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PLANS AND SPECIFICATIONS

FOR

CURRENT-METER GAGING STATIONS

WATER-RESOURCES BRANCH

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PLANS AND SPECIFICATIONS FOR CURRENT-METER GAGING STATIONS.

By C. C. Covert, G. J. Lyon, and C. H. Pierce.

ESSENTIAL FEATURES OF EQUIPMENT.

In general gaging stations for determining the total flow of a stream and its diurnal fluctuation need the following equipment:

1. A gage or gages for determining the fluctuations of stage.
2. Bench marks for referring the gages to a fixed datum.
3. Structures from which discharge measurements are made.
4. Cable and stay line to hold the meter in the vertical when soundings and velocity observations are made.
5. Graduated lines for indicating the points of measurement.
6. At places where natural control is lacking, structures to produce artificial control and regulate the relation between stage and discharge.

Although no one form of any of the requisites is necessary to obtain the results, many years of experience have demonstrated that certain standard types of structures can, as a rule, be more economically installed and that their use not only facilitates the making of the observations but insures results of a higher degree of accuracy.

The following pages describe those types of equipment which have been found to give the best results. Their specific use may, however, have to be modified to suit local conditions.

GAGES.

CLASSIFICATION.

The many styles of gages that have been used for determining the records of fluctuations of stage of rivers and other water surfaces may be grouped into two general classes—nonrecording gages and recording gages—the grouping depending on the method of obtaining the record, whether by direct readings at stated intervals from a scale board or other device, or by some type of mechanism.

NONRECORDING GAGES.

TYPES.

Of the various forms of nonrecording gages those in common use are (1) vertical staff gage, (2) hook gage, (3) float gage, (4) chain gage, and (5) inclined staff gage.

VERTICAL STAFF GAGE.

The vertical staff gage of the best type consists of a 2-inch by 6-inch base of timber, or larger, fastened rigidly in a vertical position. On this timber the graduations of the gage are placed. These graduations may be marked directly on the timber or on wooden or metal sections which can be adjusted to the bed timber in any position desired. A graduated board will be found satisfactory if made of about 5-foot sections of $\frac{7}{8}$-inch by 5-inch pine, painted white, with graduations cut as V-shaped notches, painted black (Pl. I, *A*). A special tool and guide for cutting the graduations in wooden scale boards has been devised and is shown in Plate I, *A*. If desired the graduations may be marked by means of barrel-hoop staples.

A wrought-iron face, made in foot sections, marked from 0 to 10 feet, has been devised and is especially desirable where the gage is permanent. The graduations and figures on this gage are raised from the face and painted either red or white, which makes them stand out on the black background of the gage itself.

HOOK GAGE.

A simple form of hook gage (Pl. I, *A*) can be arranged by using a movable staff, inversely graduated to feet only, with a hook at the bottom, sliding against a fixed New York rod scale 1 foot long, carefully graduated to decimal parts of a foot. In reading the stage the feet are determined by the foot mark on the movable staff, which is opposite the fixed foot scale from which tenths and hundredths are read.

FLOAT GAGE.

The float gage is similar to the hook gage, with the exception that instead of the hook there is placed at the bottom of the movable staff a float which rises and falls with the fluctuations in stage and carries with it a rod. The readings are made in the manner described for the hook gage.

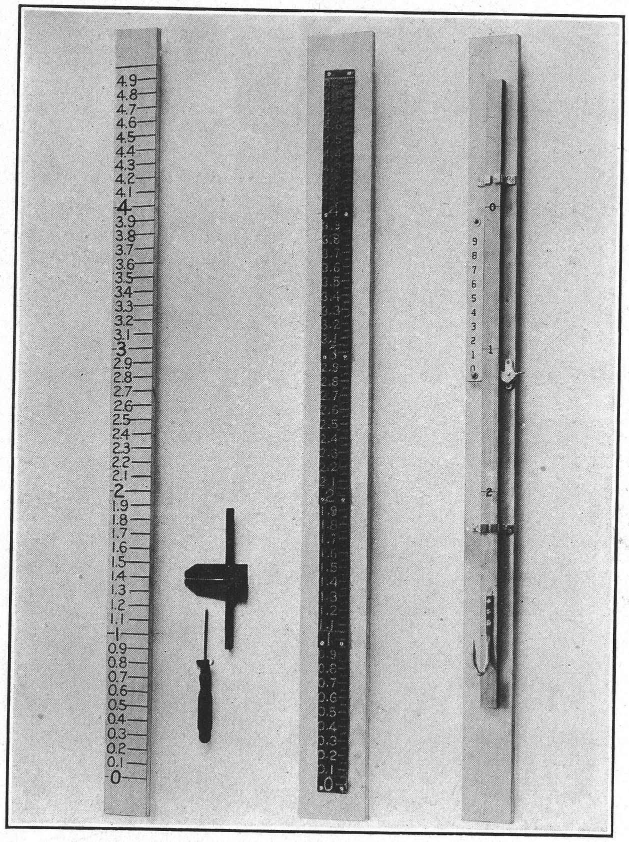
CHAIN GAGE.

The chain gage, shown in Plate I, *B*, consists of a graduated scale board, 10 feet or more in length, usually either extending from or contained in a box supporting a pulley wheel over which runs a heavy sash chain to which is attached at one end a weight and near the other end a marker. This gage as a whole is fastened in a horizontal position to a bridge or other structure, so that the weight when lowered will come in contact with moving water. When such contact is made the reading on the scale board opposite the marker is recorded.

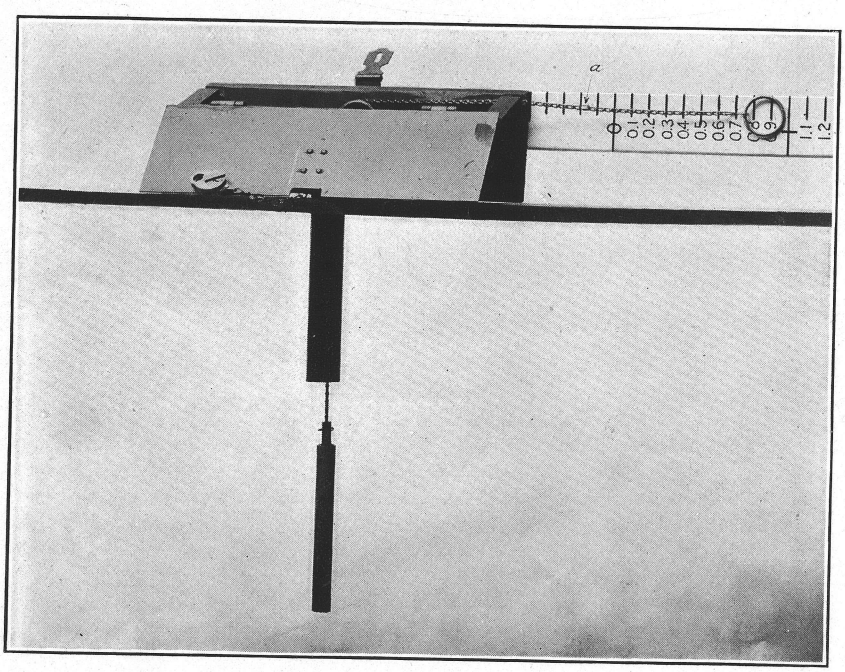
The most satisfactory chain so far used for this type of gage is Morton's champion metal window sash chain No. 1 regular. This chain, if thoroughly stretched before being put in place, will hold its length and is not much affected by the wearing of the parts.

Gage boxes should be made of first-class cypress, according to the plans shown on Plate II. Workmanship and material are to be first class.

The outside dimensions of the box, exclusive of the top, are as follows: Length, 24 inches; width, 6 inches; height in back, $8\frac{1}{8}$ inches; height in front, $5\frac{5}{8}$ inches. It is to be fastened together with bolts and screws as shown—8 screws in bottom (3 on each side and 1 in each end), and 2 screws near the top of the back.



A. VERTICAL STAFF AND HOOK GAGES.



B. CHAIN GAGE.

The bottom is to have two holes in it to permit the insertion of a 2-inch pipe in either hole, the choice depending on the way it is found necessary to lead the chain. As the pipe should fit snugly, holes should not be made until the outside dimension of the pipe to be used is known.

The two end pieces should be notched as shown, so that the chain will run horizontally from the pulley past either end of the box.

The top is to be made of $\frac{1}{8}$-inch sheet iron with 6-inch strap hinges and staple for 8-inch hasp riveted to it. The holes in the top should be punched or drilled to fit the hinges instead of following the dimensions on the drawing. The holes for the staple should be drilled so that the hasp will fit over the staple properly.

All hardware is stock material. One top may be made and used as a pattern.

On completion the box and ironwork should receive two coats inside and out of mineral paint or Dixon's graphite paint.

TABLE 1.—*Bill of material for chain gage box.*

Item.	Number.	Dimensions.
Lumber, first-class cypress:		
A. Ends	2	$6\frac{1}{4}$ by $3\frac{3}{4}$ by $1\frac{1}{8}$ inches (outside dimensions; see drawing for details).
B. Back	1	24 by 7 by $1\frac{1}{8}$ inches.
C. Front	1	24 by 5 by $1\frac{1}{8}$ inches.
D. Bottom	1	24 by 6 by $1\frac{1}{8}$ inches.
Total lumber		$3\frac{3}{4}$ feet b. m.
Iron and hardware:		
E. Top	1	24 by 7 by $\frac{1}{8}$ inches sheet iron (see drawing for detailed dimensions).
F. Rivets	12	$\frac{1}{4}$-inch diameter.
G. Hinges	2	6-inch strap.
H. Hasp	1	8-inch strap.
I. Staple	1	For 8-inch strap hasp.
J. Side pulley	1	3-inch.
K. Carriage bolts	4	$6\frac{1}{2}$ by $\frac{1}{4}$ inches, with nuts and washers.
L. Pipe	1	2 inches diameter by 14 inches long, threaded one end.
M. Screws	16	1 by $\frac{1}{4}$ inches, for hinges, hasp, and pulley.
N. Screws	10	2 by $\frac{1}{4}$ inches, for bottom (8) and back (2).
O. Stove bolt	1	$1\frac{1}{2}$ by $\frac{1}{4}$ inches, round headed, for holding pipe to bottom.

INCLINED STAFF GAGE.

ESSENTIAL FEATURES.

The inclined staff is useful where there is no existing object to which a vertical staff may be attached. It should be made of 4-inch by 6-inch timber, or larger, supported at short intervals on posts or concrete piers firmly set in the ground, and should be graduated by level after being placed in position, so as to give readings directly.

GAGE ON CONCRETE PIERS.

The general method of installing such gages is shown on Drawing No. 1 by the profile of the river bank.

The bed pieces should be 4 by 6 inches by 12 feet, of chestnut or other timber equally suitable for the work. The top of the bed pieces should be left flush with the original surface of the ground, thus offering the minimum obstruction to ice and drift. The gage rod should be of 1 by 4 inch spruce or similar wood. The life of the timber pieces may be lengthened materially by the use of carbolineum or creosote applied hot.

In order to afford drainage and thus minimize the danger of the gage being disturbed by frost, the soil for a foot below and on each side of the bed piece may be removed and replaced with small stones.

Piers reaching below the frost line should be placed 11 feet on centers, slope measurement, thus allowing a lap of 6 inches on each end of the bed pieces. These lap joints should be so framed as to allow for the changing slopes of the bank. They should be bored for ¾-inch anchor bolts and the top piece countersunk so that the nut, using flat washers, and the end of the bolt will lie below the gage rod. The bolts should be of ¾-inch iron, 18 inches long, the hook being 3 inches long.

The bolts should be placed in the bed pieces, which are laid over the holes for the piers, and the concrete then filled in up to the bed pieces and allowed to set before any work is done on the rods or bolts. This part of the pier should be left rough, and in addition a few spikes should be stuck in the concrete to insure a bond when the top of the pier is finished, in accordance with the drawings, after the gage rod is in place. When the concrete is hard the nuts should be screwed down and the gage put in place with screws, breaking joints with the bed pieces.

The proper footmarks and subdivisions to indicate the water stage should be located upon the rod by means of a wye level, and should be referred to the station bench mark. Feet of elevation along the rod should be divided into tenths and quarter-tenths, and marked by barrel-hoop staples, 1½ inches long for the foot marks, 1 inch long for the tenth marks, and one-half inch long for the quarter-tenth marks. Pattern numbers should be used to indicate the proper marking of the even foot marks. The entire length of the gage may be subdivided into quarter-tenths, or only that part of it which is required to be so divided by the table of limits for the station in question.

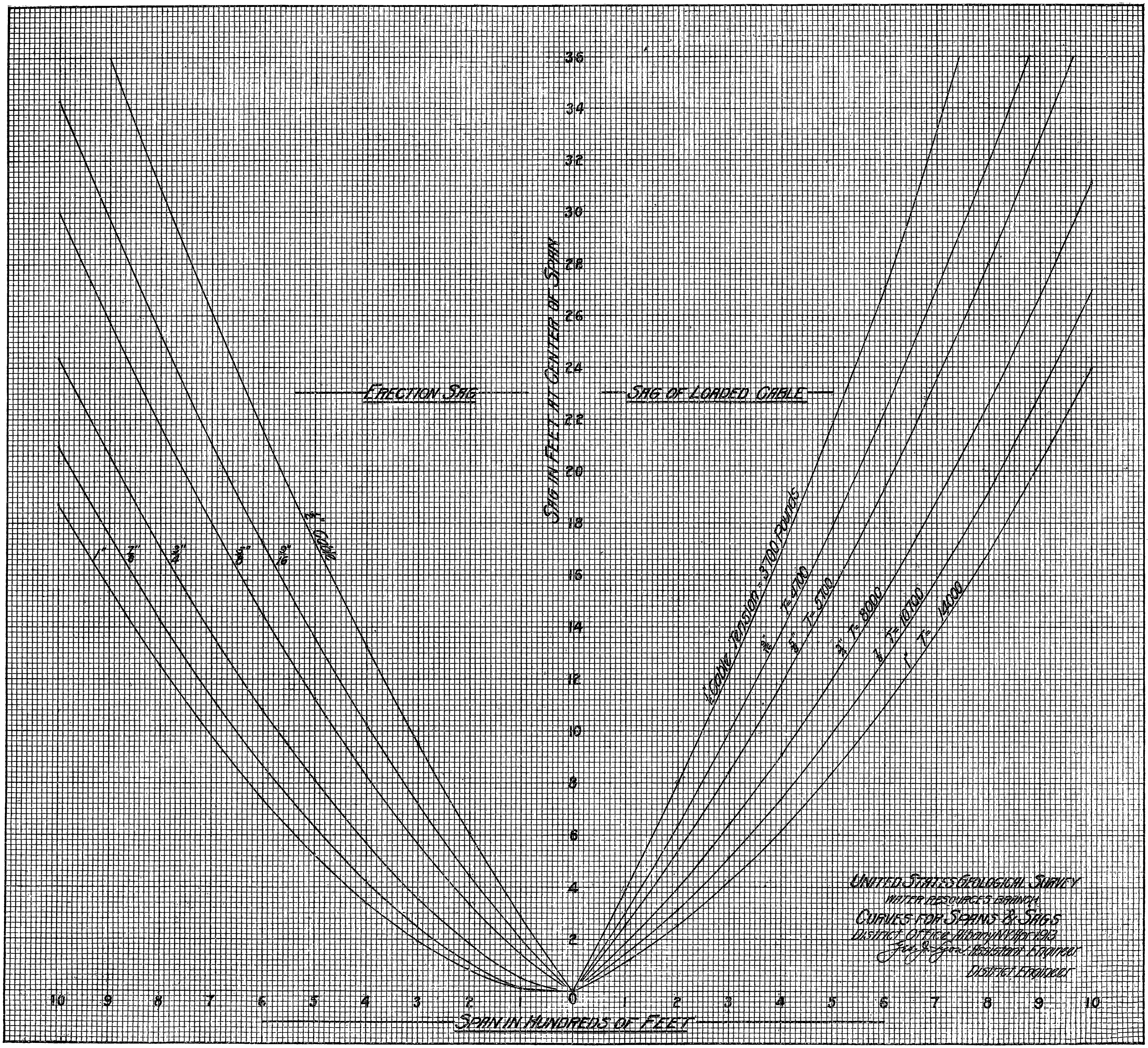
The piers may be built without forms and should be circular in cross section of 1–3–5 concrete. Type A or Type B may be used, depending on the nature of the soil. The material required for each installation is shown by Table 2.

TABLE 2.—*Material for inclined gage on concrete piers.*

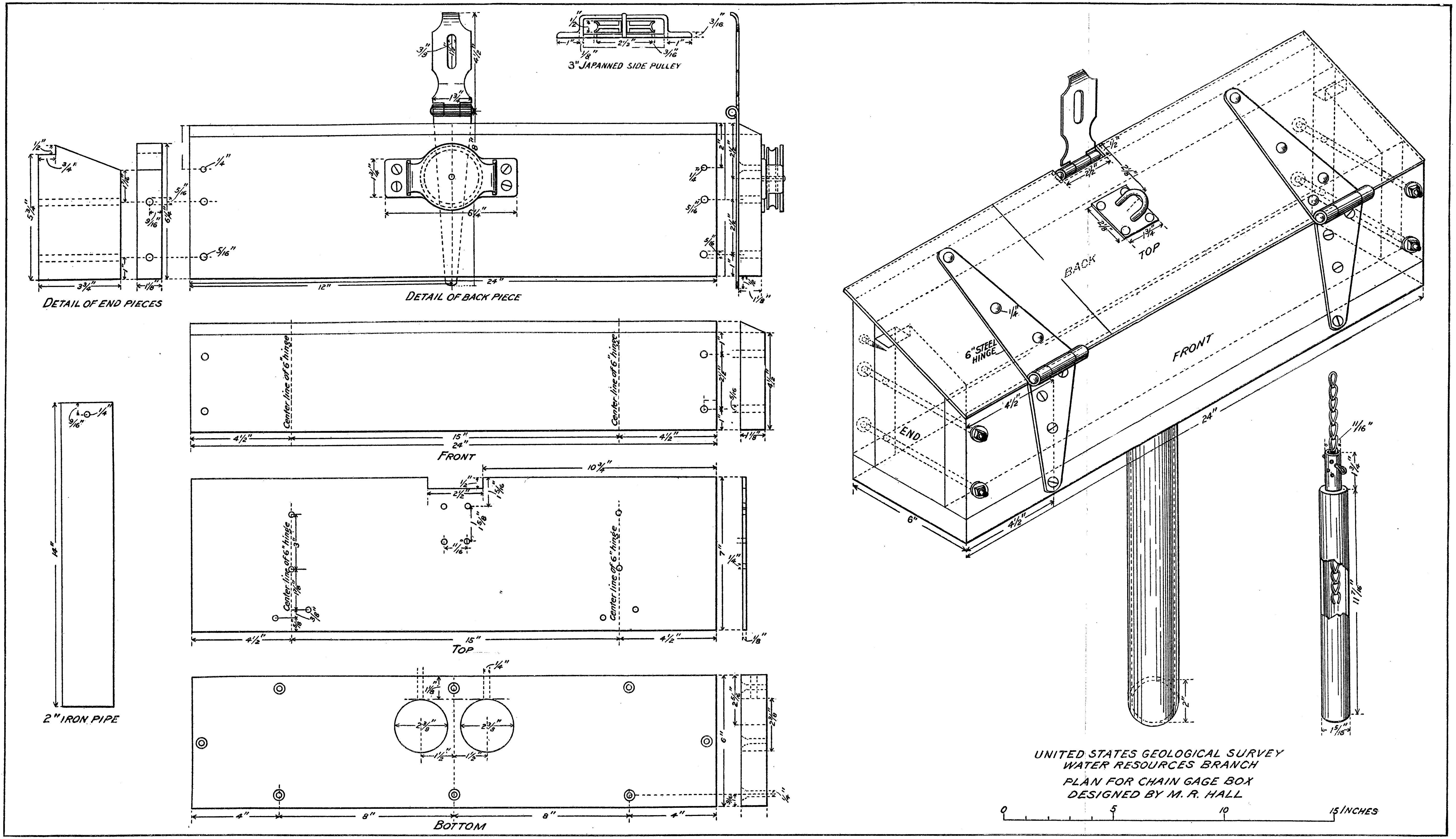
Item 1. One bed piece 4 by 6 inches by 12 feet for each section.
2. One gage rod piece 1 by 4 inches by 12 feet for each section.
3. One piece ¾-inch iron, 18 inches long, threaded one end, 3-inch hook on other end, for each pier.
4. One ¾-inch flat washer for each pier.
5. One ¾-inch nut for each pier.
6. Six 2-inch No. 12 woodscrews, round head, brass, for each gage-rod section.
7. —— numbers for footmarks.
8. —— screws for each number.
9. —— barrel-hoop staples 1½ inches long.
10. —— barrel-hoop staples 1 inch long.
11. —— barrel-hoop staples ½ inch long.
12. —— cubic yards concrete for piers.
13. —— carbolineum for timber.

GAGE ATTACHED TO TIMBER POSTS.

The method to be followed in constructing gages on timber posts is similar to that described for gages on concrete piers, the bed pieces being carried as shown in the drawing for timber anchorage for slope gages.



SAG DIAGRAM FOR CABLE.



PLANS OF CHAIN GAGE.

The supports should be bolted to the sills and the frame then placed in the trenches at the proper distances. The bed pieces should then be bolted to the 2 by 4 inch supports, as shown in the drawing, after which the backfill should be thoroughly tamped into place. If desired, a ¼-inch bolt may be placed in each side parallel to the bed pieces through the upper end of the 2 by 4 inch supports. The material required is listed in Table 3.

TABLE 3.—*Material for inclined gage on timber posts.*

Item 1. One bed piece 4 by 6 inches by 12 feet, for each section.
2. Gage rod piece 1 by 4 inches by 12 feet, for each section.
3. Four bolts one-half inch by 14½ inches, with washers and nuts, for each section.
4. Four bolts one-half inch by 10½ inches, with washers and nuts, for each section.
5. Six 2-inch No. 12 wood screws, round head, brass, for each section.
6. —— numbers for footmarks.
7. —— screws for numbers.
8. —— barrel-hoop staples 1½ inches long.
9. —— barrel-hoop staples 1 inch long.
10. —— barrel-hoop staples one-half inch long.
11. Four pieces 2 by 4 inches by distance below frost, for each section.
12. One sill 4 by 6 inches by 3 feet, for each section.
13. Carbolineum for timber.

NOTE.—The plan shows the support for the intermediate joints. At the extreme end of the gage, whether one or more sections are used, only one set of 2 by 4 inch uprights are necessary, and the bolts that fasten these to the sills are one-half inch by 10½ inches—that is, 4 inches shorter than for the intermediate section. One more sill than the number of sections is required.

If the gage is to be installed where the stream channel is subject to material change in cross section, the inclined gage on timber posts may be used, but the construction should be modified, as shown in drawing No. 1—Method of installing slope gage on shifting channels. Each section of gage should be an independent unit, so that the minimum of reconstruction will be necessary if gage is washed out. Two, instead of four, 2 by 4 inch uprights, should be attached to each sill, and two sills, instead of one, should be provided for each intermediate gage section. The only change from Table 3 in the list of material required is the addition of an extra sill for each intermediate section.

RECORDING GAGES.

ESSENTIAL PARTS.

Recording gages make a record of stage, either continuously by a curve, the coordinates of which indicate the time and the stage, or by a device that prints at stated intervals of time. The essential parts of the recording gage are: (1) A float which rises and falls with the surface of the water; (2) a device for transferring the vertical motion of the float to the record, either directly or through a reducing mechanism; (3) the recording device; and (4) the clock. Detailed description of these gages will be given in another circular.

INSTALLATION.

A large element in the satisfactory operation of an automatic gage is proper installation. The results from the best of gages will be impaired by improper installation, whereas a gage properly installed will give a record whose accuracy depends solely on the adequacy of the instrument. The value of approximate results is not commensurate with the expense of an automatic gage, and the method of installation should be so thorough as to insure accuracy. Special care in installation is necessary if the gage is to record stream heights during winter months and flood stages, in order to eliminate the effect of freezing and of disturbance from floating ice and débris.

In installing an automatic gage (Pl. III, *B*) it is necessary to provide a well for the float, connected with the river by an intake pipe; a house to shelter the gage; and staff or hook gages with bench marks for checking the record and maintaining the datum.

In the ideal installation the well and the house should be located far enough back from the river to be out of danger from floating ice or drift and to provide sufficient protection for the well and pipes to prevent freezing. A permanent ladder should extend to the bottom of the well, so that the float and intake pipe can be readily inspected. If the gage is to be maintained for a long period the well should be lined with concrete, otherwise a heavy plank lining may be used. The intake pipe should be placed well below the lowest stage of the river and provided with a screen for keeping out silt and foreign material. It should also be provided with a check gate as it enters the well, so that the flow can be reduced if necessary to eliminate wave action.

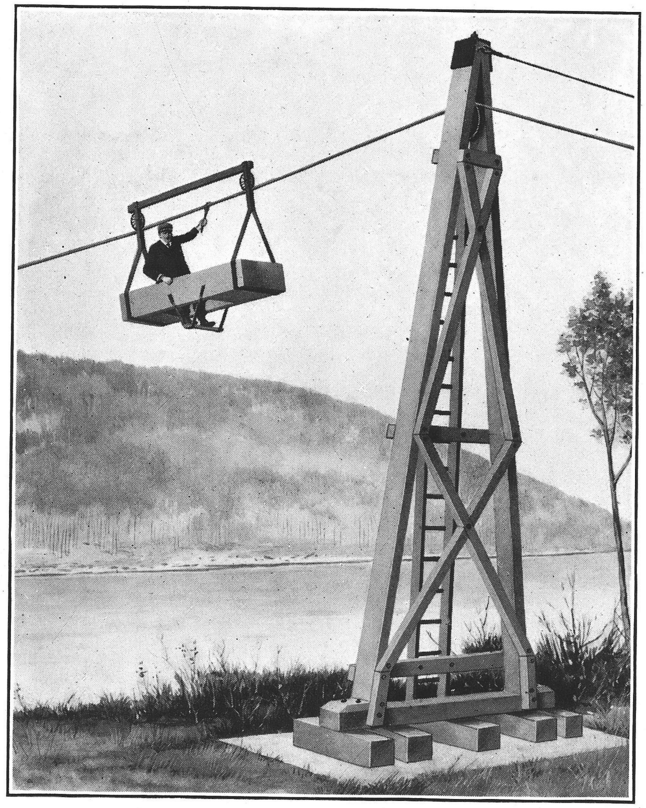
Two nonrecording gages, referred to permanent bench marks, should be installed with each automatic gage, in order to check the readings with the stage of the river. One, preferably a hook gage, should be located in the float well, to determine whether the water in the well is in free communication with the river, and the other should be placed in the river and should be of the type best suited to the locality. The river gage should be in the same cross section of the river as the intake pipe. It may, however, be dispensed with by using a reference point so located that the elevation of the water surface can be easily determined.

In a well properly constructed and placed far enough back from the river there should be no danger from frost, even in temperatures as low as 30° below zero. Freezing can be prevented by arranging a floating lamp in the well or by hanging an electric-light bulb near the surface of the water. If the float is in a tube of small diameter freezing can be prevented to some extent by pouring oil in the well.

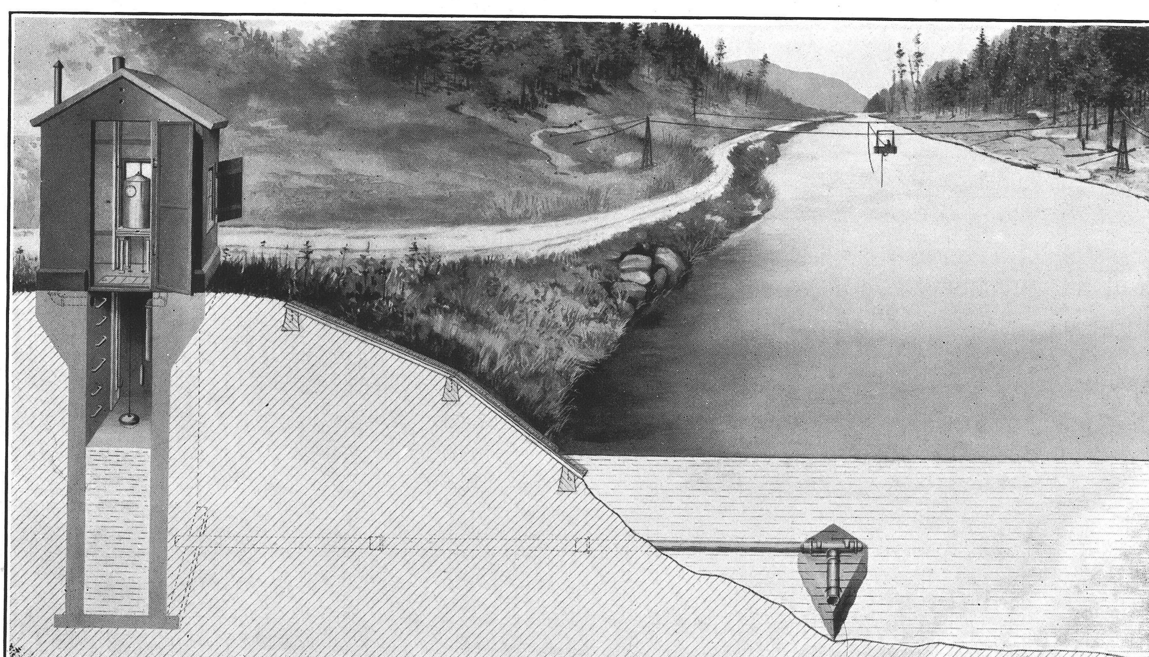
The best lamp is a floating iron kettle suspended by a counterweight. In the kettle a tight cover, carrying a burner, should be soldered a few inches from the top. Such an arrangement will provide for 2 or 3 quarts of oil, which, with an ordinary lamp burner, will burn several days.

INTAKE.

The intake from the stream to the well should be made of 4-inch standard-weight cast-iron pipe, its outward end being placed on a secure anchorage built in the bed of the stream. A 4 by 4 by 4 inch tee should be placed on the stream end of the pipe. As shown in drawing No. 3, the tee should be fitted to point downstream, with one of its hubs just at the outer edge of the concrete anchorage. A short length of pipe should be laid from the tee on top of the anchorage in the direction of the flow, and a wire screen of ¼-inch mesh placed over the opening. The pipes and



A. TYPICAL CABLE TOWER.



B. TYPICAL GAGING STATION WITH AUTOMATIC GAGE.

fittings should be securely fastened to the anchorage by iron straps bolted to the concrete. The third opening of the tee may be closed, either by means of a blank flange cemented in or by means of a wooden plug fastened with wire.

The shore end of the intake pipe should be fitted with a sluice valve with stem of suitable length, so that the water can be shut off from the well when necessary. Valves may be obtained [1] so arranged that they can be placed flush with the sides of the well and have a body of cast-iron pipe with 4-inch standard spigot end, as shown in drawing No. 3.

The anchorage shown is designed to divert silt from the entrance of the intake, thus reducing the chances of the pipe becoming choked. Where the stream carries manufacturing wastes that are likely to choke the pipe, special protection for the stream end of the pipe is necessary. Instead of ending in a tee, the pipe may pass into the anchorage and end in a small well, built into the concrete. From this well two 2-inch pipes pass to the surface of the anchorage, at which points they are protected by small conductor sieves as used on house leaders.

The anchorage may be constructed at times of low water by depositing concrete under water in a simple box form placed on the stream bottom. No current should be allowed to flow through the form. It may be an advantage to incase quick-setting concrete in paper bags to prevent the cement being washed away.

Where it is necessary to use a cofferdam to install the anchorage, the work should be done at favoring stages of the stream, always taking precautions against a sudden rise. It is usually an economy to provide a power pump at the beginning for removing the water from the cofferdam during construction. It is highly desirable that the work should be carried to completion as rapidly as possible while circumstances are favorable.

The intake pipe may be made up into sections of two lengths each, calked on shore. By using these sections, which should be handled carefully in order not to destroy the joint, the intake may be placed very quickly. All joints in the intake pipe should be calked in the usual manner with oakum and lead to prevent the entrance of silt. A calking tool should be used to make a tight joint.

WELL.

LOCATION.

The well should be of the dimensions shown on the plans; its longest cross-sectional dimension should be in the direction of the intake pipe. It should be placed far enough back in the bank, so that the water will not come close enough to the surface of the ground to freeze during cold weather.

The excavation is made in the usual manner, taking care to properly shore the sides if there is any possibility of caving. The well and the trench for the intake pipe may be dug at the same time, the excavation being kept dry, if possible, by leaving the river end of the trench unexcavated for a short distance.

WOOD LINING.

The lining of the well is ordinarily of the same material as the shelter, although a wooden or a sheet-steel shelter may be placed upon a concrete well lining.

[1] Flushing gate valve, Ludlow Valve Manufacturing Co., Troy, N. Y.

For a timber well a box should be built of 2-inch planks (S–T–U; all letters refer to drawing No. 4) around the frames (W–V). A bottom of similar material is used (X). In some wells it may be necessary to use battens over the joints in order to prevent an inflow of sand and silt. The top of the well lining should be tied in by the collars (F–J) and braced on the inside by frames (I–N). The braces J, I, N should be set level and flush with the top of the lining at the elevation of the bottom of the floor. This should be a few inches above the ground surface to facilitate drainage. The sills (F) should be placed across the ends of the lining, just below the braces (J). The 2 by 6 inch supports should be spiked below the sills (F), but along the sides of the lining. The frames mentioned, together with the sills (G), placed on top of and at the ends of (F), carry the wooden shelter. It is essential that the floor of the building carrying the gage table shall be rigidly attached to the well lining in all cases.

A ladder with side pieces of 2 by 4 inch material and 1½ by 2 inch rungs should be spiked to the inside of the lining and arranged as shown to give easy access to the hook gage and bottom of the well. The hook gage should be placed so as to be in the light from the trapdoor to the well.

CONCRETE LINING.

Concrete wells should be constructed according to the plans for concrete shelters (drawings Nos. 2 and 3). Under ordinary circumstances it is not necessary to use outside forms when placing the concrete. If the space is large, back filling can be made against a board, to hold the concrete in place, which can be drawn and raised as the walls progress. Inside forms should be used and the concrete placed between them and the sides of the excavation, which should be made no larger than necessary.

The sluice valve and the iron steps must be placed in the inside forms. The use of narrow boards, with joints at the steps if possible, will facilitate the removal of the forms. Bolts half an inch in diameter, placed 4-foot centers, should be provided for the attachment of the bed piece for the hook gage. They should project such a distance from the wall that they will not reach the surface of the bed piece, which should be countersunk for the nuts. Expansion bolts of the Double-Coil Richmond Screw Anchor type will be found convenient. A battery shelf of 2-inch plank should be built into the wall. A line of furring strips similar to those shown in the shelter would be a convenience if placed around the well about 3 feet below the floor.

The arrangement in plan brings the length of the house along the line of the trench for the intake pipe. The width of the well is such that it can be built in practically the same width as the trench for the intake pipe, and will give ample room inside for operating the gages. It also allows room to use rods for cleaning the intake pipe if necessary.

The well should be built to the surface of the ground to furnish a foundation for the shelter. The walls of the well should be of a proper thickness for the depth, giving due consideration to the nature of the material passed through. Three feet from the top of the well the sides should be corbeled out to the dimensions shown on the plan. In localities where the ground freezes to a great depth it may be advisable to begin the corbeling at a greater distance below the frost line.

Near the top of the well provision should be made for introducing the ventilation pipes shown in the section. A hook should also be provided in the wall over the sluice valve to hold the valve stem, which should have a handle at its upper end. A very satisfactory valve stem may be made of ½-inch galvanized pipe, with a forked end for fastening to the valve welded to one end and a handle welded to the other.

SHELTERS.

WOODEN SHELTER.

The wooden shelter (drawing No. 4) may be of tongue-and-grooved or of shiplap lumber, with or without clapboards. If additional protection is required, 2 by 4 inch corner posts should be placed as a support for the lining. Both sides and the rear of the house should be laid out as shown on the drawing, and nailed to the proper bands while still flat on the ground. They should then be raised into place and nailed together and to the front. The flat roof, covered with waterproof roofing, should then be built on. Windows should be placed one on each side and one in the rear of the building. One and three-eighths inch stock sashes, with four lights of 8 by 10 inch glass, are placed with the bottom of the sashes 2 feet above the floor. On the outside stops should be nailed all around, as shown, while on the inside the stops should be screwed on the top and bottom only, so that the sashes may be removed. The sashes may be made to slide or open on hinges, if desired. Each window should be protected by a wooden shutter fastened by a hasp and staple, a lock being provided for each if necessary. A door, provided with hasp, staple, and lock should be made to suit the style of shelter. For a wooden shelter ceiled inside and with siding outside, a standard door and frame, as shown on the plans for concrete shelter, may be used.

The floor should be of 2-inch plank securely spiked to the sills. In constructing the trapdoor through which entrance is had to the well, ample allowance should be made for shrinkage, say three-eighths inch on each side and half an inch at the end. The bed piece for the hook gage should be fastened to the frame of the well and to the roof. To this, standard lugs should be attached on each side of the hook gage rod, spaced about 3 feet apart. Opposite the standard scale a sash latch should be provided to hold the gage at any desired position.

Where the change of stage is considerable it may be necessary to allow the hook gage to pass through the roof, using a small trapdoor or the same device as for concrete shelters.

The shelters should be kept well painted or should be treated with carbolineum. A bill of material and cutting scheme for timber shelters is given in Tables 5 and 6.

CONCRETE SHELTER.

The arrangement of the concrete shelter is clearly shown on Plate III, *B*. It should be noted, however, that in order to show the greatest number of details in the cut, the house and well have been turned with their longer axes parallel to the stream. As actually constructed, the longer dimension of the well is placed at right angles to the stream, and the shorter dimension parallel to the stream.

The dimensions in plan (drawing No. 3) give ample but not excessive room inside the shelter to allow the gage to be inspected and adjusted without discomfort. In fact, it is desirable to have a clear passage all around the gage table.

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The 2 by 4 inch furring strips placed in the walls afford means for fastening cupboards, etc., or for placing hooks to carry various pieces of minor equipment necessary for the operation of the station. Directly over the center of the door a ½-inch eyebolt set into the concrete for carrying a pulley and rope is useful for a number of purposes, such as bailing the well. The stirrup to which is fastened the bedpiece for the rod gage should be set into the concrete and attached by means of ¼-inch bolts. Two pieces of 2-inch pipe for ventilator should be inserted in the back and front of the walls of the house. Pipe caps should be provided to close these vents. A 3-inch ventilator runs through the building in one corner, passes through the roof, and is capped by a hood. In cold weather it is desirable in some localities to close all vents to prevent the water in the well from freezing.

Where the variation in stage is great it may be necessary to lift the hook gage so high that the gage rod must pass through the roof. To meet this condition a smoke jack of galvanized iron, 6 inches in diameter, may be placed directly over the gage rod and set into the roof and covered by a close-fitting cap. If it is necessary for the protection of the apparatus, this pipe may be locked by riveting a short piece of chain to the cover and locking it to the bed piece.

The door and window frames are shown in detail on drawing No. 2. The door and window frames should be placed flush with the outside of the walls and the jambs set as shown in the details. When this has been done the 1-inch angles on the iron door and shutters will fit closely against the jambs, which will afford desirable protection against storms and cold. The windows have 1⅜-inch stock sashes, each with four lights of 8 by 10 inch glass. Stops should be screwed at the tops and bottom of sash. The door should open inward and should be hung on 3-inch butts and provided with an ordinary lock set.

Forms for the well may be made of rough lumber. Rough lumber, if not warped, may also be used for forms for the shelter. In fact a good finish may be obtained by using an inferior grade of boards faced with greased building paper. In erecting the forms care should be taken that all door and window frames are properly set and are true to shape and dimensions. The hooks for the iron door and shutter hinges should be carefully placed. As shown on the plan, these hooks have a collar welded on which fits flush with the outside wall, and the inside is provided with a nut and an ogee washer.

A top form is necessary for the roof slab. The form for the overhanging eaves can be made of not more than two boards carried on a series of brackets nailed to the uprights supporting the forms for the walls. The uprights may be wired together to preserve the line of the walls. The pouring of the walls should be a continuous operation up to within about a foot of the top. The walls for the remaining distance and the top slab should be poured at one operation. Small holes and other defects in the face should be filled with mortar after removing the forms. Ridges or rough places may be smoothed down with a carborundum stick. The entire face may be painted with a coat of thin mortar.

TABLE 4.—*Bill of material for concrete well and shelter for automatic recording gage.*

Item 1. 3.7 cubic yards 1–2–4 concrete in shelter, including floor, requiring—
- 22 bags cement.
- 1½ yards sand.
- 3 yards ¾-inch stone or gravel.

Item 2. 2.7 cubic yards 1–2–4 concrete for upper 3 feet of well, requiring—
17 bags cement.
$1\frac{1}{4}$ yards sand.
$2\frac{1}{2}$ yards stone.
3. 0.6 cubic yard (approximately) in walls of well for each foot of depth below first 3 feet. Each cubic yard requires—
$4\frac{1}{2}$ bags cement.
0.47 yard sand.
0.94 yard stone.
4. 1.2 cubic yards 1–3–6 concrete in foundation requiring—
6 bags cement.
$5\frac{2}{3}$ yards sand.
$11\frac{1}{3}$ yards stone.
5. $62\frac{1}{2}$ square feet Clinton wire cloth or substitute for reenforcing roof and floor.
6. 1 wooden doorframe with door complete as shown on drawing No. 2, with lock set, hinges and four lights of glass.
7. 1 iron door as shown on drawing, painted with one coat of Dixon's graphite paint, complete with two staples for padlocks.
8. 2 hooks fitted to hinges, with collars welded on and furnished with nuts and ogee washers as shown on drawing No. 2.
9. 3 window frames with sashes, complete as shown on drawing No. 2.
10. 3 iron shutters as shown on drawing, painted with one coat Dixon's graphite paint, with 6 staples for padlocks.
11. 6 hooks fitted to hinges, with collars welded on and furnished with nuts and ogee washers as shown on drawing No. 2.
12. 4 United States Geological Survey standard padlocks.
13. 1 lifting ring for trapdoor, with screws.
14. 1 pair 6-inch strap hinges with 4-inch stove bolts for all holes.
15. 2 pieces light rail for door rest, each $3\frac{1}{2}$ feet long.
16. 4 floor flanges $1\frac{1}{2}$ by 5 inches, with right-hand thread.
17. 4 floor flanges $1\frac{1}{2}$ by 5 inches, with left-hand thread.
18. 4 pieces $1\frac{1}{2}$-inch galvanized wrought-iron pipe 18 inches long, with one right-hand and one left-hand thread on each. The threads are to be cut 2 inches long and are to be fitted in the shop to a tight *hand* fit.
19. One-half gross F. H. No. 14 wood screws, 2 inches long, for screwing flanges to table and for making trapdoor.
20. One-half gross F. H. No. 10 wood screws, $1\frac{1}{2}$ inches long, for making gage table.
21. 1 pound $1\frac{1}{2}$-inch (6d.) nails, for trim.
22. 5 pieces 3-inch galvanized wrought-iron pipe for ventilator, cut as follows:
1 piece 2 feet long, threaded one end.
1 piece 1 foot long, threaded both ends.
1 piece 2 feet long, threaded both ends.
1 piece 1 foot long, threaded one end.
1 piece 8 feet long, threaded one end.
23. 3 3-inch galvanized elbows.
24. 1 3-inch galvanized return bend.
25. 1 hood for 3-inch ventilator as shown.
26. 4 pieces 2-inch galvanized wrought-iron pipe, 8 inches long, threaded one end.
27. 4 2-inch galvanized caps for above.
28. 1 6-inch galvanized iron smoke jack with cap as shown, over hook gage. (Use where hook gage rises above roof.)
29. 1 piece $\frac{1}{4}$ by 2 inches iron 2 feet long for stirrup.
30. 1 eyebolt $\frac{1}{2}$ by 6 inches, with nut and 4 by 4 by $\frac{3}{8}$ inches square washer.
31. 1 4-inch sluice valve, body of proper length.
32. —— feet $\frac{1}{2}$-inch galvanized pipe for valve stem.
33. —— lengths 4-inch standard weight cast-iron pipe for intake.

Item 34. 1 4 by 4 by 4 inch C. I. tee for intake.
35. 5 straps and 10 anchor bolts with nuts for holding intake to anchor, as shown on drawing No. 3.
36. One-fourth pound oakum for each joint in intake pipe.
37. 6 pounds lead for each joint in intake pipe.
38. —— pieces 1-inch iron 3 feet long for steps, inner edge to set 3 inches from face of wall.
39. —— ½-inch bolts with nuts and washers to hold bedpiece to wall.
40. 2 machine bolts one-fourth inch by 3½ inches with washers to fasten bedpiece to stirrup.
41. 1 three-fourth by 2 inch hook gage rod.
42. 1 set standard lugs with 1¼-inch No. 9 brass screws.
43. 1 window latch with screws.
44. 1 standard hook with brass screws.
45. 1 standard scale with screws and washers.
46. 1 gallon carbolineum for treating gage rod, table, etc.
47. 1 gallon gray mixed paint for door, windows, etc.

LUMBER.

48. 1 piece hemlock, 2 by 6 inches by 14 feet, for trapdoor.
49. 2 pieces lumber, 2 by 4 inches by 12 feet, for furring strips.
50. 2 pieces lumber, 2 by 4 inches by 14 feet for furring strips.
51. 2 pieces cypress, 1 by 6 inches by 12 feet, for gage table.
52. 1 piece cypress, 3 by 6 inches, for bedpiece for hook gage.

All lumber throughout the building and well shall be the best of the several kinds, thoroughly seasoned, free from large or unsound knots, saps, shakes, wanes, dry rot, or other imperfections impairing its strength or durability or affecting its appearance for the purpose for which it is to be used.

TABLE 5.—*Bill of material for timber well and shelter for recording gages.*

LUMBER.

Item 1. 24 pieces, 1 by 8 inches by 14 feet, tongue and groove or ship-lap, surfaced.
2. 2 pieces, 1 by 6 inches by 10 feet, tongue and groove, surfaced.
3. 2 pieces, three-fourths inch by 8 inches by 8 feet, surfaced.
4. 1 piece, 2 by 6 inches by 12 feet, surfaced.
5. 1 piece, three-fourths inch by 2 inches by length of hook gage, surfaced.
6. 8 pieces, 2 by 4 inches by 12 feet, surfaced.
7. 3 pieces, 2 by 4 inches by 14 feet, surfaced.
8. 6 pieces, 2 by 6 inches by 10 feet, rough.
9. 3 pieces, 2 by 6 inches by 12 feet, rough.
10. 2 pieces, 4 by 4 inches by 16 feet, rough.
11. 26 pieces, 2 by 6 inches, rough } Of proper length for depth of well.
12. 4 pieces, 2 by 8 inches, rough } Of proper length for depth of well.
13. 3 pieces, S. 4 S., 2 by 4 inches } Of proper length for depth of well.
14. 5 gallons Carbolineum.
15. 3 window sashes, 1⅜ inches, with 4 lights each, 8 by 10 inch glass.

If shelter is to be ceiled inside, add:

Item 16. 22 pieces, 1 by 8 inches by 14 feet, tongue and groove or ship-lap, surfaced.
17. 1 pound 2-inch wire nails (6d.).

For shelter with clapboard siding, substitute for item 1:

Item 18. 6 pieces, 1 by 8 inches by 14 feet, tongue and groove, surfaced, for roof.
19. 18 pieces, 1 by 8 inches by 14 feet, rough.
20. 150 square feet clapboards.
21. 150 square feet building paper.
22. 3 pieces, three-fourths inch by 8 inches by 14 feet, surfaced for trim.

Item 23. 1 door, 1⅜ inches by 2 feet by 6 feet, with butt hinges, lock set.
24. 2 gallons gray mixed paint.
25. 1 pound 2-inch wire nails (6d.).

HARDWARE.

26. 2 pounds 4½-inch wire nails (30d.).
27. 8 pounds 4-inch wire nails (20d.).
28. 5 pounds 2½-inch wire nails (8d.).
29. One-half pound 2 and 1½ inch nails (6d. and 4d.).
30. 4 pairs 4-inch T hinges for doors and shutters.
31. 1 standard United States Geological Survey lock for door.
32. 1 hasp and staple for door.
33. 3 screw hooks and eyes for shutters.
34. 1 pair 6-inch strap hinges for trapdoor.
35. 1 lifting ring for trapdoor.
36. One-half gross 2 by 12 inch flathead wood screws.
37. Waterproof roofing to cover 42 square feet, net.
38. 4 pounds No. 8 large-head, barbed roofing nails.
39. 4 pieces, 1½ by 18 inches, galvanized wrought-iron pipe, with one right-hand and one left-hand thread on each piece, for gage-table legs.
40. 4 floor flanges, 1½ by 5 inches, right-hand thread.
41. 4 floor flanges, 1½ by 5 inches, left-hand thread.

MATERIAL FOR INTAKE PIPE, ANCHORAGE, ETC.

42. One 4 by 4 inch, C. I. tee, with one blank flange.
43. One square foot ½-inch galvanized-iron wire screening.
44. 5 feet No. 10 galvanized wire.
45. One-half pound oakum and 5 pounds lead for each joint to be calked.
46. —— bags cement for concrete for intake anchorage.
47. —— cubic yards sand for concrete for intake anchorage.
48. —— cubic yards gravel or broken stone for same.
49. One 4-inch sluice valve, with stem of proper length.

TABLE 6.—*Cutting scheme for lumber for timber well and shelter.*

(For shelter of tongue-and-groove or ship-lap dressed lumber.)

For front, sides, rear, and roof:
A. 24 pieces 1 by 8 inches by 14 feet.
For frame:
8 pieces 2 by 4 inches by 12 feet, from which cut the following:
Top band—
B. 2 pieces 5 feet long (*).
C. 2 pieces 6 feet long.
Middle band—
D. 2 pieces 5 feet long (*).
E. 2 pieces fitted at front of house (*).
Bottom band or sill—
F. 2 pieces 5 feet long (*).
G. 2 pieces 6 feet long.
Top frame for well inside—
I. 2 pieces 5 feet long (*).
Top collars for well outside—
J. 2 pieces 6 feet long.
From ends from pieces marked (*) make—
K. 6 pieces 2 feet long for window frames.
3 pieces 2 by 4 inches by 14 feet, from which cut the following:

For frame—Continued.

L. Middle band, 4 pieces 6 feet long (*).

M. Door jamb, 2 pieces 7 feet long.

From ends marked (*) make—

N. 2 pieces 2 feet long for top braces inside well.

For windows:

O. 3 stock sashes with 4 lights of 8 by 10 inch glass.

P. 2 pieces, three-fourths inch by 8 inches by 8 feet stops for window and door frames.

For trim, etc.:

Q. 2 pieces 1 by 6 inches by 10 feet, cut as required.

For floor:

R. 6 pieces 2 by 6 inches by 10 feet, rough.

For well:

S. 20 pieces 2 by 6 inches, rough for sides.

T. 6 pieces 2 by 6 inches, rough for ends.

U. 4 pieces 2 by 8 inches, rough for ends.

Length of boards in well to be measured from bottom of floor of shelter to bottom of well.

For braces (2 sets, square, of 4 by 4 inch braces for 12-foot well):

2 pieces, 4 by 4 inches by 16 feet, rough, from which cut the following:

V. 4 pieces 5 feet long.

W. 6 pieces 2 feet long.

For ladder:

3 pieces, 2 by 4 inches by depth of well, for ladder and rounds.

For floor of well:

X. 3 pieces, 2 by 6 inches by 12 feet.

For hook gage:

Y. Base 2 by 6 inches by depth of well plus 6 feet.

Z. Rod three-fourths by 2 inches.

1 standard hook gage scale, with screws and washers.

1 standard hook, with brass screws.

6 standard Z-lugs for rod, with 2 flathead 1¼-inch No. 9 brass wood screws for each.

1 sash catch, with screws.

BENCH MARKS.

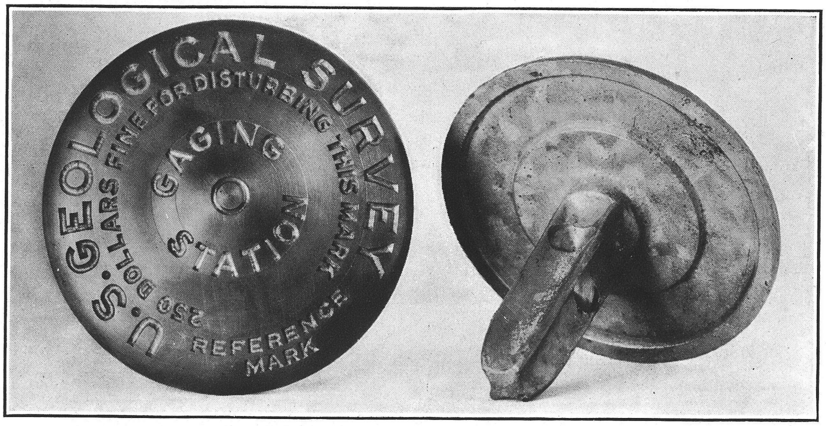
The permanent maintenance of the datum of every gage is absolutely necessary. To accomplish this, the gage must be referred to at least two permanent bench marks from which it can readily be checked by a level. The experience of the topographic branch shows that the best type of bench mark is a bronze tablet, Plate IV, *A*, set in a concrete post or in a bowlder or rock ledge if available.

Bench marks set in bridge piers, foundations to buildings, etc., as a rule have not been found satisfactory owing to changes which are liable to be made in such structures.

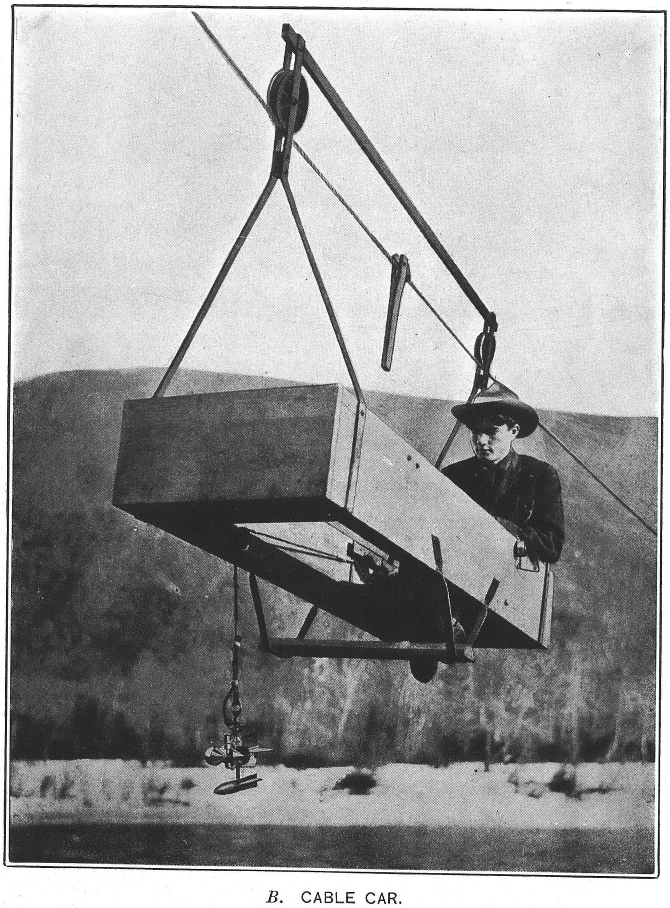
STRUCTURES USED IN MAKING DISCHARGE MEASUREMENTS.

ESSENTIAL PARTS.

A structure to support the engineer while measuring velocity and depth, when the stream is too large to permit making measurements by wading, is necessary at current meter stations. Such a structure may be: (1) A cable for carrying a car, or (2) an existing or specially constructed bridge, or (3) a boat held in position by a cable or guy line.



A. BENCH-MARK TABLET.



B. CABLE CAR.

The equipment and appurtenances for a cable station consist of the cable and its accessories, the supports and anchorages for sustaining it, and a car for carrying the observer.

CABLE EQUIPMENT.

SUPPORTS.

Standard designs for A-frame supports from 8 to 20 feet in height are shown in drawings Nos. 5 and 6. Plate III, *A*, shows a view of a typical support in place.

In determining the height of frame to be used consideration should be given the highest stage of water, the clearance required below the foot rest of the car, the distance between foot rest and car pulleys and the loaded sag of the cable. The sizes of posts for frames of any height should be fixed by the requirements of the load, which varies with the length of span. A bill of material is given for three or more post sizes for each frame height illustrated.

In all designs the main posts should be framed with a 1 in 5 batter; the distance across the top of the frame should be three-fourths inch less than the length of the top plate; and the spread at the bottom should be as shown in the drawings. The inside dimensions of frames are fixed by the height of frame, the use of the larger sizes of posts increasing only the outside dimensions. The longer cross-sectional dimension of the post should be placed parallel to the cable.

The frames should be supported on mudsills, concrete piers, or other foundations that will distribute the load satisfactorily.

When concrete or other piers are used, provision should be made for fastening the frames to the piers. Such fastening may be accomplished by pairs of three-fourths inch bolts set into the concrete 1 foot inside the posts; the bolts of each pair being spaced far enough apart to allow the sill (A) to pass between them. An iron strap one-half by 2 inches, bored to receive the bolts, should be placed on the sill and screwed down to the bolts to hold it in place.

To prevent the A frame from falling forward, a backstay of proper size should be carried through a turnbuckle to the anchorage. The backstay may be attached either to the eyebolt carrying the sheave or to a U bolt, or 2-inch spread of sufficient length to pierce the posts 3 inches below the top plate. A Crosby clip is placed on the cable just back of the sheave to prevent the frame from falling backward.

The rounds of the ladder may be spiked to the poles, or may be gained in and fastened with a $\frac{1}{4}$-inch by $4\frac{1}{2}$-inch carriage bolt, using a washer on the inside.

All timber used in the construction of the frames should be the best of its kind, thoroughly seasoned and free from large or unsound knots, saps, shakes, wanes, dry rot, or other imperfections impairing its strength, durability, or appearance.

All top plates, as shown on drawing No. 5, should be one-half inch thick and should have a $1\frac{5}{8}$-inch hole through the center. All side plates should be three-eighths inch thick. Side plates for 8-foot frames with 2 by 6 inch posts should have $\frac{3}{4}$-inch holes; all other side plates should have $\frac{7}{8}$-inch holes. The length and breadth of top and side plates, length of head bolts, and spacing of holes in side plates are shown in the tables following.

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TABLE 7.—*Dimensions of top and side plates and bolts.*

Height of A-frame.	Size of posts.	Top plate.	Side plate.	Length of three-fourths inch head bolts.	
				Upper.	Lower.
Feet.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*
8	2 by 6	(a)	(a)	(a)	(a)
	4 by 6	6 by 6	6 by 6	10	11
	6 by 6	6 by 10¾	6 by 6	15	16
12	4 by 6	6 by 6	6 by 6	10	11
	6 by 6	6 by 10¾	6 by 6	15	16
	6 by 8	8 by 10¾	6 by 8	15	16
16	4 by 6	6 by 6	6 by 6	10	11
	6 by 6	6 by 10¾	6 by 6	15	16
	6 by 8	8 by 10¾	6 by 8	15	16
	8 by 8	8 by 15	6 by 8	19	20
20	6 by 6	6 by 10¾	6 by 6	15	16
	6 by 8	8 by 10¾	6 by 8	15	16
	8 by 8	8 by 15	6 by 8	19	20
	8 by 10	10 by 15	6 by 10	19	20

a Special head plate with one-half inch bolts.

TABLE 8.—*Spacing of holes in side plates.*

Side plates for posts.	Dimensions.					
	a	b	c	e	f	h
Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*
4 by 6 and 6 by 6	2	2	2	1¾	2½	1¾
6 by 8 and 8 by 8	2	4	2	2	2	2
8 by 10	2⅛	5¾	2⅛	3	0	3

The length (*m*) of eyebolt (*X*), drawing No. 5, which is furnished with the sheave (*S*) should be 22 inches in all cases, except for the 8-foot frame with 2 by 6 inch posts, in which the dimension (*m*) should be 18 inches. The thread should be cut 3 inches long in all posts. A nut and ogee washer should be furnished with the eyebolt.

The sheave should be made up of a 10-inch block of proper size for the cable used, a 1-inch pin, and a strap, made from round iron flattened, of the dimensions shown on the drawing.

TABLE 9.—*Bill of material for 8-foot frames.*

[Lettered items refer to drawings Nos. 5 and 6.]

Items.	No. of pieces.	2 by 6 inch posts.	4 by 6 inch posts.	6 by 6 inch posts.
A1, sill	1	4 by 6 inches by 5 feet.	6 by 6 inches by 5 feet.	6 by 6 inches by 5 feet.
B1, posts	2	2 by 6 inches by 9 feet.	4 by 6 inches by 9 feet.	6 by 6 inches by 9 feet.
C1, cross braces	2	1½ by 6 inches by 6 feet 6 inches.	1½ by 6 inches by 6 feet 6 inches.	2 by 6 inches by 6 feet 6 inches.
D1, brace	1	2 by 6 inches by 3 feet 3 inches.	2 by 6 inches by 3 feet 3 inches.	2 by 6 inches by 3 feet 6 inches.
E1, brace	1	2 by 6 inches by 2 feet.	2 by 6 inches by 2 feet 3 inches.	2 by 6 inches by 2 feet 6 inches.
J1, stops	2	2 by 6 by 6 inches	4 by 6 by 6 inches	4 by 6 by 6 inches.
S, sheave	1 sheave complete with eyebolt, nut, and ogee washer as per drawing No. 5.			
W, bevel washers	4		See drawing No. 5.	
T1, top plate	1	do	See Table No. 7	See Table No. 7.
P1, side plates	2	do	do	do.
N, head bolts	1	½ by 9 inches	do	do.
	1	½ by 10 inches	do	do.
M, sill bolts	a 4	½ by 8½ inches	½ by 8½ inches	¾ by 8½ inches.
P, post bolts	a 4	do	do	6 bolts ¾ by 8½ inches.
V, lag screws	a 2	½ by 5 inches	½ by 7 inches	½ by 7 inches.
T, crossing bolt	1	½ by 4 inches	½ by 4 inches	½ by 4½ inches.
Gray mixed paint		½ gallon	1 gallon	1 gallon.

a With 2 flat washers each. One washer only for lag screws.

TABLE 10.—*Bill of material for 12-foot frames.*

Items.	No. of pieces.	4 by 6 inch posts.	6 by 6 inch posts.	6 by 8 inch posts.
A2, sill	1	6 by 6 inches by 8 feet.	6 by 6 inches by 8 feet 3 inches.	6 by 8 inches by 8 feet 3 inches.
B2, posts	2	4 by 6 inches by 14 feet.	6 by 6 inches by 14 feet.	6 by 8 inches by 14 feet.
C2, cross braces	2	1½ by 6 inches by 9 feet 6 inches.	2 by 6 inches by 9 feet 6 inches.	2 by 6 inches by 9 feet 6 inches.
D2, brace	1	2 by 6 inches by 5 feet 3 inches.	2 by 6 inches by 5 feet 6 inches.	2 by 6 inches by 5 feet 6 inches.
E2, brace	1	2 by 6 inches by 3 feet 8 inches.	2 by 6 inches by 4 feet.	2 by 6 inches by 4 feet.
F2, brace	1	2 by 6 inches by 2 feet.	2 by 6 inches by 2 feet 4 inches.	2 by 6 inches by 2 feet 4 inches.
G2, brace	1	2 by 4 inches by 2 feet 8 inches.	2 by 4 inches by 3 feet.	2 by 4 inches by 3 feet.
J2, stops	2	4 by 6 inches by 1 foot 3 inches.	4 by 6 inches by 1 foot 3 inches.	4 by 6 inches by 1 foot 3 inches.
L2, ladder poles	2	2 by 4 inches by 10 feet.	2 by 4 inches by 10 feet.	2 by 4 inches by 10 feet.
R, ladder rounds	8	1½ by 2 inches by 1 foot 9 inches.	1½ by 2 inches by 1 foot 9 inches.	1½ by 2 inches by 1 foot 9 inches.
S, sheave	1 sheave complete with eyebolt, nut, and ogee washer as per drawing No. 5.			
W, bevel washers	4		See drawing No. 5.	
T2, top plate	1	See Table No. 7	See Table No. 7	See Table No. 7.
P2, side plates	2	do	do	do.
N, head bolts	a 2	do	do	do.
M, sill bolts	a 4	½ by 9 inches	¾ by 9 inches	¾ by 13 inches.
P, post bolts	a 8	do	do	¾ by 11 inches.
Q, post bolts	a 2	½ by 13 inches	¾ by 13 inches	¾ by 15 inches.
T, crossing bolt	a 1	½ by 4 inches	½ by 5 inches	½ by 5 inches.
Y, ladder bolts	a 4	½ by 7 inches	½ by 7 inches	½ by 7 inches.
Z, eyebolt	a 1	½-inch eyebolt, shank 2½ inches long, with 6 feet of galvanized pump chain.		
V, lag screws	4	½ by 8 inches	½ by 8 inches	½ by 8 inches.
Gray mixed paint		½ gallon	½ gallon	1 gallon.

a With 2 flat washers each. One washer only on lag screw.

TABLE 11.—*Bill of material for 16-foot frames.*

Items.	Number of pieces.	4 by 6 inch posts.	6 by 6 inch posts.
A3, sill	1	6 by 6 inches by 9 feet	6 by 8 inches by 9 feet.
B3, posts	2	4 by 6 inches by 18 feet	6 by 6 inches by 18 feet.
C3, cross braces	2	2 by 6 inches by 9 feet	2 by 6 inches by 9 feet.
H3, cross braces	2	2 by 6 inches by 7 feet	2 by 6 inches by 7 feet.
D3, brace	1	2 by 6 inches by 7 feet 3 inches.	2 by 6 inches by 7 feet 3 inches.
E3, brace	1	2 by 6 inches by 4 feet 3 inches.	2 by 6 inches by 4 feet 8 inches.
F3, brace	1	2 by 6 inches by 2 feet	2 by 6 inches by 2 feet 3 inches.
G3, brace	1	2 by 6 inches by 2 feet	2 by 6 inches by 2 feet 3 inches.
J3, stops	2	4 by 6 inches by 1 foot	4 by 6 inches by 1 foot.
K3, cleats	4	2 by 4 inches by 1 foot 9 inches.	2 by 6 inches by 1 foot 9 inches.
L3, ladder poles	2	2 by 4 inches by 14 feet	2 by 4 inches by 14 feet.
R, ladder rounds	13	1½ by 2 inches by 1 foot 9 inches	1½ by 2 inches by 1 foot 9 inches
S, sheave	1 sheave complete with eyebolt, nut, and ogee washer, as per drawing No. 5.		
W, bevel washers	4	See drawing No. 5.	
T3, top plate	1	See Table No. 7	See Table No. 7.
P3, side plates	2	do	do.
N, head bolts	2	do	do.
M, sill bolts	a 6	¾ by 11 inches	¾ by 11 inches.
P, post bolts	a 6	¾ by 11 inches	¾ by 11 inches.
Q, post bolts	a 2	¾ by 15 inches	¾ by 15 inches.
Q, post bolts	a 2	¾ by 9 inches	¾ by 9 inches.
T, crossing bolts	1	¾ by 3 inches	¾ by 3 inches.
Y, ladder bolts	4	½ by 7 inches	½ by 7 inches.
Z, eyebolt	1	½ inch by same length as crossing bolt, with nut and 6 feet of galvanized pump chain.	
V, lag screws	a 4	½ by 8 inches	½ by 8 inches.
Gray mixed paint		2 gallons	2 gallons.

Items.	Number of pieces.	6 by 8 inch posts.	8 by 8 inch posts.
A3, sill	1	6 by 8 inches by 9 feet	8 by 10 inches by 9 feet 3 inches.
B3, posts	2	6 by 8 inches by 18 feet	8 by 8 inches by 18 feet.
C3, cross braces	2	2 by 6 inches by 9 feet	3 by 6 inches by 9 feet.
H3, cross braces	2	2 by 6 inches by 7 feet	3 by 6 inches by 7 feet.
D3, brace	1	2 by 6 inches by 7 feet 3 inches.	3 by 8 inches by 7 feet 6 inches.
E3, brace	1	2 by 8 inches by 4 feet 8 inches.	3 by 8 inches by 4 feet 10 inches.
F3, brace	1	2 by 6 inches by 2 feet 3 inches.	3 by 6 inches by 2 feet 6 inches.
G3, brace	1	2 by 6 inches by 2 feet 3 inches.	3 by 6 inches by 2 feet 6 inches.
J3, stops	2	4 by 6 inches by 1 foot	4 by 6 inches by 1 foot.
K3, cleats	4	2 by 6 inches by 1 foot 9 inches.	3 by 6 inches by 1 foot 9 inches.
L3, ladder	2	2 by 4 inches by 14 feet	2 by 4 inches by 14 feet.
R, ladder rounds	13	1½ by 2 inches by 1 foot 9 inches	1½ by 2 inches by 1 foot 9 inches.
S, sheave	1 sheave complete with eyebolt, nut, and ogee washer as per drawing No. 5		
W, bevel washers	4	See drawing No. 5.	
T3, top plate	1	See Table No. 7	See Table No. 7.
P3, side plates	2	do	do.
N, head bolts	2	do	do.
M, sill bolts	a 6	¾ by 14½ inches	¾ by 16½ inches.
P, post bolts	a 6	¾ by 14½ inches	¾ by 16½ inches.
P, post bolts	a 2	¾ by 12½ inches	¾ by 13½ inches.
Q, post bolts	a 2	¾ by 18½ inches	¾ by 20½ inches.
T, crossing bolts	a 1	¾ by 4½ inches	¾ by 5½ inches.
Y, ladder bolts	4	½ by 7 inches	½ by 8 inches.
Z, eyebolt	a 1	½ inch by same length as crossing bolt, with nut and 6 feet of galvanized pump chain.	
V, lag screws	a 4	½ by 8 inches	½ by 8 inches.
Gray mixed paint		2½ gallons	2½ gallons.

a With posts over 6 by 6 inches cross section use ogee washers. The additional thickness of ogee washers is allowed for in billing the bolt. For 6 by 6 inches or less use flat washers, 2 on each bolt and 1 on each lag screw.

TABLE 12.—*Bill of material for 20-foot frames.*

Items.	No. of pieces.	6 by 6 inch posts.	6 by 8 inch posts.
A4, sill	1	6 by 8 inches by 11 feet	6 by 8 inches by 11 feet.
B4, posts	2	6 by 6 inches by 22 feet	6 by 8 inches by 22 feet.
C4, cross-braces	2	3 by 6 inches by 10 feet 9 inches	3 by 6 inches by 10 feet 9 inches.
H4, cross-braces	2	3 by 6 inches by 9 feet 6 inches.	3 by 6 inches by 9 feet 6 inches.
D4, brace	1	3 by 6 inches by 9 feet	3 by 6 inches by 9 feet.
E4, brace	1	3 by 8 inches by 5 feet 10 inches	3 by 8 inches by 5 feet 10 inches.
F4, brace	1	3 by 6 inches by 2 feet 3 inches.	3 by 6 inches by 2 feet 3 inches.
G4, brace	1	3 by 6 inches by 2 feet 3 inches.	3 by 6 inches by 2 feet 3 inches.
J4, stops	2	3 by 6 inches by 1 foot	3 by 6 inches by 1 foot.
K4, cleats	4	3 by 6 inches by 1 foot 6 inches.	3 by 6 inches by 1 foot 6 inches.
L4, ladder poles	2	2 by 4 inches by 19 feet	2 by 4 inches by 19 feet.
R, ladder rounds	17	1½ by 2 inches by 1 foot 9 inches	1½ by 2 inches by 1 foot 9 inches.
S, sheave	1 sheave complete with eyebolt, nut, and ogee washer as per drawing No. 5.		
W, bevel washers	4	See drawing No. 5.	
T4, top plate	1	See Table No. 7	See Table No. 7.
P4, side plates	2	do	do.
N, head bolts	a 2	do	do.
M, sill bolts	a 6	¾ by 14½ inches	¾ by 16½ inches.
P, post bolts	a 6	¾ by 14½ inches	¾ by 16½ inches.
P, post bolts	a 2	¾ by 11½ inches	¾ by 13½ inches.
Q, post bolts	a 2	¾ by 18½ inches	¾ by 20½ inches.
T, crossing bolt	a 1	¾ by 5½ inches	¾ by 5½ inches.
Y, ladder bolts	4	½ by 8 inches	½ by 8 inches.
Z, eyebolt	a 1	½ inch by same length as crossing bolt, with nut and 6 feet of galvanized pump chain.	
V, lag screws	a 4	⅝ by 7 inches	⅝ by 7 inches.
Gray mixed paint		2 gallons	2 gallons.

Items.	No. of pieces.	8 by 8 inch posts.	8 by 10 inch posts.
A4, sill	1	8 by 10 inches by 11 feet 3 inches	8 by 10 inches by 11 feet 3 inches.
B4, posts	2	8 by 8 inches by 22 feet	8 by 10 inches by 22 feet.
C4, cross-braces	2	3 by 6 inches by 10 feet 9 inches	3 by 6 inches by 10 feet 9 inches.
H4, cross-braces	2	3 by 6 inches by 9 feet 6 inches.	3 by 6 inches by 9 feet 6 inches.
D4, braces	1	3 by 6 inches by 9 feet 4 inches.	3 by 6 inches by 9 feet 4 inches.
E4, brace	1	3 by 8 inches by 6 feet 2 inches.	3 by 8 inches by 6 feet 2 inches.
F4, brace	1	3 by 6 inches by 2 feet 7 inches.	3 by 6 inches by 2 feet 7 inches.
G4, brace	1	3 by 6 inches by 2 feet 7 inches.	3 by 6 inches by 2 feet 7 inches.
J4, stops	2	3 by 8 inches by 1 foot	3 by 10 inches by 1 foot.
K4, cleats	4	3 by 8 inches by 1 foot 6 inches.	3 by 8 inches by 1 foot 6 inches.
L4, ladder poles	2	2 by 4 inches by 19 feet	2 by 4 inches by 19 feet.
R, ladder rounds	17	1½ by 2 inches by 1 foot 9 inches	1½ by 2 inches by 1 foot 9 inches.
S, sheave	1 sheave complete with eyebolt, nut, and ogee washer as per drawing No. 5.		
W, bevel washers	4	See drawing No. 5.	
T4, top plate	1	See Table No. 7	See Table No. 7.
P4, side plates	2	do	do.
N, head bolts	a 2	do	do.
M, sill bolts	a 6	¾ by 16½ inches	¾ by 18½ inches.
P, post bolts	a 6	¾ by 16½ inches	¾ by 18½ inches.
P, post bolts	a 2	¾ by 13½ inches	¾ by 15½ inches.
Q, post bolts	a 2	¾ by 20½ inches	¾ by 22½ inches.
T, crossing bolt	a 1	¾ by 5½ inches	¾ by 5½ inches.
Y, ladder bolts	4	½ by 8 inches	½ by 8 inches.
Z, eyebolt	a 1	½ inch by same length as crossing bolt, with nut and 6 feet of galvanized pump chain.	
V, lag screws	a 4	⅝ by 7 inches	⅝ by 7 inches.
Gray mixed paint		3 gallons	3 gallons.

a On 20-foot frames use ogee washers. These are approximately three-fourths inch thick, which additional thickness is allowed for in billing the bolt. Use 1 flat washer on each lag screw and 2 on ladder bolts.

ANCHORAGES.

COMMON TYPES.

The most usual types of anchorages for cables are deadmen, trees, and rock ledges. Designs of timber and concrete deadmen are shown on drawing No. 7. The anchorages should always be placed so that they may readily be inspected. A station record showing the type, construction features, and date of installation of anchorages should be kept. Timber deadmen should be thoroughly inspected at least once in four years to determine the condition of the timber.

DEADMEN.

The timber for deadmen should be carefully selected. Logs rather than dimension timber should be used. All timber should be sound, durable, and cleaned of all bark and foreign matter. Carbolineum or creosote should be used as a preservative; if neither is available the timber may be charred.

No deadmen should be less than 12 inches in diameter nor less than 8 feet long. All deadmen should be so constructed as to provide a large factor of safety. The length of the stick and the depth to which it should be buried will depend on the stress on the cable and the nature of the soil. In ordinary loam, clay, or sand the depth should not be less than 6 feet. Additional bearing power may be given by inserting pieces of plank in front of the deadman. The cable should be wrapped around the center of the timber three complete turns and the end of the cable carried above ground, so that the Crosby clips used in fastening may be readily examined. Where the cable is wrapped around the stick the corners, if sharp, should be adzed off, leaving an approximately circular cross section. For great stresses or with small cable the timber should be protected by placing around it a piece of sheet iron one-eighth inch thick, extending under and about 4 inches either way from the cable, and so fitted that the cable can not chafe upon it.

To facilitate drainage about 12 inches of small bowlders, broken stone, coarse cinders, or coarse gravel should be placed around the ends and sides and under the timber.

A concrete anchorage from which an iron eyebolt of appropriate size passes above the ground surface, as illustrated in drawing No. 7, is probably the best type of construction, but on account of its cost it can be used only in exceptional cases. It should be built of such size that its weight and the earth resistance will exceed the pull of the cable. This type of anchorage may be founded upon rock, as shown on the drawing.

Deadmen of properly reenforced concrete may be used where circumstances require them. Forms are not ordinarily required for such construction.

An eyebolt should, if possible, be used to pass from the concrete to the surface of the ground, because the bar of an eyebolt is much less likely to corrode than is the stranded cable. A ship-eye weld should be used on the eyebolt. The bolt should be painted.

The following table (Table 13) of lengths and required burial depths of deadmen is calculated for the working stresses in the cable shown in Table No. 15 on the assumption that the covering material has an angle of repose of 45° (slope 1 to 1), and that the cable after passing through the sheave makes an angle of 30° with the horizontal. The table of distances from the A frame to the deadman is computed for a cable angle of 30° with the horizontal and for level ground. If for any reason the deadman must be placed closer than the tabulated distance, care should be taken to weight the deadman properly. Suitable correction should be made for ground slope. Under ordinary circumstances it is not desirable to have the cable make an angle of more than 45° with the horizontal.

TABLE 13.—*Length and depth of installation of deadmen.*

Diameter of cable.	Working stress.	Length of log.	Depth buried.
Inches.	*Pounds.*	*Feet.*	*Feet.*
One-half	3,700	8	6
Nine-sixteenths	4,700	8	6
Five-eighths	5,700	10	6
Three-fourths	8,000	12	8
Seven-eighths	10,700	12	8
One	14,000	13	10

Deadmen must be not less than 12 inches in diameter.

TABLE 14.—*Distance from foot of A frame to deadmen.*

Diameter of cable.	Height of frame in feet.			
	8	12	16	20
Inches.	*Feet.*	*Feet.*	*Feet.*	*Feet.*
One-half	24	31	38	45
Nine-sixteenths	24	31	38	45
Five-eighths	24	31	38	45
Three-fourths	24	31	38	45
Seven-eighths	28	35	42	49
One	31	38	45	52

TREES.

A tree, if sound and free from windshakes, so located as to be free from danger or erosion, and of sufficient diameter to safely withstand the stress put upon it by the cable, makes a good and cheap anchorage. The roots must be so firmly embedded that the tree will not be subject to excessive vibration in high winds.

The cable should be wrapped three times around the tree, close to the base, and the tree protected by placing a suitable material between the cable and the bark to prevent cutting. Short sections of 2 by 4 inch studding make a very satisfactory protection for the tree. Heavy spikes should be used to prevent the cable slipping up the tree.

ROCK LEDGES.

A rock ledge is in many places the only available anchorage. The ledge must be carefully investigated before being used, to uncover possible fissures or faults, the texture of the rock examined very carefully, and the thickness of the ledge measured if possible. If the rock proves durable and heavy enough, a hole should be drilled into it not less than 24 inches deep and 2 inches in diameter and larger at the bottom than at the face. The anchor bolt should be made of 1½-inch steel, with a split or expansion end provided with a steel wedge, and an eye with a ship-eye weld at the other end. The bolt should be sledged into the hole until the wedge has expanded the split as far as possible. The remaining space, out to the face of the ledge, should be filled with neat Portland cement grout and left to set for 48 hours before the load is put upon the bolt. Sulphur, or sulphur and lead, may be used for the filling and in many places is preferred to cement.

A very secure fastening may be made on top of a ledge with a U bolt with square corners made of 1½-inch round steel. The spread of the bolt should be 12 inches and the length of each leg 18 inches. The U bolt, inverted, is placed into two holes drilled in line with the cable and fastened as described above for the eyebolt. The cable should be passed through the U bolt and fastened with Crosby clips, a thimble being used to protect the cable.

CABLES AND ACCESSORIES.

THE CABLE.

The cable should be composed of six strands, each strand containing seven wires around a hemp center. The material should be the best quality plow steel. The cable should be galvanized and should be one continuous piece, no splicing being allowed. As a rule the cable must be ordered from the factory, as few dealers carry galvanized plow-steel cable in stock.

The calculations for cables are based upon the method published by J. C. Stevens in Engineering News, May 6, 1909. A working stress of one-sixth the ultimate strength, as published by manufacturers of cable, is used throughout. The tables present data for regular sizes of cables from a half inch to 1 inch and for spans from 100 to 1,000 feet, covering all ordinary requirements of stream-gaging work. For other conditions special designs should be made.

Table 15 shows, for specified spans, cable sizes and corresponding allowable working stresses, and the "loaded sag" that will occur in various span lengths under the dead load of the weight of cable and an assumed concentrated load of 550 pounds, which represents the approximate weight of the car, meter equipment, and two observers.

Table 16 shows the "erection sag," or sag without concentrated load, of the cables listed in Table 15 and also shows the tension placed on each cable or the pull required in erecting it to the prescribed sag distance.

Plate V shows graphically the information contained in Tables 15 and 16.

Table 17 shows for specified span lengths the diameter of the smallest cable that may properly be used and the corresponding sag.

TABLE 15.—*Sag for loaded cables.*

[Plow steel cable—6 strands of 7 wires each—concentrated load 550 pounds.]

Span in feet.	Allowable working stress in pounds.					
	One-half inch cable, 3,700.	Nine-sixteenths inch cable, 4,700.	Five-eighths inch cable, 5,700.	Three-fourths inch cable, 8,000.	Seven-eighths inch cable, 10,700.	One-inch cable, 14,000.
	Feet.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*
100	3.85	3.06	2.55	1.86	1.43	1.12
200	7.96	6.38	5.37	3.99	3.13	2.53
300	12.33	9.97	8.46	6.41	5.12	4.22
400	16.97	13.83	11.82	9.10	7.38	6.18
500	21.88	17.95	15.46	12.07	9.93	8.44
600	27.04	22.34	19.36	15.32	12.75	10.97
800	38.16	31.91	28.00	22.65	19.25	16.88
1,000	50.34	42.55	37.71	31.09	26.87	23.92

TABLE 16.—*Erection sag (in feet) and tension in erecting cables.*

[Plow steel rope—6 strands of 7 wires each.]

Span in feet.	Diameter of cable in inches.					
	One-half.		Nine-sixteenths.		Five-eighths.	
	Sag.	*Tension.*	*Sag.*	*Tension.*	*Sag.*	*Tension.*
100	2.86	170	2.04	310	1.45	530
200	6.03	320	4.45	560	3.37	920
300	9.49	460	7.19	780	5.67	1,230
400	13.23	590	10.25	980	8.29	1,490
500	17.26	710	13.58	1,150	11.24	1,720
600	21.53	810	17.20	1,310	14.45	1,930
800	30.86	1,010	25.23	1,590	21.72	2,280
1,000	41.20	1,180	34.28	1,820	30.02	2,580
Span in feet.	**Diameter of cable in inches.**					
	Three-fourths.		**Seven-eighths.**		**One.**	
	Sag.	*Tension.*	*Sag.*	*Tension.*	*Sag.*	*Tension.*
100	0.54	2,060	0.14	10,710	0.12	16,460
200	1.84	2,420	1.11	5,400	.83	9,520
300	3.58	2,800	2.46	5,490	1.92	9,260
400	5.68	3,130	4.20	5,710	3.41	9,270
500	8.09	3,440	6.29	5,960	5.24	9,420
600	10.80	3,710	8.67	6,230	7.38	9,630
800	17.05	4,180	14.27	6,730	12.52	10,100
1,000	24.35	4,570	20.93	7,170	18.70	10,560

TABLE 17.—*Smallest allowable cable, with corresponding sag for various spans.*

Span.	Cable.	Loaded sag.	Erection sag.
Feet.	*Inches.*	*Feet.*	*Feet.*
Up to 200	One-half	8	6
200 to 300	Nine-sixteenths	10	7.2
300 to 400	Five-eighths	11.8	8.3
400 to 650	Three-fourths	17	12.2
650 to 850	Seven-eighths	21.1	15.9
850 to 1,000	One	24	18.7

When selecting a cable for a given span, note first the smallest size that may be used, as specified in Table 17. Next find from Plate V or Table 15 the loaded sag and estimate the necessary height of support. It should be noted that for a given span, cables other than the smallest size allowable have a less sag, so that where it is necessary, as for reducing the height of support, a cable of larger size than the minimum may be used.

TURNBUCKLES.

In order to adjust the cable to the proper sag, a turnbuckle is placed between the deadman and the support. It should be placed close to the ground, so that it may be easily operated. With $\frac{1}{2}$-inch, $\frac{9}{16}$-inch, and $\frac{5}{8}$-inch cables, a 1-inch turnbuckle is used. With $\frac{3}{4}$-inch, $\frac{7}{8}$-inch, and 1-inch cables, a $1\frac{1}{2}$-inch turnbuckle is used. A thimble of proper size is used in each eye of the turnbuckle.

The turnbuckles should be of standard manufacture, of round iron, eye and eye, galvanized, and have 36-inch takeups.

CLIPS.

Three Crosby clips are applied at each point where the cable is fastened. Clips of the same size as the cable must be used in all cases.

BACKSTAY.

A backstay should be run from the top of the support to the anchorage and should be fastened with wire rope clamps. A galvanized eye and eye turnbuckle with 6-inch takeup should be inserted in the backstay.

For stations using $\frac{1}{2}$-inch, $\frac{9}{16}$-inch, or $\frac{5}{8}$-inch cables, use $\frac{1}{4}$-inch galvanized-wire strand backstay, with $\frac{1}{4}$-inch eye and eye turnbuckle; with installations using $\frac{3}{4}$-inch, $\frac{7}{8}$-inch, and 1-inch cables, use galvanized-wire strand backstay half an inch in diameter, with $\frac{1}{2}$-inch galvanized eye and eye turnbuckle. The galvanized-wire strand is composed of seven steel wires twisted into a single strand and is commonly used as a guy rope by electric-light companies.

LIST OF MATERIALS.

For each cable station the materials shown in the following table are required.

TABLE 18.—*Bill of material for cable installation.*

—— feet galvanized plow steel cable, —— diameter.
14 Crosby clips, same size as cable, 3 at each anchorage, 3 at each end of turnbuckle, 1 behind each sheave "S" of support.
—— feet galvanized wire strand, —— diameter.
8 wire rope clamps, same diameter as wire strand, 1 at each anchorage, 1 at each support, 1 at each end of turnbuckle.
1 galvanized turnbuckle, eye and eye, proper size for cable used.
2 oval wire rope thimbles, galvanized, same size as cable.
2 galvanized turnbuckles, eye and eye, same size as wire strand.

CARS.

The dimensions of the standard car are shown in full detail on drawing No. 8, and a complete list of the material for its construction is given in Table 19. The frame and sides of the car may be made of any suitable lumber, the pieces preferably being fastened together with screws. The appearance of the finished car is shown in Plate IV, *B*.

The frame of the car should be given two coats of good paint, one before and one after assembling. A high-grade gray paint may be made by mixing white lead and boiled linseed oil and adding one part of mixed coach black to eight parts of mixed lead and oil. Carbolineum, applied hot, instead of paint, makes a very satisfactory finish.

The marker (T) which may be made of a piece of lath of similar wood, is attached to the spacing bar (G), exactly 5 feet from a point over the side sheave (K),[1] so that in connection with markings on the cable the measuring section may be readily located.

The notebook rest or table should be attached to the top and outside of the right-hand side board of the car, as used, at a convenient distance in front of the main hanger. It should be attached by means of a pair of 3-inch strap hinges and two screw hooks and eyes, which hold it in position for use. When not in use, the hook is released and the table folds down over the outside of the car. A steel paper clip screwed to the top of the table holds the notebook while the measurement is being made.

All ironwork on the car must be galvanized.

TABLE 19.—*Bill of material for standard cable car.*

LUMBER.

Item 1. 1 piece yellow pine, 2 by 4 inches by 18 feet, S4S, from which cut—
- 2 pieces A sides of bed frame, 2 by 4 inches by 6 feet.
- 2 pieces B ends of bed frame, 2 by 4 inches by 1 foot 6 inches.
- 1 piece F foot rest, 2 by 4 inches by 1 foot 2 inches.

2. 2 pieces yellow pine, 1 by 10 inches by 10 feet, S4S, from which cut—
- 2 pieces C sides of car, 1 by 10 inches by 6 feet.
- 2 pieces E1 seats of car, 1 by 10 inches by 1 foot 10 inches.
- 2 pieces E2 bottom of tool box, 1 by 10 inches by 2 feet.

3. 1 piece yellow pine, 1 by 12 inches by 4 feet, from which cut—
- 2 pieces D ends of car, 1 by 11 inches by 2 feet.

4. 1 piece yellow pine, 1 by 6 inches by 12 feet, S4S, from which cut—
- 2 pieces E3 seats, 1 by 6 inches by 1 foot 10 inches.
- 2 pieces E4 bottom of tool box, 1 by 6 inches by 2 feet.
- 2 pieces E5 front of tool box, 1 by 4 inches by 1 foot 6 inches.

5. 1 piece yellow pine, 2 by 2 inches (exact) by 8 feet 3 inches, S4S, from which cut—
- 1 piece G top spacing bar, 2 by 2 inches by 7 feet 7 inches.
- 2 pieces H spacing blocks, 2 by 2 by 4 inches.

6. One-half gallon gray mixed paint.

HARDWARE.

All hardware on this bill shall be the best of its kind, and shall be thoroughly galvanized.

7. 2 cast-iron sheaves, 10 by $1\frac{3}{4}$ by $\frac{7}{8}$ inches....Index I.
8. 2 cast-iron sheaves, 4 by 1 by $\frac{3}{8}$ inches....Index K.
9. 2 main hangers, as per detail....Index L.
10. 2 machine bolts, $\frac{7}{8}$ by $2\frac{3}{4}$ inches, with cotter pins....Index M.
11. 6 machine bolts, $\frac{1}{4}$ by $2\frac{3}{4}$ inches, for spacers....Index N.
12. 4 machine bolts, $\frac{1}{4}$ by $1\frac{1}{2}$ inches, in main hanger[2]....Index O.

[1] Star brand 6-roller bushed sheaves, made by the Boston & Lockport Block Co., Boston, Mass., have been found satisfactory.

[2] With one washer to use next to wood.

Item 13. 4 machine bolts, $\frac{3}{8}$ by $1\frac{1}{2}$ inches, in main hanger[1] .... Index O1.
14. 2 foot rest hangers, as per detail .... Index V.
15. 4 machine bolts, $\frac{3}{8}$ by 4 inches, in foot-rest hanger .... Index P.
16. 2 carriage bolts, $\frac{3}{8}$ by $2\frac{1}{2}$ inches, in foot rest .... Index Q.
17. 2 sheave brackets as per detail for meter cord sheave .... Index W.
18. 2 machine bolts, $\frac{3}{8}$ by 5 inches, in side sheave[1] .... Index R.
19. 4 machine bolts, $\frac{1}{4}$ by 4 inches, in bracket .... Index S.
20. 2 U bolts, as per detail .... Index U.
21. 4 machine bolts, $\frac{1}{4}$ by $1\frac{1}{2}$ inches, in U bolt[1] .... Index Y.
22. 4 Tee hinges, 3 inches, for seat boxes .... Index X1.
23. 1 pair 3-inch strap hinges, for notebook rest .... Index X2.
24. 1 screw hook and eye for notebook rest .... Index Z.
25. 1 gross 2-inch No. 10 F. H. Bright wood screws.
26. 2 cleats 4 inches long.

ERECTION.

The selection and design of the cable equipment having been completed and the material assembled, the erection of the cable structure should preceed about as described below. The anchorages should be completed first and the supports and car constructed next. Then the cable should be attached to the anchorage on the side of the stream least accessible, threaded through the sheaves of the first support, stretched across the stream, threaded through the sheaves of the car and second support, the turnbuckle inserted and attachment to the second anchorage made. The supports should then be raised and the cable set to the proper sag, a differential block generally being used.

The cable may be stretched across the stream most easily by first stringing a No. 10 wire and securing it to each bank. Then the cable is hung on the wire with carrier hooks, such as are used for carrying lead telephone cables, and drawn across the stream. On streams of moderate velocity, where a boat may be used, the end of the cable may be fastened to the boat and thus kept off the bottom while the boat is pulled across the stream by means of a rope or wire.

On a stream with smooth bottom the cable may be run across the stream in the following manner: Stretch an ordinary telephone wire, of a length at least three times the width of the stream, along the bank at the water's edge, and upstream from the cable site. The upper end should be fastened or held by an assistant and the lower end fastened to a 2 by 6 inch timber, 14 to 16 feet long. The timber should be fastened with a yoke to the wire so that it will float at a decided angle to the current. Another wire, long enough to reach well across the stream, should be fastened to the timber at the cable site, the timber set afloat, and the wire paid out as the timber travels across the stream, swinging in an arc around the point where the long wire is fastened or held. With this line a larger line, or rope, may be brought across with which in turn the cable may be pulled across.

The desired sag should be obtained by using a level at the proper distance below the top of the sheave block of one support, and setting the lowest point of the cable up to this elevation. With favorable topography a wye level set on the side hill may be used. Otherwise an observer with a hand level is placed on the support with his eye at the proper distance below the sheave.

[1] With one washer to use next to wood.

To detect the possible slipping of the Crosby clips the clip nearest the end of the cable should be so placed that the cable between it and the next clip back is sufficiently slack to give the effect of a slight loop.

The following list will be found helpful in collecting the tools necessary for the erection of the cable stations and standard shelters. Ordinarily it will be advantageous to fit out a box for the tools, which may then be shipped to the site of the work. The box should contain the following:

TABLE 20.—*Helpful tools.*

Set carpenter's tools.
Axes.
Long-handled shovels, round point.
Short-handled shovels, round point.
Short-handled shovels, square point.
Picks.
Spading fork for concrete work.
Striking hammers.
Set rock drills, diamond point.
Crowbar.
Pinch bar.
10-ton differential block.
100 feet manila rope, one-half inch in diameter.
Set metal blocks to be used with above.
Rope and tackle, depending on local conditions.
Water pail and dipper.
Bailing pails.
Monkey wrench.
Spanner wrench for nuts on slope gage.
Caulking tools for intake pipe.
Small force pump with hose may be used to flush out intake pipe.

BRIDGES.

A gaging station established at a place where a stream is crossed by a bridge can generally be installed at a lower cost than that involved in any other installation. Unfortunately the conditions of channel and current that insure accurate records are not usually found at existing bridges, so that the saving of expense generally involves the sacrifice of accuracy, which is more surely attained by selecting a site without reference to existing structures. Even if the first cost of the station is large, it will be justified by the material saving that will be effected in maintenance, if the station is to be continued through a considerable period of time, because fewer discharge measurements will be necessary to determine the station rating curve.

If the stream is not too large it may sometimes be advantageous to construct a special wooden or suspension bridge.

Streams less than 200 feet wide may be spanned by footbridges constructed on supporting cables of three-eighths inch galvanized plow steel, or of cables built up of a sufficient number of parallel strands of No. 10 galvanized iron wire. When a suspension cable of the latter type is used it should be built up by passing separate strands across the stream and fastening them in place, the wire being unwound from the coil as used.

Two suspension cables should be carried over the stream at the same elevation and 3 feet apart. They should be supported by trees or A frames if necessary, and the ends should be fastened either to trees or deadmen. Directly over and 3 feet above the main cables there should be two cables to serve as guards and to furnish support and stiffness to the bridge. Each of these cables should be connected vertically with the corresponding lower cable by means of No. 12 wire, or by seizing wire which, being drawn taut, transmits a portion of the load to the upper cable. These verticals should be put in at the end of each 2 by 4 inch by 3 foot 6 inch floor beam.

The floor beams should be placed 4 feet apart along the lower cable with the 4-inch dimension vertical. They should be notched 1 inch deep 3 inches back from each end. The notches, together with the vertical connecting wires wound around the crosspieces and the cable at each end, will prevent the crosspieces slipping from the cable.

The floor may be made of two parallel lines of 1 by 8 inch boards, spaced 2 inches apart. Either 12-foot or 16-foot boards should be used, and so laid as to break joints at the ends. The floor boards should be nailed to the 2 by 4 inch floor beams by 2½-inch (8d.) nails.

Measuring points should be marked on the bridge floor and the distance from the initial point should be painted beside the marks.

BOATS.

Boat stations as ordinarily equipped are unsatisfactory because of the difficulty in holding the boat in position while making soundings and in operating the meter, but ferryboats operated from cables can often be used advantageously. In measuring large streams, such as Niagara, St. Lawrence, and Mississippi rivers, specially constructed and equipped catamarans have been used with great success by the engineers of the United States Army, but the equipment is expensive and its use is practically restricted to special investigations on important rivers.

STAY LINE.

A stay line to hold the meter in the vertical against the drag of the current is a desirable adjunct to a current-meter station. The use of the stay line is illustrated in Plate III, *B*. Stay lines should be fastened to trees or to posts set firmly in the ground and properly guyed. A galvanized eye and eye turnbuckle should be inserted at one end of the line to take up the sag.

The stay line should be placed so far upstream from the cable that the line from meter to stay line makes an angle of not more than 30° with the horizontal. Half of the distance between the stay line and car may be covered by a No. 10 galvanized wire, one end of which should be attached to a 2½-inch clothes-line pulley[1] rolling on a stay line, the end nearest the car being attached to a 2-inch galvanized awning pulley that will accommodate ⅜-inch braided sash cord.

[1] Sargent & Co. No. 162.

The following table will aid in the selection of stay lines:

TABLE 21.—*Data for selection of stay lines.*

Span.	Stay line.	Breaking strength.	Minimum sag.	Turnbuckle.	Fastening.
Feet.		*Pounds.*	*Feet.*	*Inches.*	
Up to 200...	No. 8 galvanized telegraph wire.	1,000	2	One-fourth..........	Twisted.
200 to 500...	One-fourth standard steel wire strand.	2,300	7	.....do.............	Wire clamps.
500 to 750...	One-half high strength (crucible steel) wire strand.	18,000	8	Five-eighths........	do.
750 to 1,000.	One-half extra high strength (plow steel) wire strand.	27,000	15	Seven-eighths......	do.

LINES FOR INDICATING MEASURING POINTS.

In order that the measuring points at a gaging station may be easily found at the time of making measurements and that the distance between the measuring points may be readily determined, they should be referred to a fixed initial point, and the span should be divided into sections by permanent marks placed at regular intervals on the bridge rail or floor of a bridge station; on the main cable or on a secondary tagged cable of a cable station, or, for measurements made from a boat or by wading, on a tape or tagged line stretched across the stream. If tape or tagged line can not be left in place, the initial point should be so located and marked that at each discharge measurement the line can be stretched in the same position as for previous measurements.

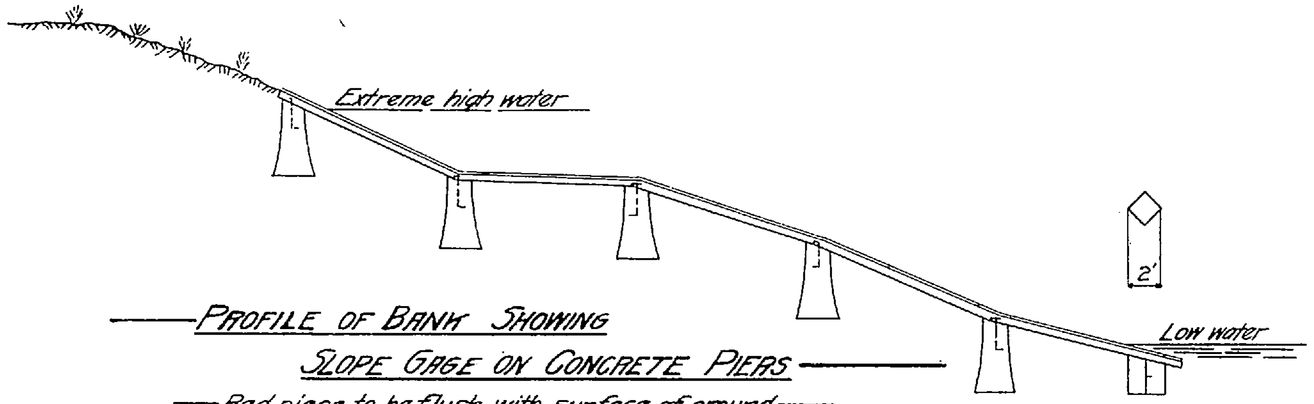
ARTIFICIAL CONTROLS.

To determine the discharge of a stream which, because of shifting bed or other conditions, affords no satisfactory section for making discharge measurements or for collecting records of stage from which the discharge may be computed, it may be necessary to provide an artificial control to maintain a constant relation between gage height and discharge and also to improve the channel so that satisfactory measurements can be made.

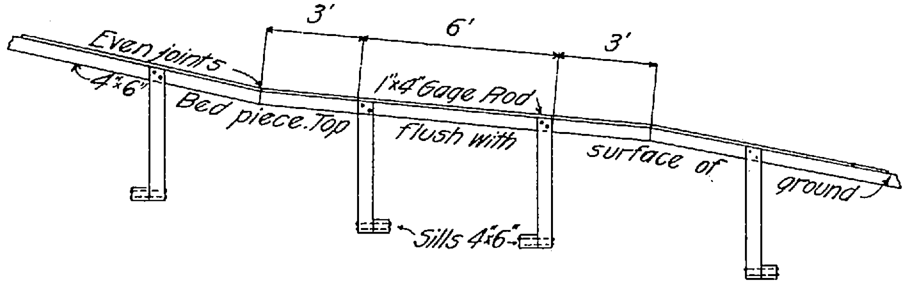
In constructing an artificial control care should be taken to preserve as nearly as possible the natural condition of the channel; that is, it should be made to conform closely to the natural bed of the stream and should not project into the channel, as such projection will greatly reduce the sensitiveness of the station at low stages, and thus reduce the accuracy of the record. At a control formed by a reef or bar of gravel or bowlders, scouring and change of channel may possibly be prevented by grouting with cement. Sheet piling driven across the section nearly flush with the bottom of the stream may tend to prevent scouring of channels in sand or silt and form a barrier over which the natural current may reduce the probability of silting.

Artificial controls and channel improvements should, however, be attempted only after a careful study of the local conditions which determine their effectiveness. Any structure intended to modify the cross section or alignment of a stream which will change the conditions of equilibrium established by nature may be expensive to maintain and should always be carefully planned and closely watched.

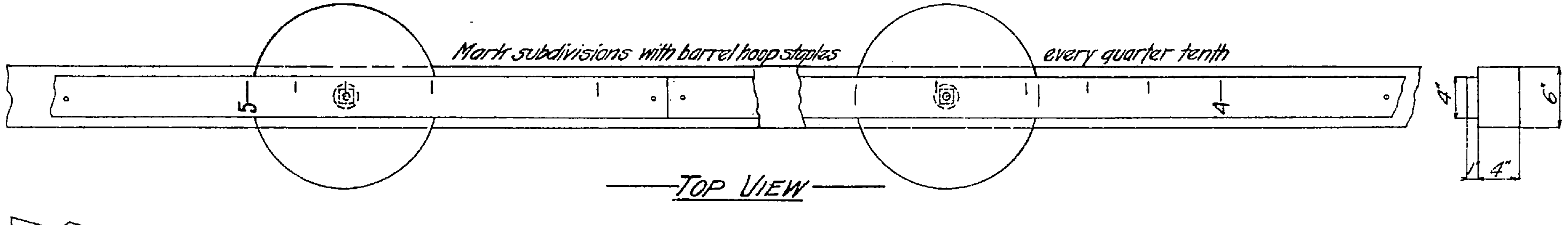
O



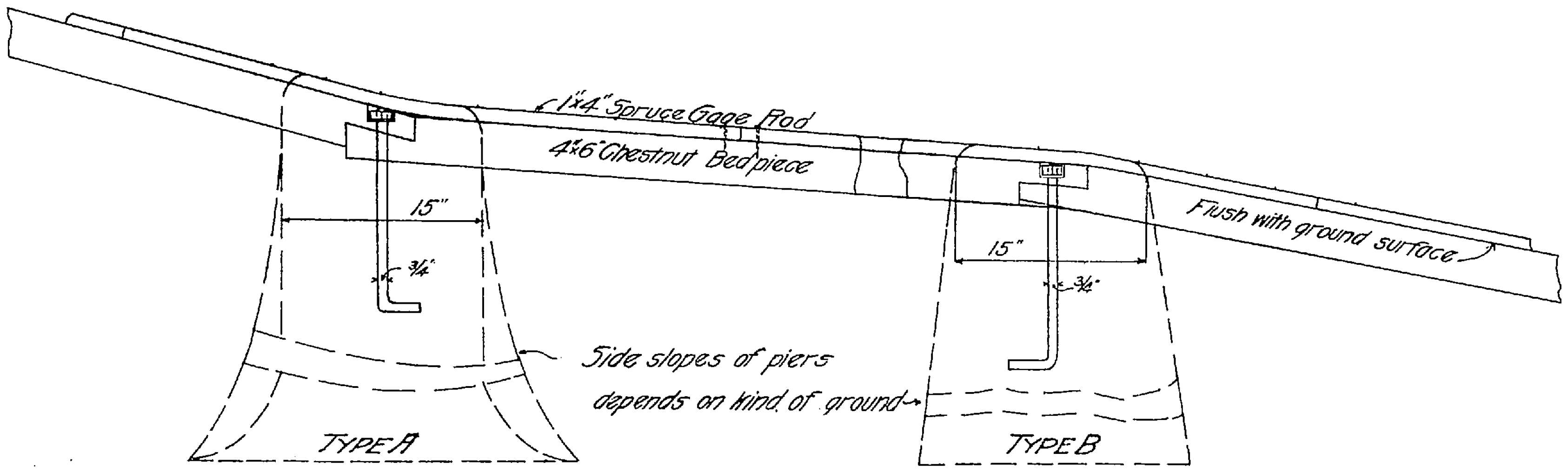
PROFILE OF BANK SHOWING
SLOPE GAGE ON CONCRETE PIERS
Bed piece to be flush with surface of ground
Piers to extend below frost line



METHOD OF INSTALLING SLOPE GAGE
ON SHIFTING CHANNELS

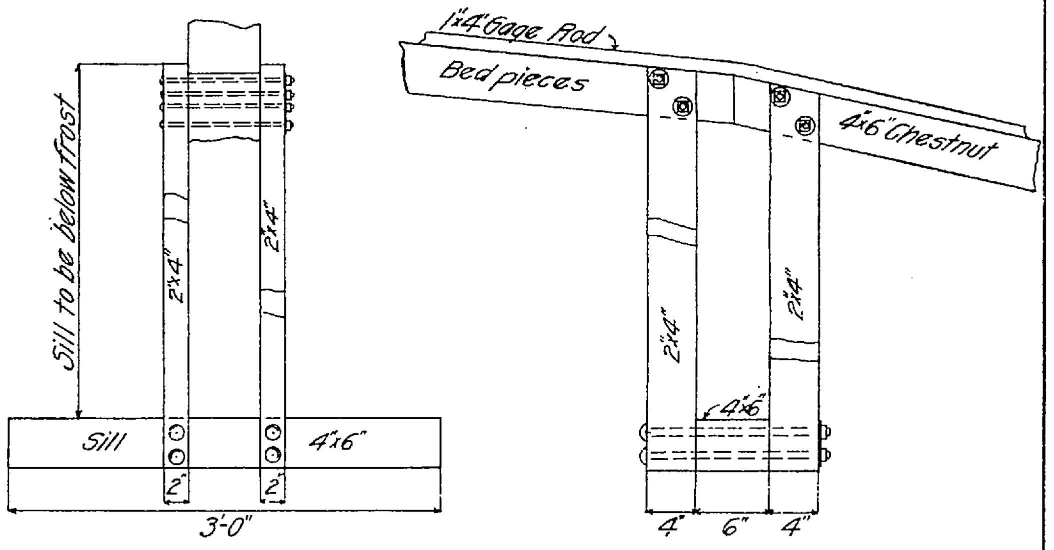


TOP VIEW



Piers Spaced 11'-0" C-C Slope Measurement

DETAIL OF SLOPE GAGE CONCRETE ANCHORAGES
Section on Center Line

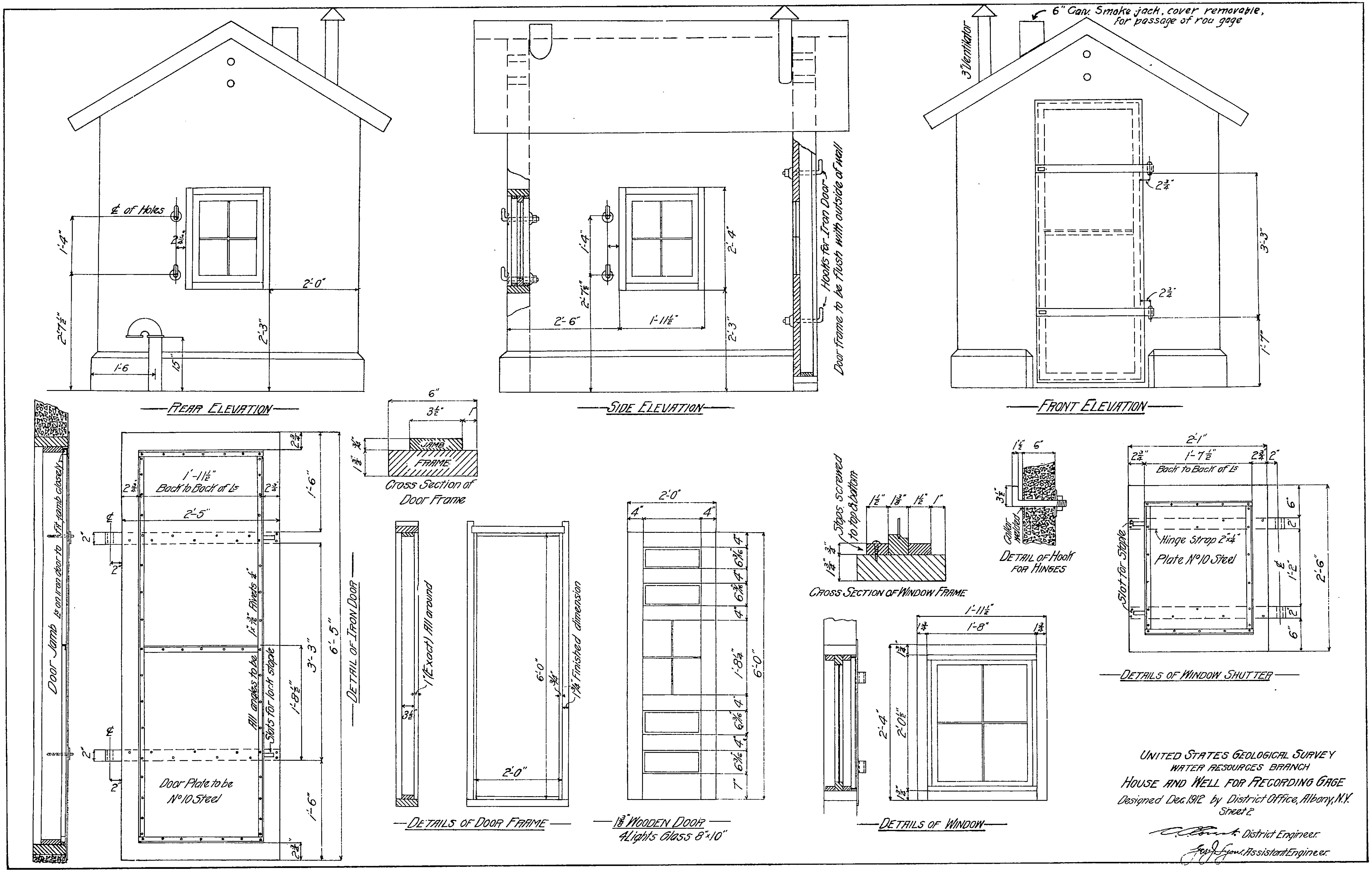


TIMBER ANCHORAGE FOR SLOPE GAGE

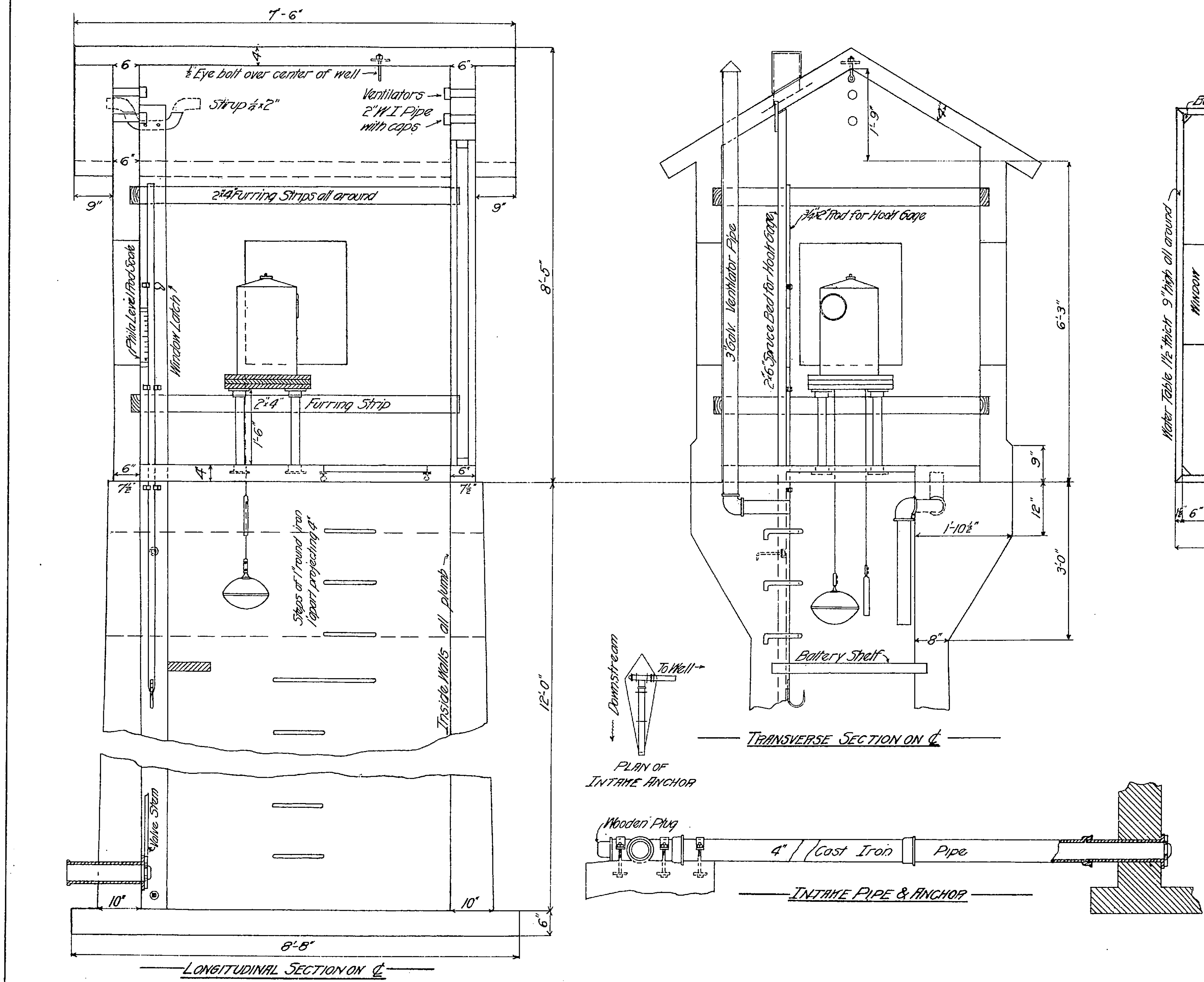
UNITED STATES GEOLOGICAL SURVEY
WATER RESOURCES BRANCH
SLOPE GAGES & ANCHORAGES
Designed Mar. 1913 by District Office, Albany, N.Y.
Asst. Engineer
District Engineer

WEBB & BOCORSELSKI, INC. WASHINGTON, D. C.

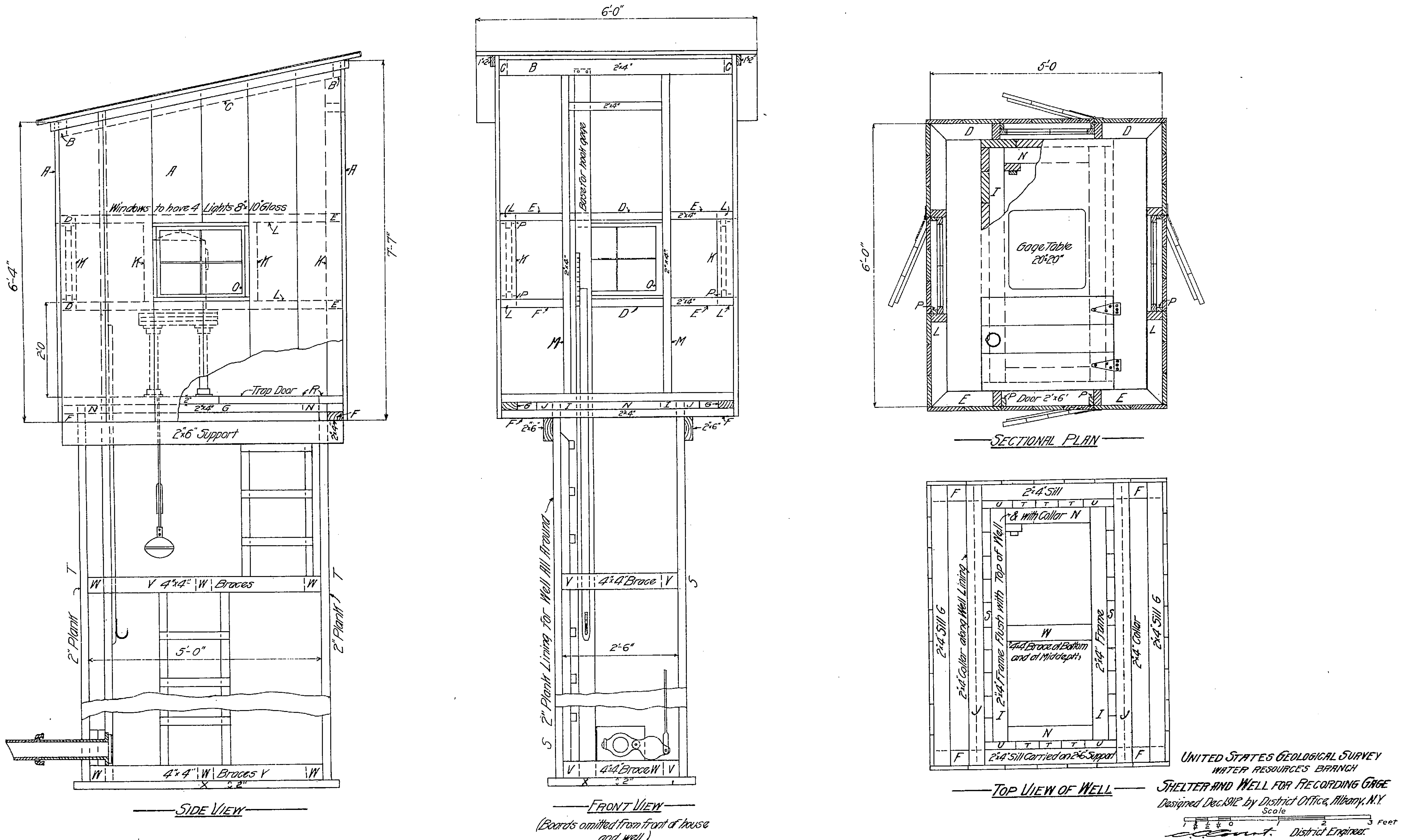
DRAWING NO. 2



Webb & Bocorselski, Inc., Washington, D. C.



UNITED STATES GEOLOGICAL SURVEY
WATER RESOURCES BRANCH
HOUSE AND WELL FOR RECORDING GAGE
Designed Dec. 1912 by District Office, Albany, N.Y.
Scale
1 0 1 2 3 Feet
District Engineer.
Assistant Engineer.



UNITED STATES GEOLOGICAL SURVEY
WATER RESOURCES BRANCH

SHELTER AND WELL FOR RECORDING GAGE

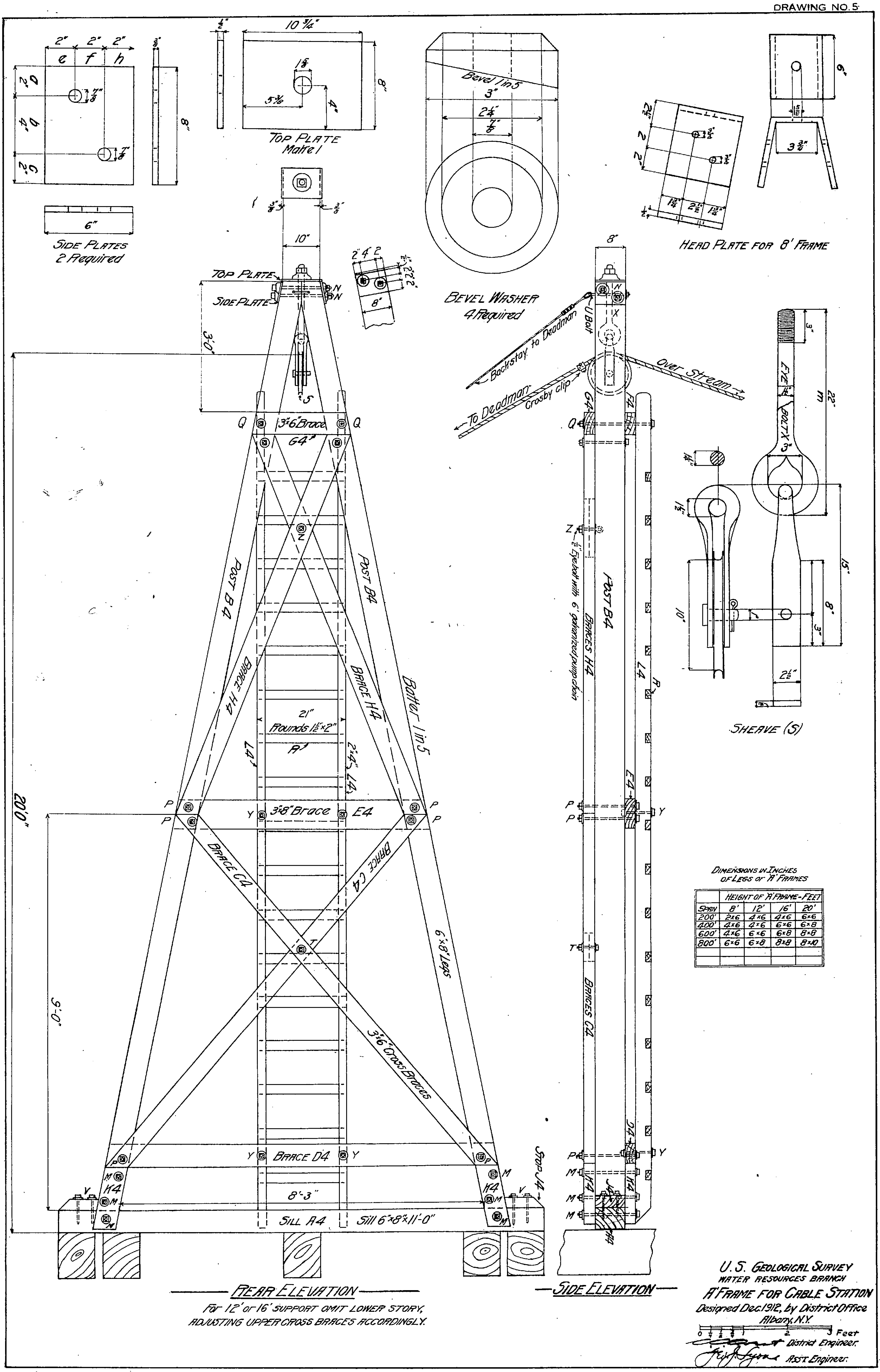
Designed Dec. 1912 by District Office, Albany, N.Y.

Scale: 0 — 3 Feet

District Engineer.

Assistant Engineer.

WEBB & BOCORSELSKI, INC., WASHINGTON, D. C.



DIMENSIONS IN INCHES OF LEGS OF 'A' FRAMES

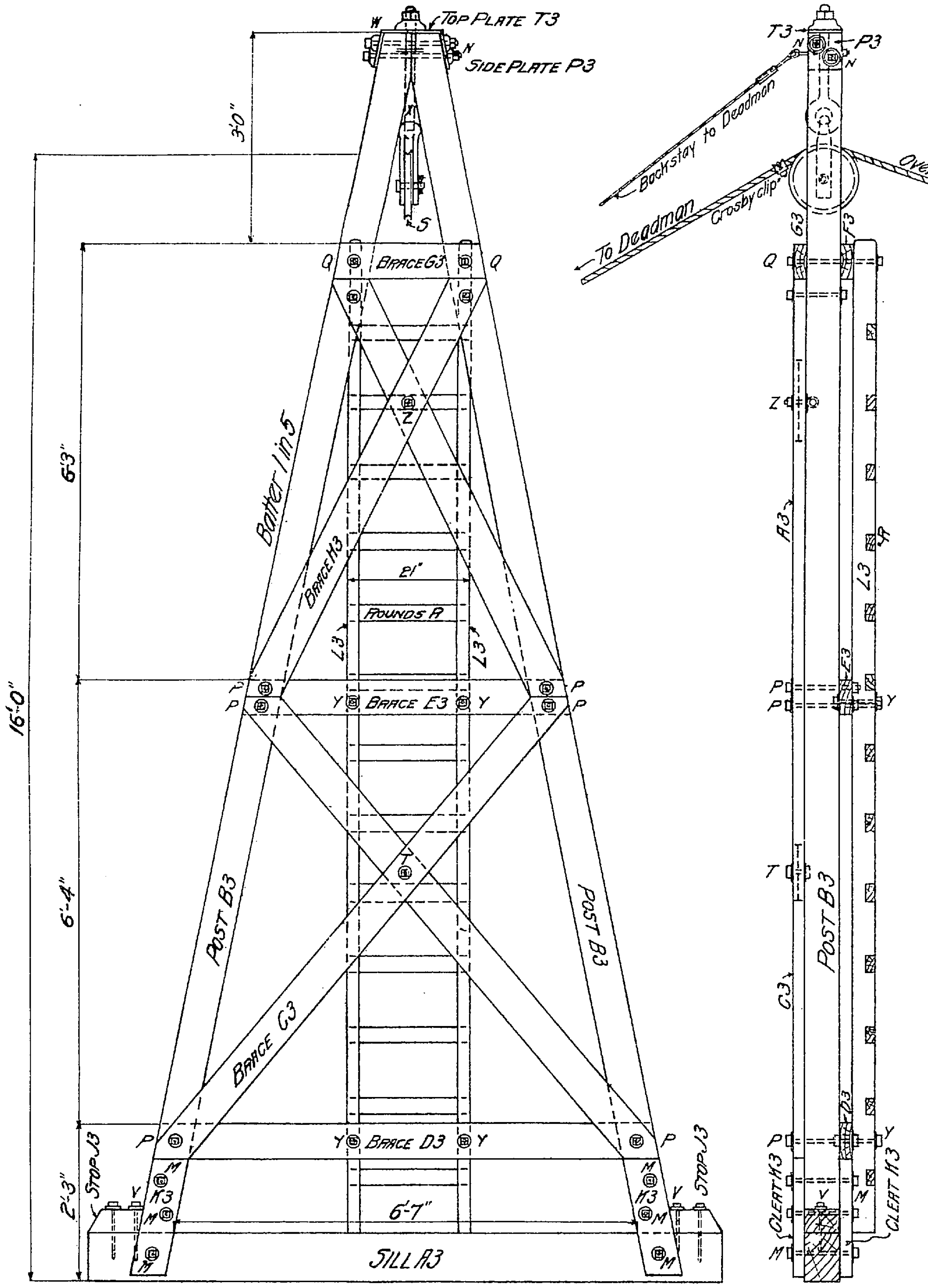
	HEIGHT OF 'A' FRAME - FEET			
SPAN	8'	12'	16'	20'
200'	2x6	4x6	4x6	6x6
400'	4x6	4x6	6x6	6x8
600'	4x6	6x6	6x8	8x8
800'	6x6	6x8	8x8	8x10

U. S. GEOLOGICAL SURVEY
WATER RESOURCES BRANCH
'A' FRAME FOR CABLE STATION
Designed Dec. 1912, by District Office
Albany, N.Y.

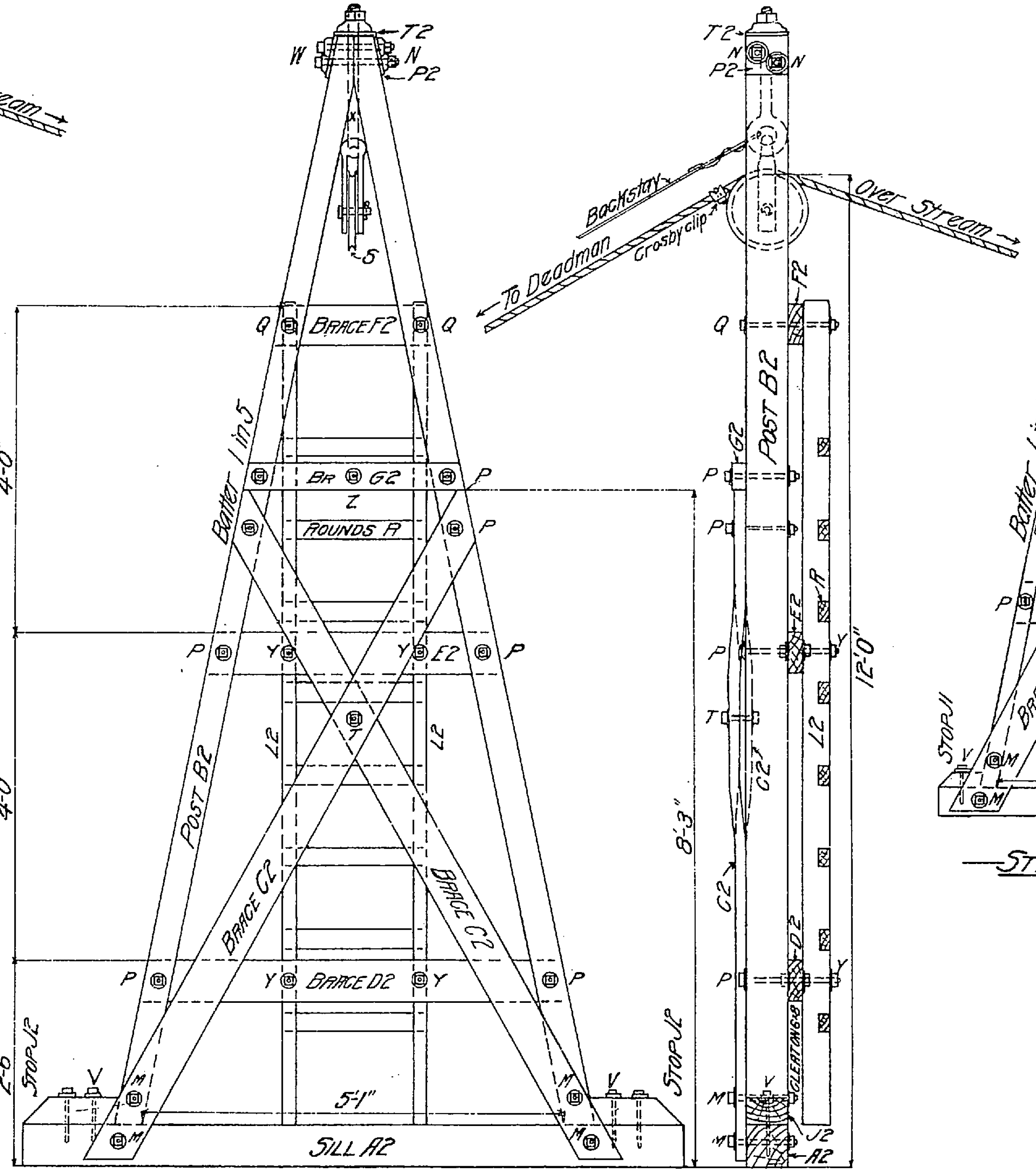
0 — 1 — 2 — 3 Feet

District Engineer.
Asst. Engineer.

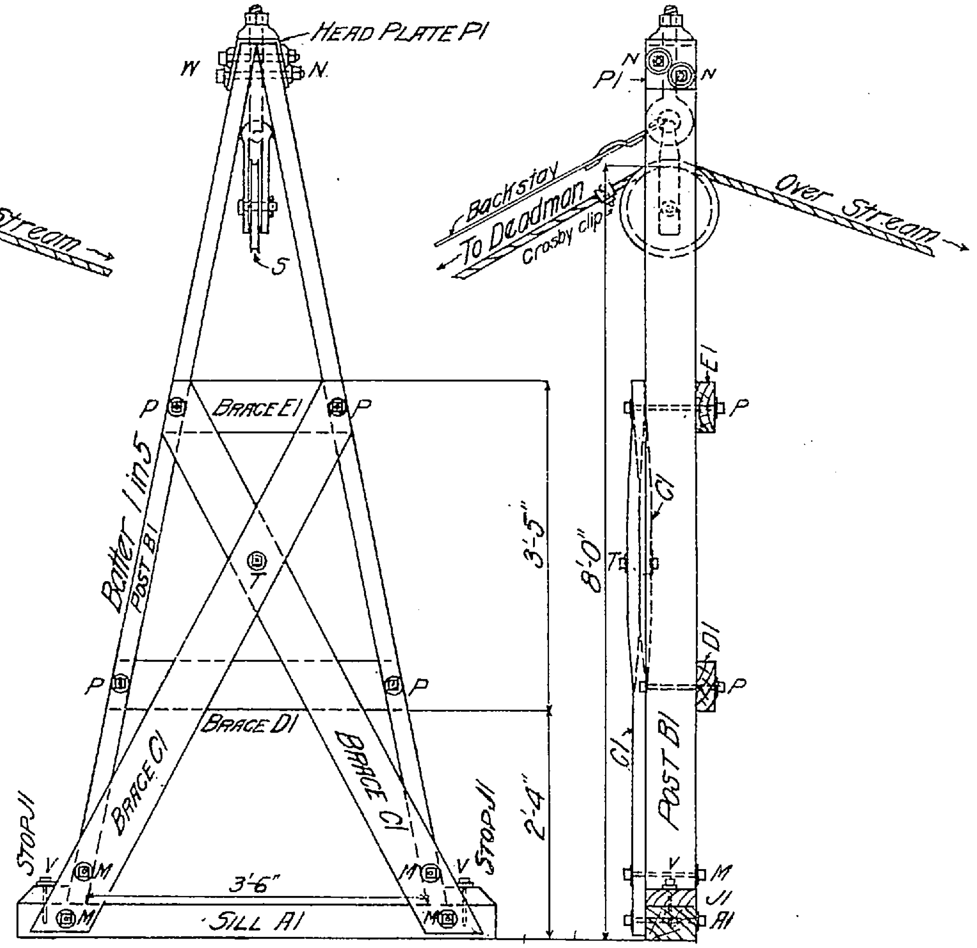
DRAWING NO.6



—STANDARD 16' A FRAME—



—STANDARD 12' A FRAME—



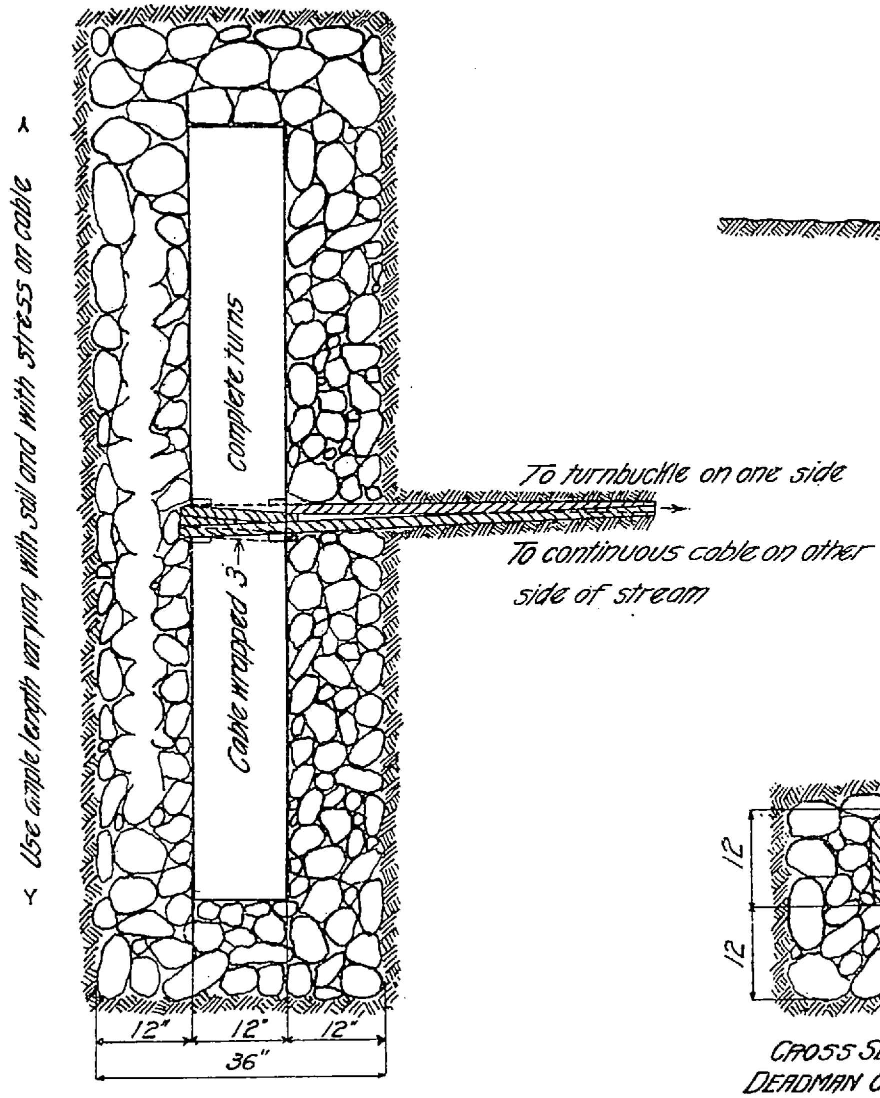
—STANDARD 8' A FRAME—

UNITED STATES GEOLOGICAL SURVEY
WATER RESOURCES BRANCH
A FRAMES FOR CABLE STATIONS
Designed Mar. 1913 by District Office, Albany, N.Y.

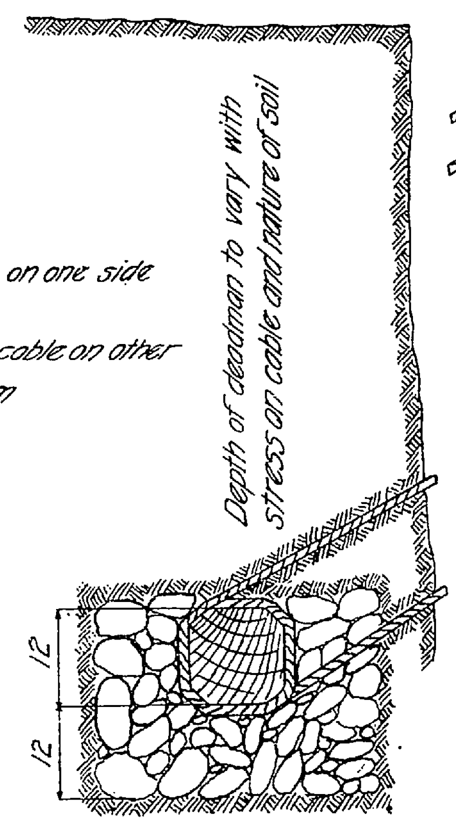
0 ¼ ½ ¾ 1 2 3 4 Feet

Asst. Engineer.
District Engineer.

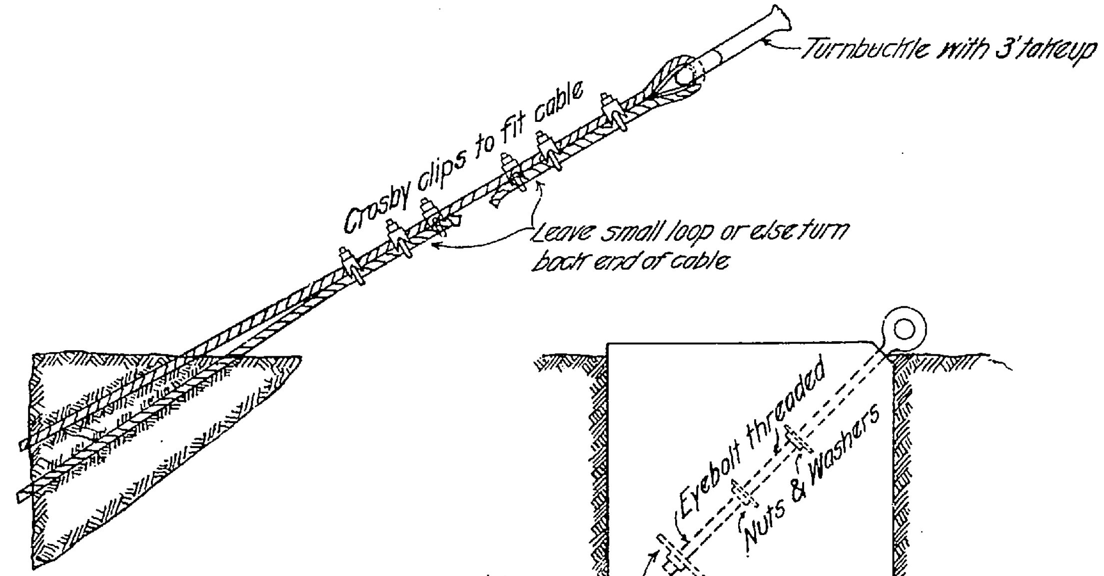
WEBB & BOCORSELSKI, INC., WASHINGTON, D. C.

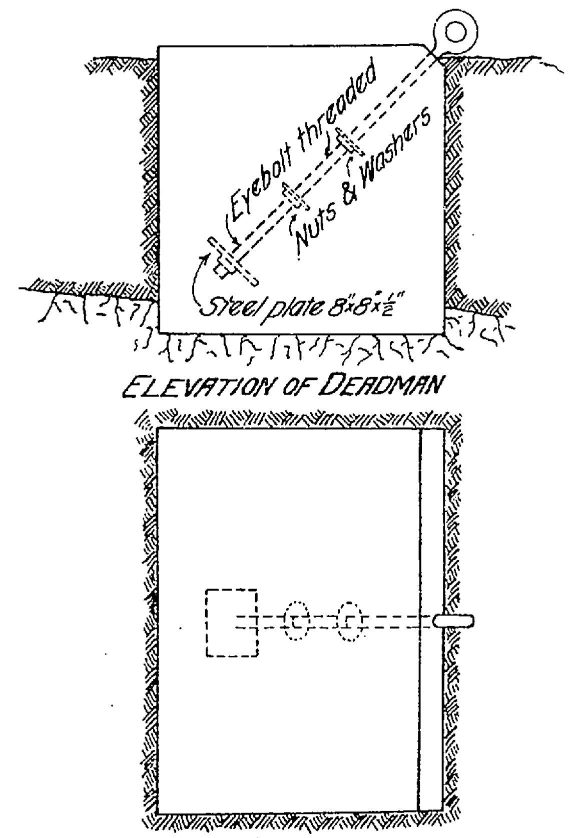


PLAN OF TIMBER DEADMAN
CABLE AND BALLAST



CROSS SECTION OF TIMBER
DEADMAN CABLE AND BALLAST





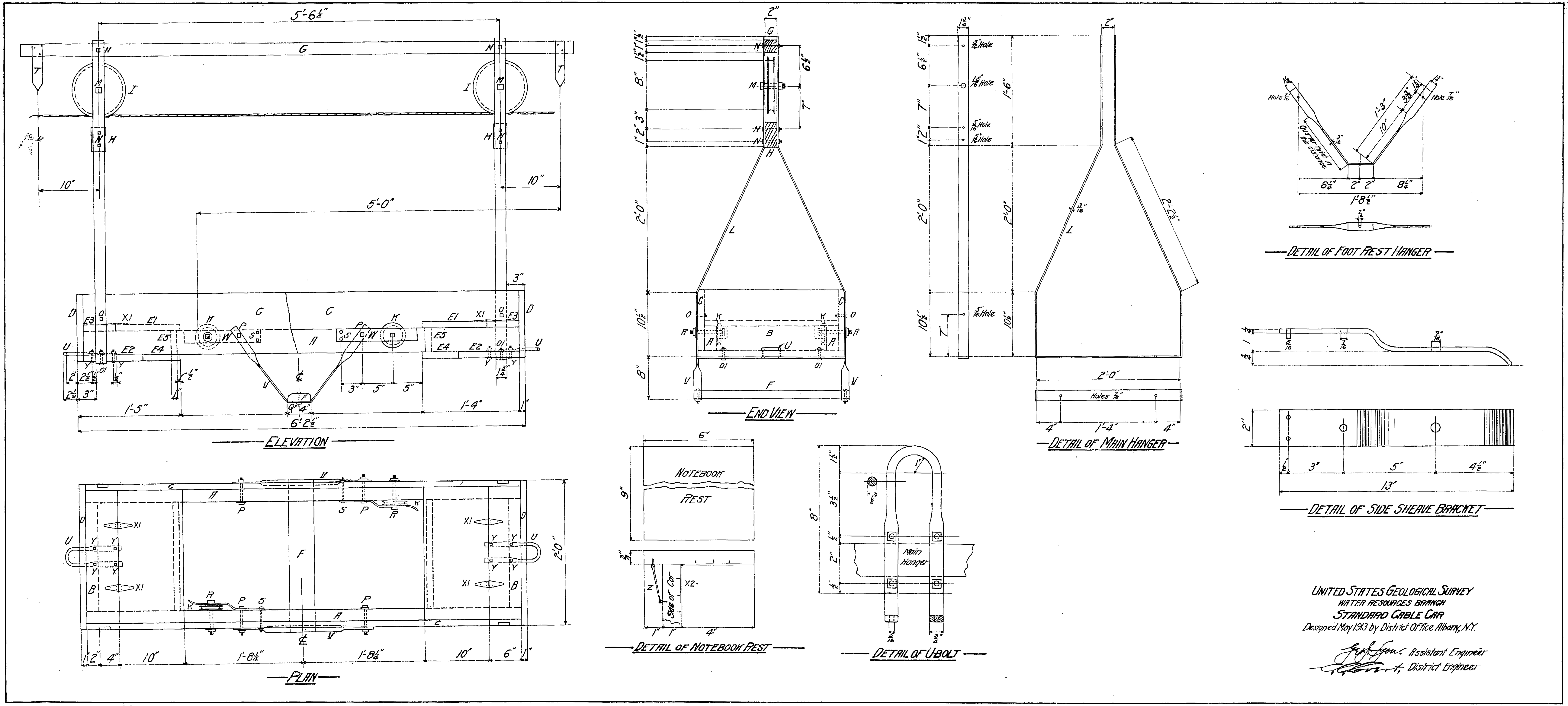
PLAN
CONCRETE DEADMAN
WITH ANCHOR BOLT
Dimensions to fit local conditions

UNITED STATES GEOLOGICAL SURVEY
WATER RESOURCES BRANCH
ANCHORAGES FOR CABLE AT GAGING STATIONS
Designed Mar. 1913 by District Office, Albany, N.Y.

Assistant Engineer

District Engineer

WEDD & BOGORSELSKI, INC., WASHINGTON, D. C.



WEBB & BOCORSELSKI, INC., WASHINGTON, D. C.