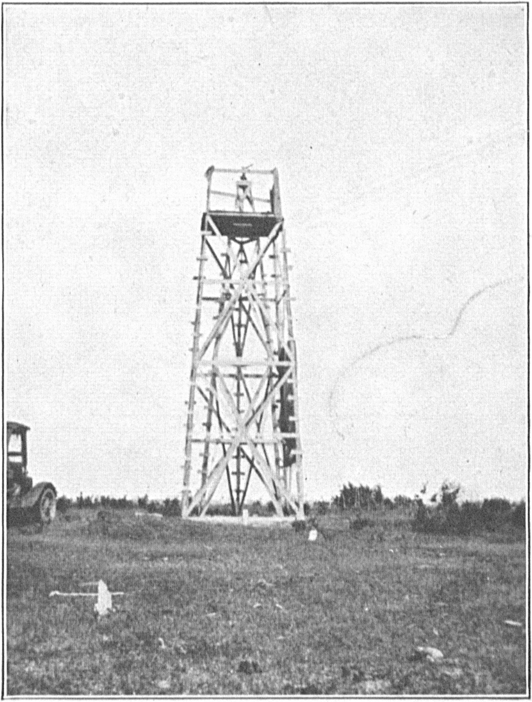


FIG. 57.—SIGNAL 30 FEET HIGH USED ON TRAVERSE.

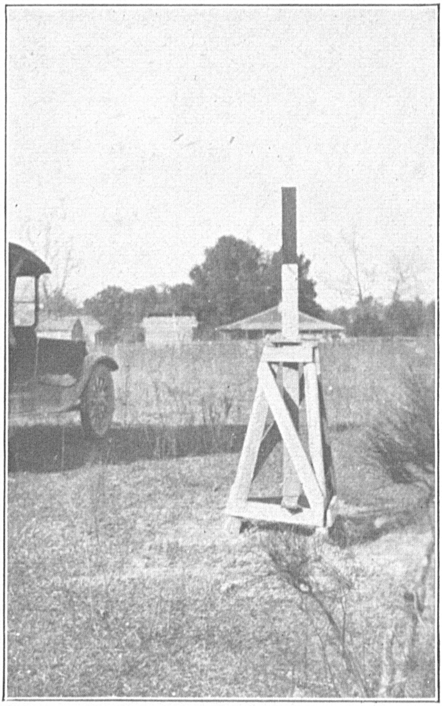


FIG. 59.—INSTRUMENT STAND WITH TARGET.

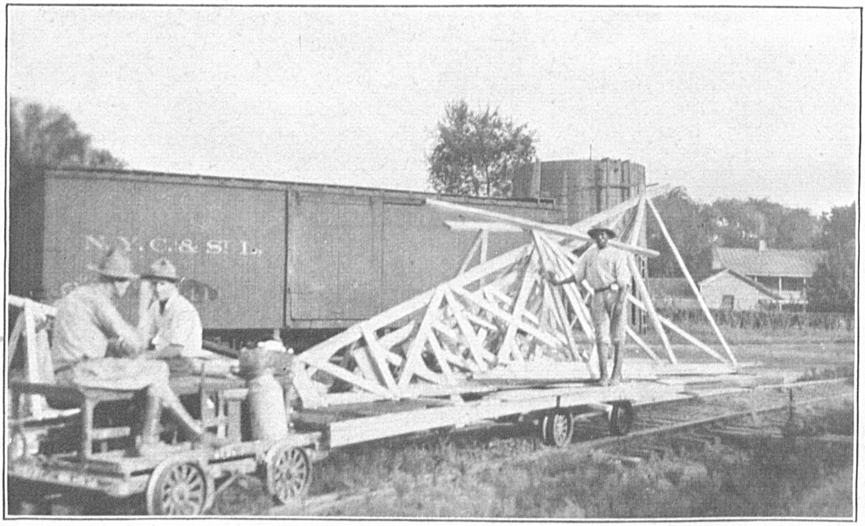



FIG. 60.—NEST OF PORTABLE TRIPODS AND MATERIAL FOR SCAFFOLDS LOADED ON A TRAILER WHICH IS HAULED BY MOTOR VELOCIPEDE CAR.

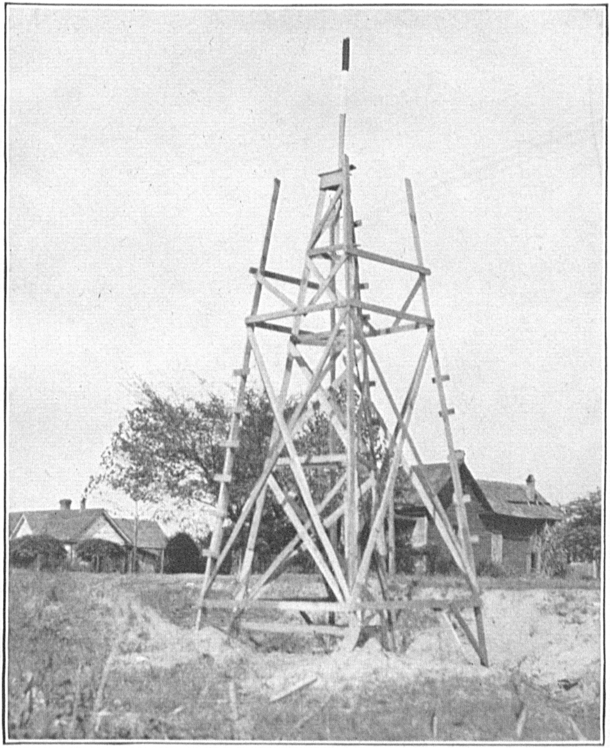


FIG. 61.—PORTABLE SIGNAL 20 FEET HIGH ERECTED.

Nos. 2 and 4. The legs for both tripod and scaffold are made of 2 by 4 inch timbers and all ties and diagonals of 1 by 4, except the ties which support the floor timbers, which are 2 by 4. Two men will erect a signal of this type in about three-quarters of an hour and will take it down in 20 minutes.

If the signal is to be erected over a mark at the intersection of two rail tangents or on line with one tangent, a temporary point on a stake should first be lined in. Set the tripod upright over the stake in approximate position by placing each leg the same distance from the mark. This will determine where to dig the hole for each tripod leg. The holes should be about 15 inches square and about 1 foot deep or to the solid subsoil. If the ground is very uneven, the tripod may be leveled by driving a 2 by 4 inch stake at each of the two low legs of the tripod and on the same slant as the leg. The low legs are then raised to bring the lower tie horizontal and nailed to the stakes. Before nailing the legs to the stakes, however, a heavy plummet should be swung from the center of the tripod head and the tripod head plumbed over the temporary mark. Each leg is anchored by driving two stakes at an angle of about 30° to each other and at a slight inclination to the vertical and nailing them to the leg. The scaffold is erected in a similar manner.

For a 20-foot portable signal the lower tie on the tripod is 7 feet long and the board at the tripod head is 14 inches long. The lower ties of the scaffold are 8 feet long and the floor tie is 6 feet long. The lower ties on both the scaffold and tripod are 2 feet from the bottom end of the legs.

## HYDROGRAPHIC SIGNALS.

Several different types of signals are used for hydrographic work, depending upon the general character of the coast. Along a low, flat coast it is often necessary to construct high signals to make possible the location of sounding lines several miles from shore. These high signals are sometimes built to a height of 100 feet or more and carry large targets to make them visible for long distances. They are usually spaced 4 or 5 miles apart. For the hydrographic work not so far out, smaller signals, usually about 40 feet in height, are erected midway between the high signals. Another type of hydrographic signal, which is also used in carrying triangulation along a flat coast, is known as the water signal. It is located quite a distance from shore in a depth of water as great as 13 feet, but it rests on the bottom and so is not shifted in position by the waves or the wind.

For hydrographic work so far offshore that it is impossible to see signals along the shore floating signals are sometimes used. These signals are anchored in the desired locations, and their positions are then determined by "cuts" from a ship, as follows: The ship is anchored in several successive positions near enough to the shore that the shore signals and the floating signals are visible at the same time. In each position the location of the ship is accurately determined from the shore stations, and then the "cuts" are taken on the floating signals.

## INSTRUCTIONS FOR BUILDING TALL HYDROGRAPHIC SIGNAL.

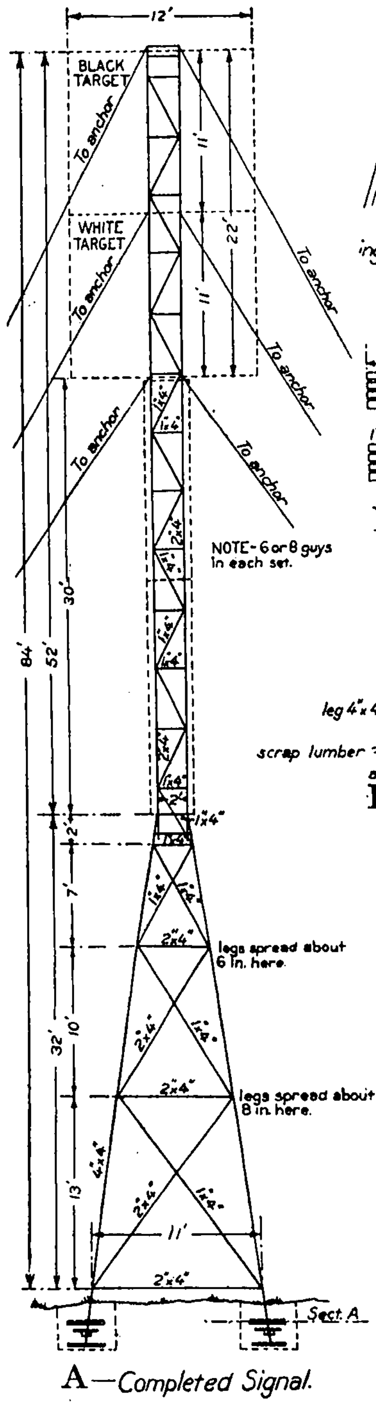
In the following instructions, signal refers to the completed structure, foundation to that part of the signal below ground, scaffold to the wide lower converging part, superstructure to the slender upright section which surmounts the scaffold, target to the broad surface fastened to the superstructure to make it conspicuous, and guys and anchors to the wires and their fastenings which are used to secure the target and superstructure against the wind.

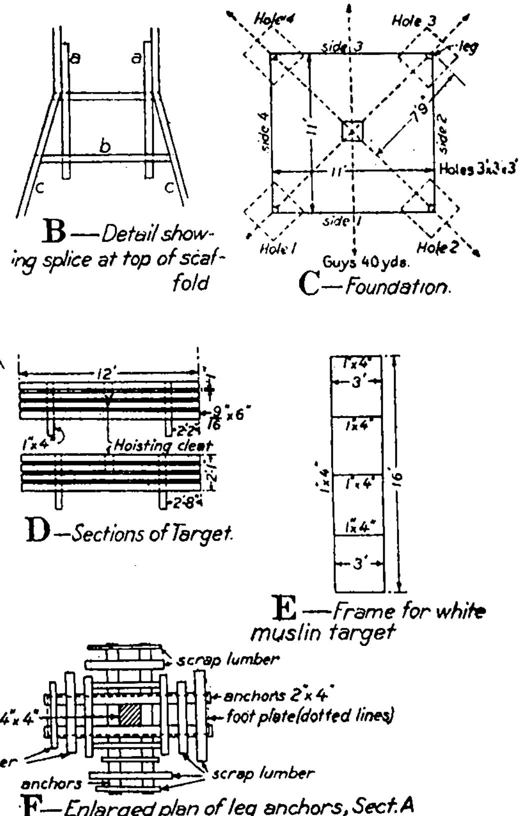
**Foundation.**—Stakes are driven to mark the positions for the holes, Nos. 1, 2, 3, and 4, as shown in *C*, Figure 62. The holes should be made about 3 feet square and 3 feet deep. In the bottom of each hole place a footplate 2 by 8 inches and 2½ feet long made of two 2 by 4 inch pieces held together with 1 by 4 inch pieces nailed across the ends. Spend no time in bringing the bottom of the four holes to the same level, but after the footplates are set take a round of levels with a carpenter's level, using any one of the footplates as a zero bench, and cut the corresponding legs of the scaffold to agree with the differences of elevations.

**Scaffold.**—*A*, Figure 62, shows the working plan for the scaffold. Outside measurements are consistently shown except in the spacing of the horizontal ties. Two of the sides of the scaffold are completely framed and assembled on the ground and raised to place with a tackle, as in the case of a triangulation signal. (See p. 43.) The horizontal ties and diagonal braces belonging to the other two sides are then nailed on.

In selecting the place on the ground for laying out the two sides that are built before raising it should be observed that the ties and diagonals are placed on the outside of the scaffold, and so the first side of a signal can be framed on the ground and raised without first turning it over; but the other side must be turned over on the ground to get the ties and diagonals underneath. (See p. 43.)

**Framing.**—The first step is to frame the four legs and number them 1, 2, 3, and 4. The legs are made 4 by 4 inches and 36 feet long by using 2 by 4 inch pieces and breaking joints, so that a distance of at least 4 feet will intervene between them. Strengthen each joint by nailing a 1 by 4 inch piece 3 feet long over it. Place marks on the legs for the horizontal ties at distances of 2, 9, 19, and 32 feet center to center, measuring from the top of the leg as zero. Put legs Nos. 1 and 2 on the ground in position to frame and nail on the top and bottom ties which have been cut to the length given in the working plan. As each of the intermediate ties is nailed on, force the legs apart from 6 to 10 inches, thereby giving them the desired bend. After the ties are in place, saw off the ends flush with the outside of the leg. Next square each panel by using a steel tape and making both diagonals measure the same, commencing at the bottom panel. Then lay the pieces for the diagonal braces in place and cut the ends parallel with the horizontal ties; nail in place and saw off the projecting ends flush with the outside of the leg. Use twentypenny nails for 2 by 4 inch pieces and eightpenny nails for 1 by 4 inch pieces. Call the finished side No. 1. Then cut the horizontal ties and diagonal braces for sides Nos. 2, 3, and 4 by laying each piece on the corresponding piece of side No. 1 and cutting to match. With a pencil make a cross mark on the outside of the top end of each




**MATERIALS FOR 84 FT. SIGNAL**

| | | | |
|---|---|---|---|
| 40 pieces | 9/16"x6"x12' | - | 240 board ft. |
| 50 " | 2"x4"x16' | - | 533 " " |
| 75 " | 1"x4"x16' | - | 400 " " |
| 40 " | 1"x4"x12' | - | 160 " " |

50 pounds 8 penny nails
25 " 20 " "
1/2 gal. white paint
1/2 " black "
12 yds. white muslin
1/4 pound 8 oz. tacks
2800' smooth galv. wire #8 – 6 guys
Note: *lumber to be dressed on 4 sides*

**LIST OF TOOLS**

| | |
|---|---|
| 2 hand saws | 1 rope, 5/8 in. 125' |
| 1 axe | 2 ropes, 1/2 in. 60' |
| 1 carpenters level | 1 rope, 1/2 in. 200' |
| 1 bevel | 3 6 in. shingle blocks |
| 1 try square | 1 spade |
| 2 rules | 1 shovel |
| 1 hatchet | 2 paint brushes |
| 2 clawhammers | |

FIG. 62.—Working drawings for tall hydrographic signal.

diagonal and assemble the parts for sides Nos. 2 and 4 in a manner convenient to be sent aloft. Before raising the scaffold cleat the legs with 1 by 4 inch pieces 1 foot long, spaced about 2 feet apart.

**Raising.**—Drag side No. 1 back to holes Nos. 1 and 2 in position to raise. Attach two ropes to be used for guys after the side is up. A tackle made of two single blocks and 200 feet of ½-inch rope is used for raising the side. One block is made fast to a post about 20 yards back from the scaffold and the other is made fast near the top of the side to be raised. Start the side up by using props; then raise to a standing position with the tackle and make the two guy ropes fast to stakes.

The side opposite No. 1 is No. 3 and is made up of legs Nos. 3 and 4. It is framed in the same way as side No. 1, but before raising it must be turned over so that the ties and diagonals will be underneath. In placing the legs on the ground for framing select a position such that after the side is framed and turned over no additional maneuvering will be necessary to bring the foot of each leg to its foundation hole. When side No. 3 has been raised to a standing position, nail the ties and diagonals on sides Nos. 2 and 4 and then toenail the legs to the footplates and put on the leg anchors. Figure 63 shows the scaffold erected and the superstructure started.

**Anchors for legs.**—*F*, Figure 62, shows an enlarged plan of the leg anchors which form an important part of the foundation of the signal. To construct an anchor, spike two 2 by 4 inch pieces 2½ feet long on opposite sides of the foot of the leg parallel to each other. Use five twentypenny nails in each piece. Fill in with earth to the top of these pieces, then spike two more pieces of the same size on opposite sides of the leg at right angles to the first two. Nail scrap lumber across the top of the lower pieces and after filling in earth to the top of the upper pieces nail scrap lumber across those, too. Fill the hole with earth, keeping it well tamped.

**Superstructure.**—*A*, Figure 62, shows the front side of the signal. The dotted lines indicate the outline of the targets. The superstructure is made 2 feet square throughout. The ties and braces are 1 by 4 inch pieces. All the ties are cut 2 feet long and spaced 4 feet apart on the legs. The braces are all cut by one pattern by framing one panel of the superstructure and using a brace from that panel in marking and cutting the other braces. The legs are 4 inches square, built up of 2 by 4 inch pieces 4, 8, 12, or, preferably, 16 feet long.

*B*, Figure 62, shows the method of joining the superstructure to the top of the scaffold. As shown in this sketch, 2 by 4 inch pieces 4 feet long (marked "*a*") are used for splices at the top of the scaffold, and the lower end of these pieces are nailed to 2 by 4 inch pieces 2½ feet long (marked "*b*"), which are nailed across the scaffold legs.

When extra large targets are used, the juncture of the superstructure with the scaffold should be made somewhat stronger, as this point is usually the first to fail in a heavy storm. One method of securing the extra strength at this point is illustrated in Figure 64.

The legs, ties, and braces for the superstructure are all marked and cut by the pattern before sending them aloft. Send the legs up by single pieces and the braces in sets of four. One man aloft and inside the structure nails the pieces in place (see fig. 63), while one man on

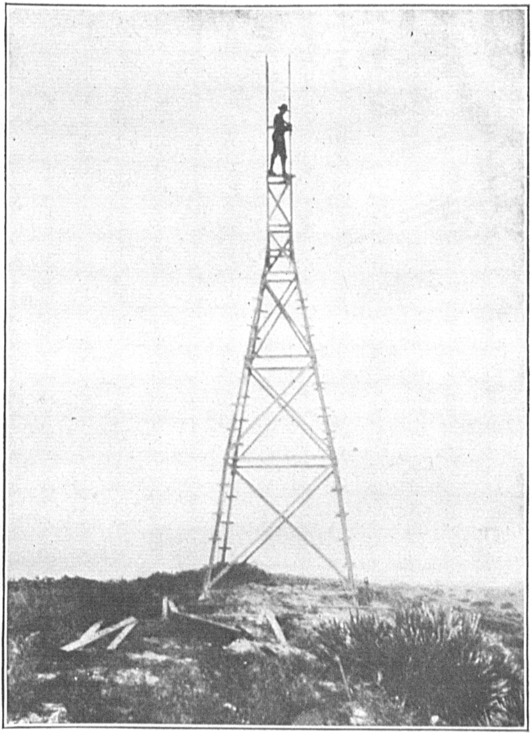


FIG. 63.—BUILDING THE SUPERSTRUCTURE OF A TALL HYDROGRAPHIC SIGNAL.

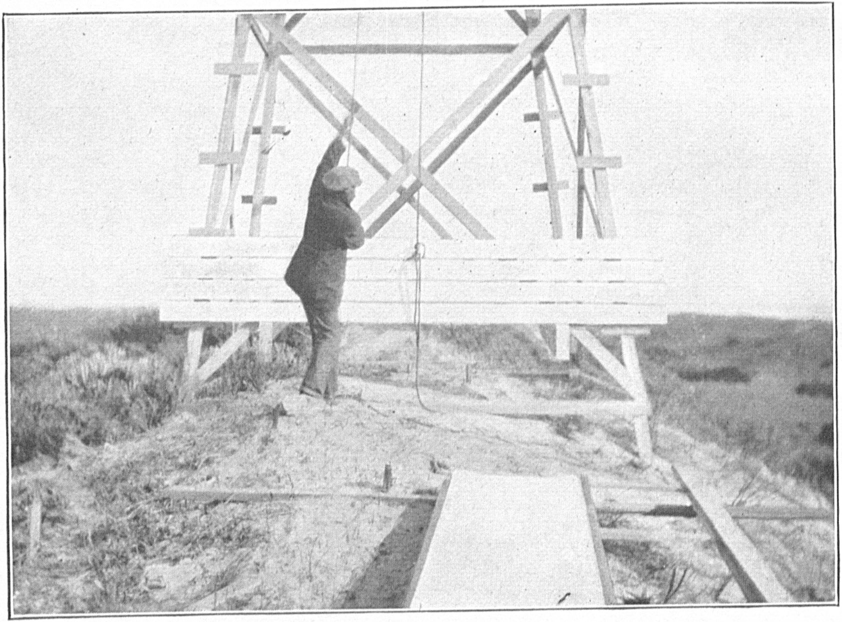


FIG. 65.—SENDING THE TARGET OF A HYDROGRAPHIC SIGNAL ALOFT.

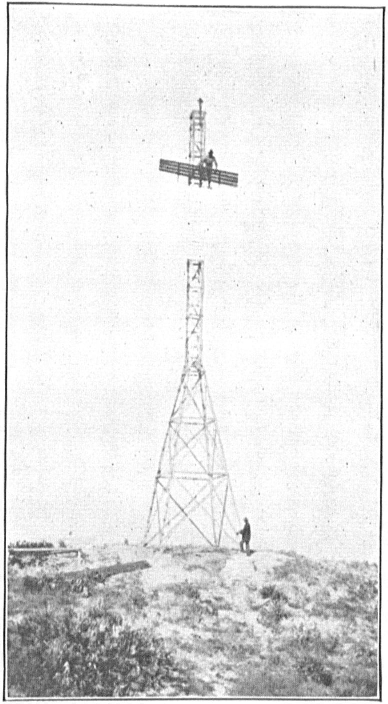


FIG. 66.—PLACING THE TARGET ON A HYDROGRAPHIC SIGNAL.

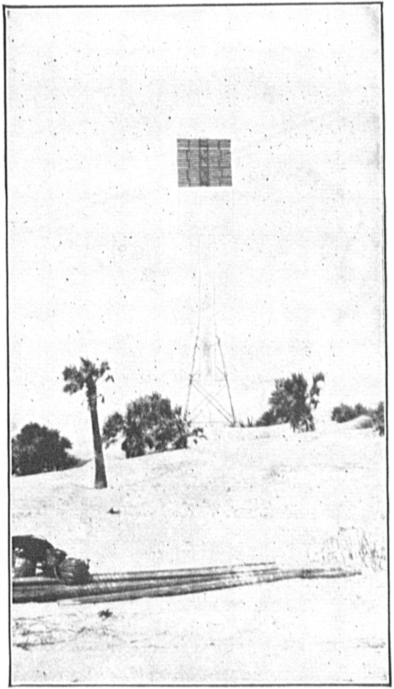


FIG. 67.—COMPLETED TALL HYDROGRAPHIC SIGNAL.

the ground cuts the pieces and sends them up by means of a hauling line. The superstructure may be built 80 or 90 feet above the ground before it is necessary to put on any of the wire guys.

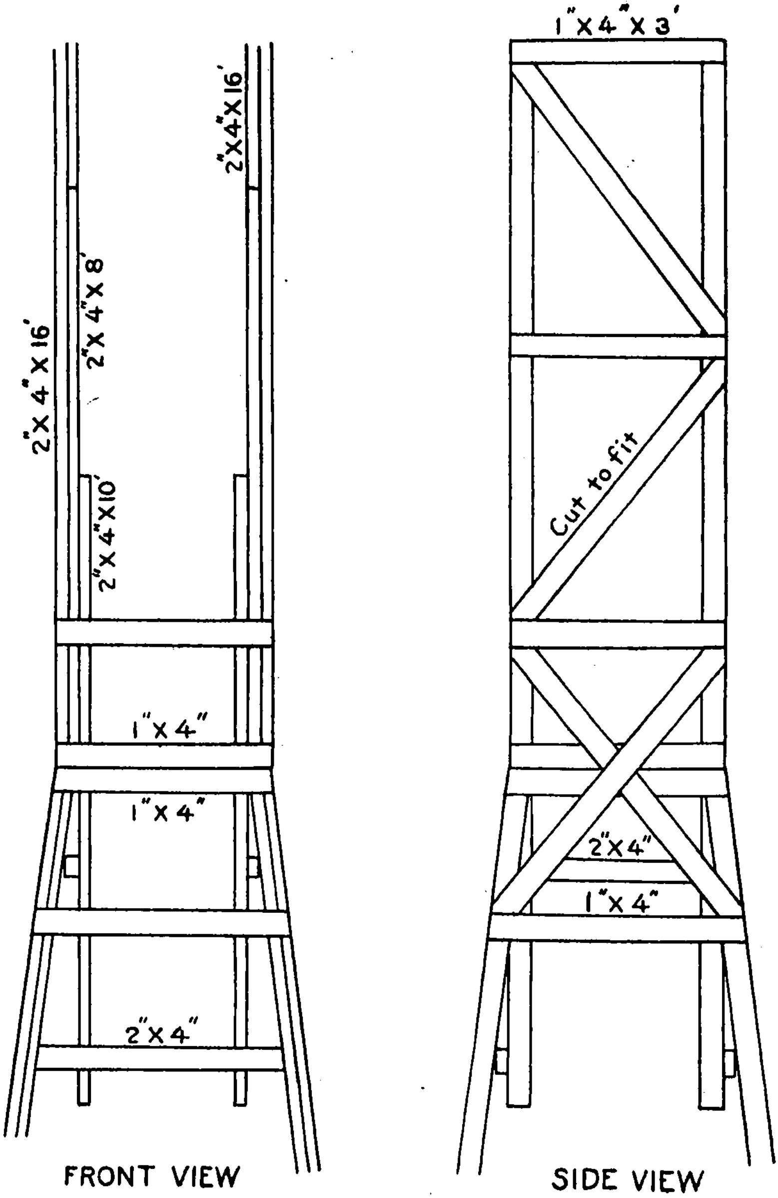



FIG. 64.—Method of strengthening the juncture of the superstructure and scaffold of a tall hydrographic signal.

**Anchors for guys.**—For a signal from 80 to 90 feet in height the anchors should be about 40 yards from the base of the signal. Six anchors should be used for a signal with a target showing in one direction and eight anchors for a signal with two targets at right angles to each other. There should be one anchor opposite each corner in line with the diagonal of the ground plan of the signal, and in addition there should be one anchor directly in front of each target and one directly behind.

For each anchor dig a trench 8 feet long, 2 feet wide, and about 3 feet deep. Lay an anchor timber 8 feet long and not less than 4 by 4 inches in section in the trench and fill the trench with earth to a level with the top of the timber. Then nail scraps of lumber across each end of the timber and fill in the ends of the trench with earth, leaving the middle of the trench open until the guys have been made fast. More scrap lumber is then nailed across the middle part of the timber and the trench filled. Timber for the anchors can usually be picked up on the beach.

**Guys.**—The guys should be No. 8 smooth galvanized wire in three sets, each set consisting of a guy to each anchor. One set is made fast at the top of the superstructure; another set 11 feet below the top, or at the middle of the target; and the third set 22 feet below the top, or at the bottom of the target. The guys are drawn taut by means of a tackle made of two single blocks carrying ½-inch rope. One block is made fast to the standing part of the guy, and the end of the guy is then passed around the anchor and made fast to the other block. With this purchase two men hauling on the rope will put a strain of about 900 pounds on the guy. When the guy is taut, it is held temporarily by a twentypenny nail driven into the anchor close up to the wire and bent over the wire. The tackle is then removed and the end of the wire wound around the anchor two or three times and made fast to the standing part. Tighten the top set of guys first and the lower set last, as this brings more nearly an equal strain on each set of guys when strong wind pressure comes against the signal.

**Targets.**—*A*, Figure 62, shows one side of the signal. The outline of the targets is indicated by broken lines. The top target is 11 by 12 feet in size and is painted black. Beneath it is a target of the same size but painted white. They are made of dressed boards ½ by 6 inches and 12 feet long. Each target is made in five sections of four boards each, nailed to 1 by 4 inch pieces 3 feet long, with a space of 1 inch left between the boards.

*D*, Figure 62, shows two sections of the target and the manner in which the 1 by 4 inch pieces are placed. These pieces project 10 inches below the board when the target is sent aloft. The lower section of the white or lower target is nailed in place first, and when the second section is sent aloft and set in place the projecting 1 by 4 inch pieces drop behind the two top boards of the section below and are nailed to them. The remaining sections are made and put up in the same way as the first two. Five of the sections are painted white and five are painted black. They are given two coats of paint and left to dry before sending aloft.

When building the superstructure, the ties and diagonals on the front side of the five top panels are placed on the inner side of the legs so as to leave a smooth surface for attaching the target. Use eightpenny nails in securing the target to the superstructure, five nails to each board in each leg. Figure 65 shows target with hauling line attached ready to be sent aloft, and Figure 66 shows man aloft setting target in place.

Frames covered with muslin are fastened to the superstructure below the target. Two of these frames, each 16 feet long by 3 feet wide (see *E*, fig. 62), are made and covered with white muslin, then sent aloft and nailed on the superstructure below the targets, as indicated at *A* in Figure 62. The completed signal is shown in Figure 67.

**Notes.**—The signal described above was designed to be visible for a distance of from 10 to 12 miles for hydrographic work. It is constructed at a very low cost for material and labor and yet is strong enough to withstand any ordinary wind and most storms without injury. Signals of this type of an average height of 80 feet were built along the coast of Florida in 1915 at a cost of about $1 per vertical foot, including all materials, pay and subsistence of party, and transportation of party and outfit. Two men built a signal in two days on an average after the material was on the ground.

Should it be necessary to increase the size of the target after the signal has been completed, the superstructure may be built up the required amount and additional sections of the target placed above the part already in place, but in no case should the size of a target be increased without the addition of extra guys.

TOOLS AND MATERIAL NEEDED TO ERECT TALL HYDROGRAPHIC SIGNAL.

*Tools.*

| | | | |
|---|---|---|---|
| Ax | 1 | Rope: | |
| Bevel | 1 | ⅝-inch, 125-foot piece | 1 |
| Blocks, single, 6-inch | 3 | ½-inch, 60-foot pieces | 2 |
| Brushes, paint | 2 | ¼-inch, 200-foot piece | 1 |
| Hammers, claw | 2 | Rules | 2 |
| Handsaws | 2 | Shovel | 1 |
| Hatchet | 1 | Spade | 1 |
| Level, carpenter's | 1 | Square, try | 1 |

*Material for 84-foot signal.*

| | | |
|---|---|---|
| Lumber, dressed: | | |
| 2 by 4 inches by 16 feet | pieces | 50 |
| 1 by 4 inches by 16 feet | do | 75 |
| 1 by 4 inches by 12 feet | do | 40 |
| $\frac{9}{16}$ by 6 inches by 12 feet | do | 40 |
| Muslin, white | yards | 12 |
| Nails: | | |
| Eightpenny | pounds | 50 |
| Twentypenny | do | 25 |
| Paint: | | |
| White | gallon | ½ |
| Black | do | ¼ |
| Tacks, 8-ounce | pound | ¼ |
| Wire, smooth galvanized, No. 8 | feet | 2,800 |

TALL HYDROGRAPHIC SIGNAL, 1917 TYPE.

In 1917 some tall hydrographic signals were constructed which had large board targets 16 by 50 feet and on this account required additional strength in the superstructure, guys, and anchors. The superstructure was made 3 feet square, and all joints in the legs were reinforced with 2 by 4 inch pieces, 4 or 5 feet long. Twelve anchors were used for the wire guys, two opposite each corner in line with the diagonal of the ground plan of the signal, two directly in front of the signal target, and two directly behind it. For a 100-foot signal one set of anchors were placed about 30 to 35 yards from the signal and the second set 45 to 50 yards.

Five guys were attached at different heights to each corner of the signal and four guys to the front and four guys to the back of the

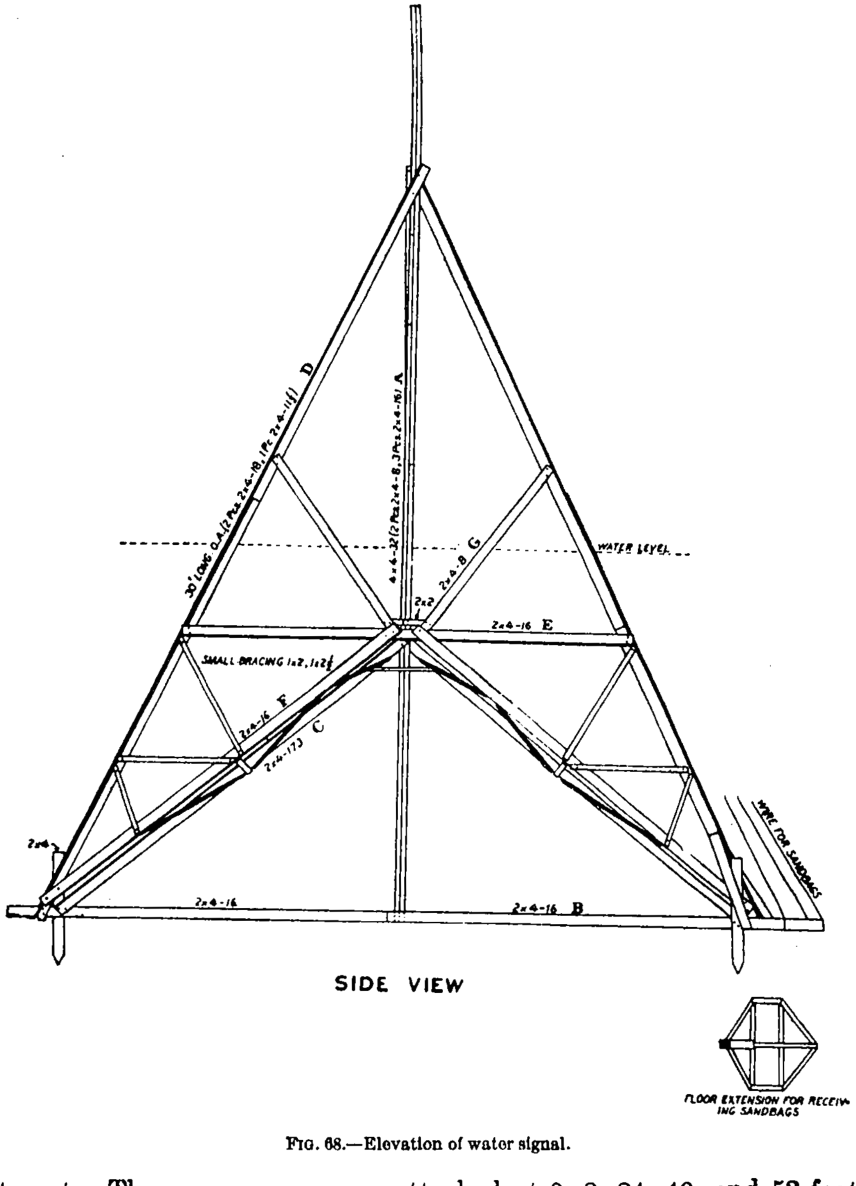



Fig. 68.—Elevation of water signal.

target. The corner guys were attached at 0, 8, 24, 40, and 52 feet from the top of the superstructure and the target guys at 4, 16, 32, and 46 feet from the top. All guys were No. 6 smooth galvanized wire except the corner guys at 0 and 40 feet from the top, which were No. 4 smooth galvanized wire. About 200 pounds of No. 4 wire and 350 pounds of No. 6 wire were required for each signal.

### WATER SIGNALS FOR TRIANGULATION AND HYDROGRAPHY.

Along certain sections of the coast it is sometimes desirable to locate a station in the water some distance from the shore. In some cases the position of this station is determined by observations from land stations. In other cases it becomes necessary to occupy the water station itself with a theodolite. The signal must be built in such a way that it will not be shifted in position by wave action or wind pressure, and if it is to be occupied with an instrument it must be steady enough to permit accurate angle measurements.

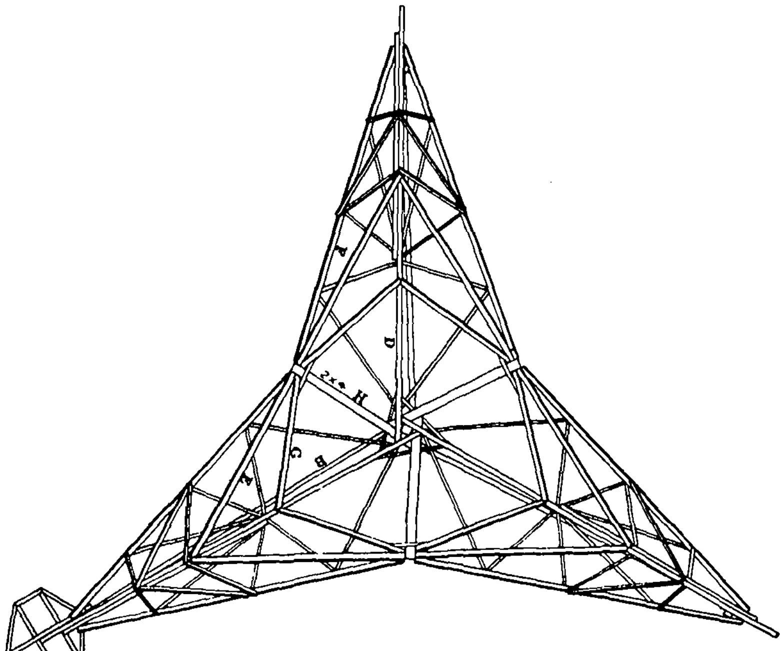



FIG. 69.—Plan of water signal.

The type of water signal described below is one that has been used successfully in depths as great as 13 feet. The elevation and plan of the tripod instrument support of this signal are shown in Figures 68 and 69, and the different steps in its construction are shown in Figure 70. The tripod has a large spread at the base to minimize the amount and effects of any unequal settling in soft bottom and has an extensive system of bracing for rigidity. A vertical stake attached to the foot of each leg of the tripod and weights in the form of bags of sand placed on platforms attached to each foot help to prevent any shift of position of the signal. The tripod is designed so that the center of bracing is well below the surface of the water where the greatest rigidity is required and to offer the least possible resistance to the waves at the surface of the water. The twisting motion caused by the waves acting unequally on different parts of the structure is by far the greatest factor to be considered in obtaining a rigid structure.

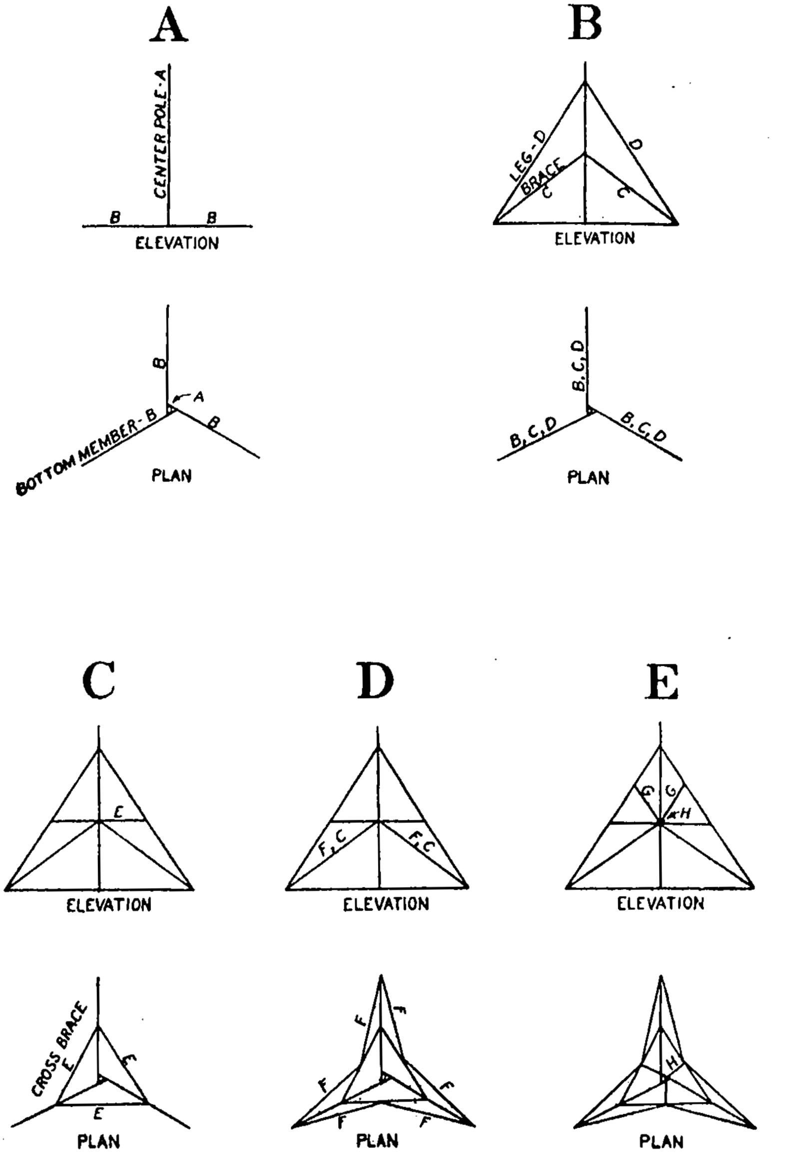



FIG. 70.—Steps in construction of water signal.

The tripod is built on shore, carried into the water and launched, towed to the desired location, and finally placed in position and weighted down. The scaffold for supporting the observer is then built independently of the tripod. The size of the structure depends, of course, upon the depth of water in which it is used. The dimensions given in Figure 68 were found suitable for a depth of 13 feet.

CONSTRUCTION.

For building the tripod a level place on the beach is selected as near as possible to deep water and not too far from where the station is to be located. The bottom section of the center pole, consisting of two 2 by 4 inch pieces 8 and 16 feet long, respectively, is placed in a vertical position and held by temporary supports. The three bottom members *B* are then placed on the ground in a level position at angles of about 120° with each other and nailed to the bottom of the center pole. Temporary braces are then nailed from each bottom member *B* to the center pole and the center pole extended by lapping on another 2 by 4 inch piece 16 feet long. The lower diagonal braces *C* (see *B*, fig. 70) are next nailed in place, and after the center pole has again been extended the upper diagonals or legs *D* are put on. The horizontal braces *E* are then nailed to the legs *D* at about the same height as the tops of the *C* diagonals. The members *F* (see *D*, fig. 70), which extend from the bottom of the legs *D* to the middle of the members *E*, are then attached, and the remainder of the construction, such as cross and diagonal bracing between the members *C*, *D*, and *F*, is done as indicated in Figure 69 in order to insure a rigid structure.

The dimensions of the various members are shown in Figure 68. The materials needed for the signal are given in the list on page 72.

**Launching and towing.**—Twelve men are required to carry the tripod into the water. When a depth of about 3 feet has been reached, the tripod is put down and turned over on its side. The overturning movement is controlled by attaching a line to the leg being raised and keeping this line taut after the balancing point has been passed. The water also helps to retard the movement and prevent injury to the structure. The tripod is floated in the overturned position by means of lines from the two submerged legs to the bow and stern of a whaleboat and a line from the end of the center pole to a dinghy. After the tripod has been raised just enough to clear the bottom it is towed to the ship by a launch. Barrel buoys are then substituted in place of the boats to float the signal, and the ship is used to tow it to the desired position, using care not to allow the barrel buoys to become submerged.

**Uprighting tripod.**—When the tripod is released form the buoys in 10 or 12 feet of water, it will tend to rest on the bottom on the ends of two of its legs. Temporary weights can be used to hold it in this position. The leg which projects out of the water can then be boarded by two men, who built the platform for holding the weights on the foot of the leg and attached four wires to different parts of the platform for use in guiding the weights when the tripod has been uprighted. The tripod is next rolled over to bring another leg up, and a similar platform with wires attached is built at the foot of this leg. After the third leg has been completed in the same way the tripod is uprighted by lifting the end of the center pole a few feet above the water; using a line to the ship if necessary.

About 60 cement bags filled with sand are needed to weight the tripod down. They may be placed in position by attaching a wire loop to the neck of each bag and letting this loop slide down one of the wires attached to one of the three platforms while the wire is held vertical. The bags should be lowered carefully with a slip line.

After all the bags have been lowered the guide wires should be attached securely to the tripod.

If necessary to add a superstructure to elevate the instrument, it should be built in the form of a slender tripod attached to the legs of the main tripod and properly braced. (See fig. 71.) It should not be extended more than 12 feet above the apex of the main tripod. The target is attached to the top of the superstructure in such a way that it may be detached easily. When the station is occupied, the target is removed and the instrument, mounted on its own tripod, is lashed securely to the top of the superstructure.

The observer's stand is built independent of the instrument support by driving pipes into the bottom, to each of which a scantling is lashed with wire seizing. The necessary bracing and floor can then be attached to these legs. (See fig. 72.)

## LIST OF MATERIAL FOR WATER SIGNAL.

*Tripod instrument support.*

| | | |
|---|---|---|
| Bags, cement, containers for sand ballast | | 60 |
| Lumber, rough: | | |
| 2 by 4 inches by 18 feet | pieces.. | 9 |
| 2 by 4 inches by 16 feet | do.... | 15 |
| 2 by 4 inches by 12 feet | do.... | 4 |
| 2 by 4 inches by 8 feet | do.... | 8 |
| 1 by 2½ inches | linear feet.. | 72 |
| 1 by 2 inches | do.... | 112 |
| Marline, for tying bags | feet.. | 140 |
| Nails: | | |
| Forty-penny | pounds.. | 10 |
| Twenty-penny | do.... | 10 |
| Ten-penny | do.... | 10 |
| Wire: | | |
| Telephone No. 5, for guide wires | feet.... | 240 |
| Telephone No. 10, for attaching bags to guide wires | do.... | 200 |

*Superstructure.*

| | | |
|---|---|---|
| Lumber, rough: | | |
| 2 by 4 inches by 16 feet | pieces.. | 5 |
| 2 by 3 inches | board feet.. | 48 |
| 1 by 3 inches | do.... | 24 |

*Observers stand.*

| | | |
|---|---|---|
| Lumber: | | |
| 1 by 6 inches, for floor | board feet.. | 14 |
| Rough— | | |
| 2 by 4 inches by 16 feet | pieces.. | 6 |
| 2 by 4 inches by 10 feet | do.... | 3 |
| 2 by 3 inches by 16 feet | do.... | 7 |
| Pipe, 2½ inches in diameter, 20 feet long | do.... | 3 |

## FLOATING HYDROGRAPHIC SIGNAL, THREE-BARREL BUOY.

The following type of floating signal has been used with success by parties on the Atlantic coast: Three barrels, each of 50-gallons capacity, are fastened together, bilge to bilge. They float upright and support a center pole 4 inches square by 23 feet long. A concrete counterweight, weighing about 700 pounds, is cast on the bottom of the center pole to hold the signal upright. A target of two crossed banners of bronze screening, each 6 by 8 feet, is bolted to the center

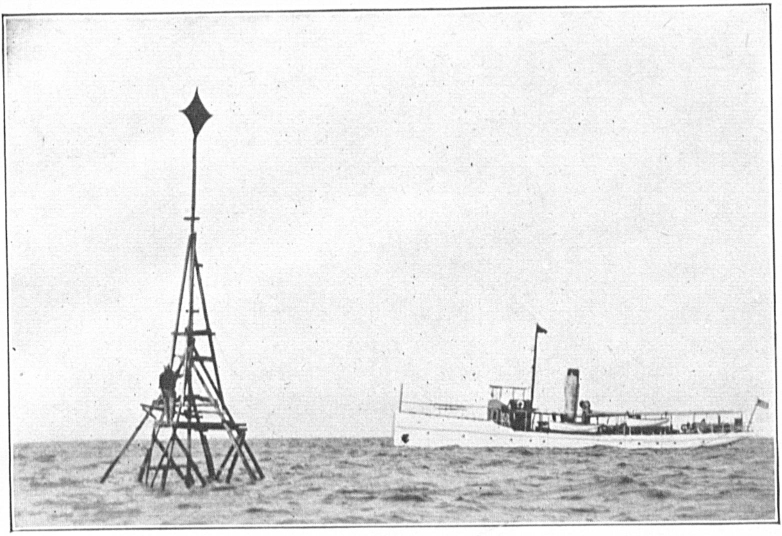


FIG. 71.—COMPLETED WATER SIGNAL IN PLACE.

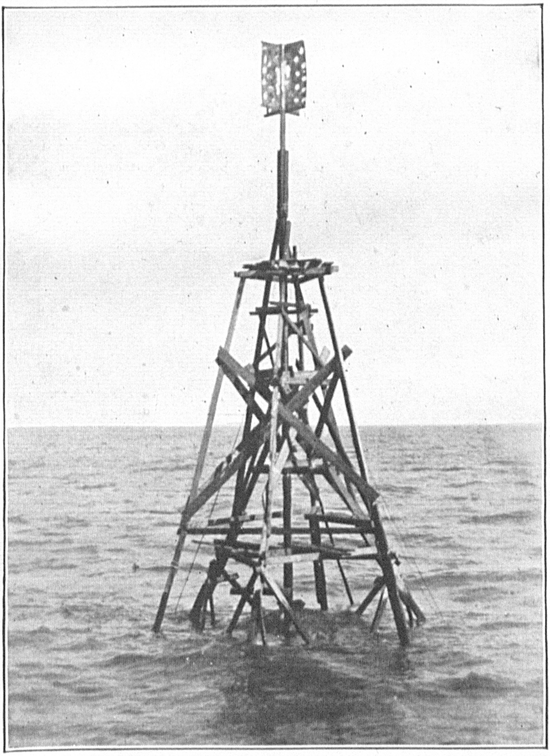


FIG. 72.—WATER SIGNAL WITH SCAFFOLD FOR OBSERVER.

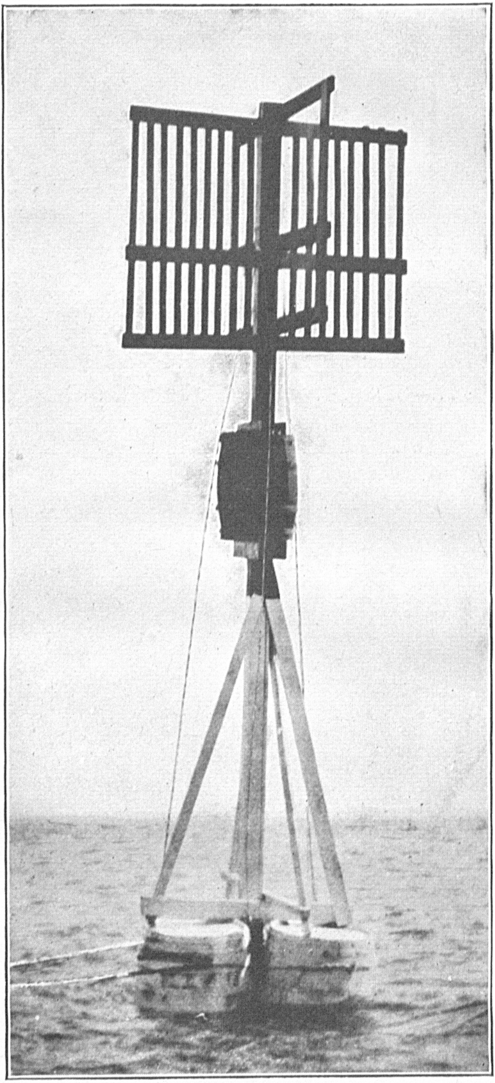


FIG. 74.—THREE-BARREL BUOY SIGNAL.

pole so as to make the top of the target about 16 feet above the top of the barrels. This target is guyed to the cross braces on the top of the barrels. A 1,500-pound concrete block is used as an anchor. The anchor line is ½-inch wire rope, except for an 18-foot section of

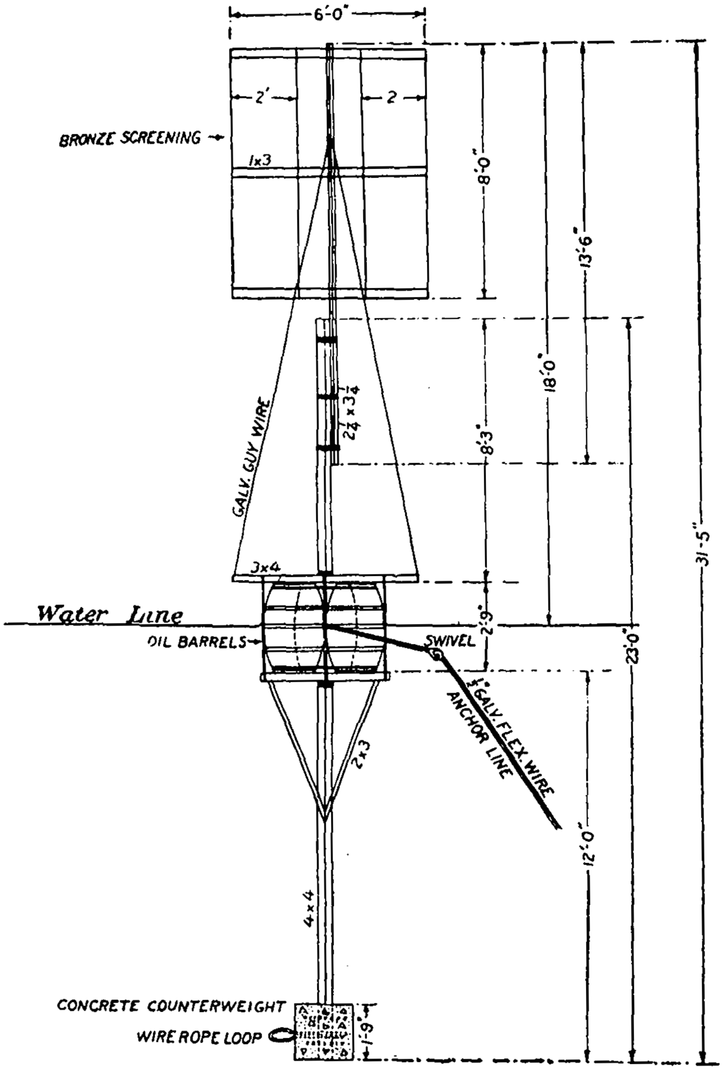



FIG. 73.—Working drawing of the three-barrel buoy signal.

chain next to the anchor, and has a thimble spliced in the upper end for shackling to the buoy.

In constructing the buoy two of the barrels are laid side by side on their bilges and temporarily secured. The center pole is laid on top parallel with the barrels and with two of its faces tangent to their bilges. The center pole is notched slightly to receive the top barrel, which is placed on top of and parallel to the other two. This top barrel will naturally rest on one barrel and the center pole. Wooden wedges are used as necessary to fill in any space between the barrels. The three barrels are lashed together, using several turns of ⅛-inch

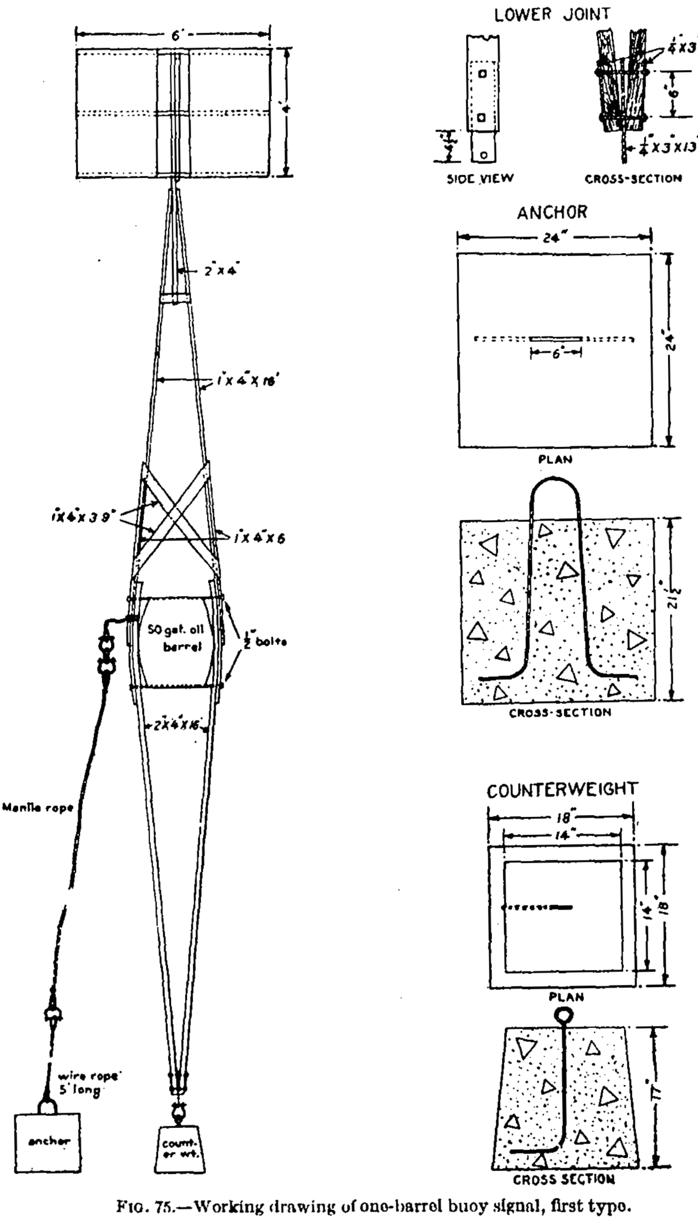



FIG. 75.—Working drawing of one-barrel buoy signal, first type.

galvanized wire at each end of the barrels just below the hoops. These two lashings are cross lashed and all are set taut with a Spanish windlass. Four cross pieces 3 by 4 inches notched to receive the chimes of the barrels are nailed to the center pole, two at each end of the barrels, and lashed together with ⅛-inch galvanized wire. These cross braces are to prevent any movement of the barrels along the center pole. The cross pieces at the top of the barrels extend about 6 inches beyond the barrels, and the guy wires from the target pole are secured to them and set taut with a Spanish windlass. Four diagonal braces 2 by 3 inches and 6 feet long are run from the bottom cross pieces to the lower extension of the center pole for additional stiffening. (See fig. 73.)

The concrete counterweight should have suitable reinforcement to secure it to the center pole. It can be cast at the same time the other work is in progress. The bottom of the counterweight should be about 12 feet from the bottom of the barrel. A wire rope loop for tackle fastening is cast in the counterweight on the same side of the counterweight as the anchor line pendant mentioned in the next paragraph and in line with it. When handling the buoy, two tackles are used, one fastened to this loop and the other to the anchor pendant, and the buoy is hoisted or lowered while horizontal.

An anchor pendant 3 feet long of ½-inch wire rope with a swivel on the free end is made fast to the buoy at the water line. The anchor line is shackled to this swivel. The target can be secured to the buoy just before lowering and can be removed immediately after hoisting. This permits two or three buoys to be nested on deck when necessary. A three-barrel buoy similar to the one described above, except for the target, is shown in Figure 74.

### FLOATING HYDROGRAPHIC SIGNAL, ONE-BARREL BUOY.

The construction of the one-barrel buoy signal is clearly indicated in Figure 75. This type of signal is very simple, and the complete buoy, including anchor and counterweight, can be readily constructed aboard ship in a limited deck space. It can therefore be built by members of the ship's crew while on the working grounds. Five or more of these buoys may be conveniently nested in a limited space on deck by unshackling the counterweight and anchor and removing the target.

Experience has shown that this type of signal buoy, because of its much lighter construction, is more easily "planted" in position and picked up again than the three-barrel buoy described on page 72. The target remains visible to the observer to practically as great a distance as the target of the three-barrel buoy. It can be built very quickly and at much less cost than the three-barrel buoy.

*Materials for one-barrel buoy signal.*

| | | |
|---|---|---|
| Bar, iron, ¼ by 3 inches | feet | 2½ |
| Barrel, wooden, oil | | 1 |
| Bolts, ½ by 6 inches, with nuts and washers | | 2 |
| Cement, Portland | bags | 4 |
| Cloth | yard | 1 |
| Lumber: | | |
| 2 by 4 inches by 16 feet | pieces | 2½ |
| 1 by 4 inches by 16 feet | do | 3 |
| Nails, eightpenny | pounds | 2 |
| Paint, black | gallon | ⅓ |
| Rod, iron: | | |
| ¾ inch in diameter | feet | 9½ |
| ½ inch in diameter | do | 6 |

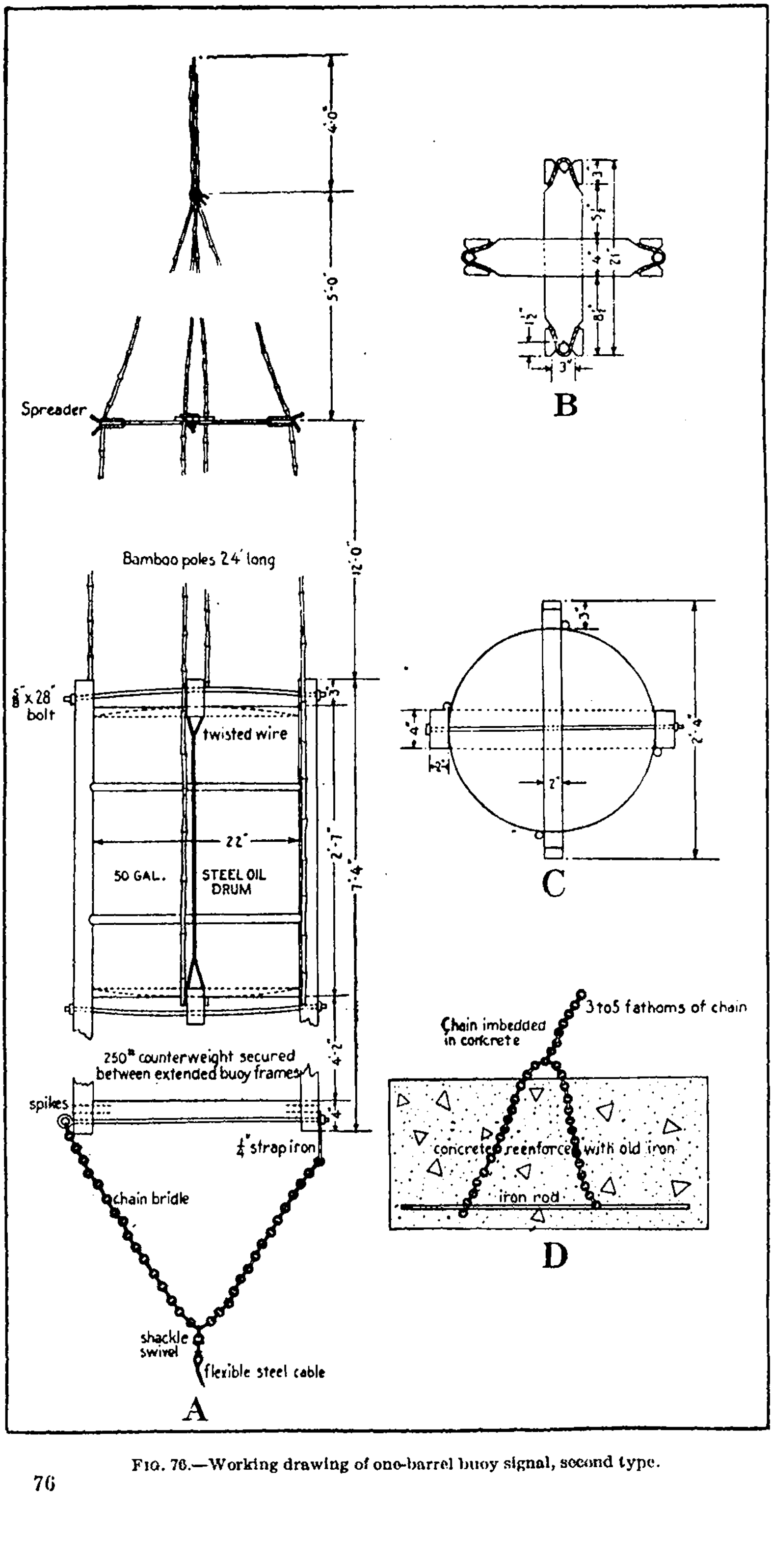



FIG. 76.—Working drawing of one-barrel buoy signal, second type.

| | | |
|---|---|---|
| Rope: | | |
| Manila, 3½ inches in circumference | feet | 180 |
| ½-inch stranded wire | do | 5 |
| Screen, wire, black | square feet | 32 |
| Shackles, G. I.: | | |
| ¾-inch | | 5 |
| ½-inch | | 2 |
| Tacks, 6-ounce | package | 1 |
| Thimbles, G. I.: | | |
| 1-inch | | 3 |
| ½-inch | | 2 |

Another type of one-barrel buoy signal is shown in Figure 76. It is made of a 50-gallon steel oil drum, carrying a framework to which a bamboo superstructure and a suitable counterweight is attached. The drum is tested for leaks and painted with red lead. The framework is made of 2 by 4 inch pieces, notched to fit the projections on the drum, and is bolted and lashed together as shown in *A*, Figure 76. Four bamboo poles each 24 feet long are lashed securely to this framework and the tops of the poles are lashed together. A spreader shown in *B*, Figure 76, is inserted 8 or 9 feet from the top of the poles and securely lashed to them with marline.

White signal cloth is sewed to the poles between the spreader and the point where the poles come together and two black flags are attached to the top of the poles.

The counterweight may consist of junk iron, such as old grate bars, and is secured to the lower ends of two extended frame members, as indicated in *A*, Figure 76. This counterweight should weigh approximately 200 pounds.

The anchor should weigh about 700 pounds. It may be made of concrete reinforced with junk iron and should have a chain bridle properly secured, as shown in *D*, Figure 76. A convenient form for the concrete may be made of three discarded motor truck rims piled on edge. From 3 to 5 fathoms of chain should be attached to the bridle in the anchor. The anchor cable should consist of ⅜-inch flexible galvanized-steel rope with a swivel at each end, one end shackled to the chain leading from the anchor and the other end shackled to the chain bridle secured to the extended frame of the buoy. (See *A*, fig. 76.)

The anchor and the framework around the drum may be constructed ashore over week ends while the ship is in port for coal. The rest of the signal may be constructed aboard ship.

When preparing to plant a buoy the cable is secured to the anchor and is led along the outside of the rail, around the stern of the vessel, and up the port side to the buoy which is launched from the forward port davit. After the buoy is lowered into the water the vessel proceeds slow ahead full left until the buoy has cleared the port side. The wheel is then thrown full right to bring the buoy on the starboard quarter and give a clear lead to the anchor. The anchor is lifted over the side from the after starboard davit and, after all slack has been taken out of the cable, is cut away.

Fourteen buoys of this type were planted during one season and all but two remained in place until work had been completed upon them. In spite of several storms the superstructure on all buoys remained intact throughout the season.

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