C 34

EVERY MAN HIS OWN

Civil Engineer and Surveyor

A Manual in Two Parts.

PART I.

The Principles and Practice of

LEVELING.

Containing rules and examples for computing the cubical contents of ditches, etc., and for estimating the work.

PART II.

Practical Hints on

LAND SURVEYING.

Showing how the public lands are surveyed, and how every man may do his own surveying.

—BY—

SMITH CASTERLINE, C. E.

1895.

E. S. HUFFMAN,

PRINTER,

HARTFORD CITY.

CONTENTS.

PART I.

PART II.

EVERY MAN HIS OWN

Civil Engineer and Surveyor

A Manual in Two Parts.

PART I.

The Principles and Practice of

LEVELING.

Containing rules and examples for computing the cubical contents of ditches, etc., and for estimating the work.

PART II.

Practical Hints on

LAND SURVEYING.

Showing how the public lands are surveyed, and how every man may do his own surveying.

—BY—

SMITH CASTERLINE, C. E.

1895.

PREFACE.

It is generally supposed that to understand the practice of leveling and surveying, one must be well versed in the higher branches of mathematics and provided with costly instruments. This is necessary if the object of the learner is to fit himself for a thorough, practical engineer. But the object sought by the author of this little book, is to so simplify the principles of leveling and surveying that any one, having a very limited knowledge of mathematics, can understand and practice them; and it is designed for the use of farmers, contractors of earth-work and practical ditchers; whereby they will be enabled to do their own surveying and leveling, and estimate their own work.

Many hard earned dollars have been paid to engineers for leveling, that might have been saved to the farmer, and others, for want of the knowledge contained herein; and thousands of rods of tiled drains are nearly worthless because of not having been properly leveled, or not leveled at all.

SMITH CASTERLINE.
Hartford City, Ind.

A MANUAL OF

Leveling and Surveying.

PART FIRST.

Leveling and the Level.

Leveling is the art of finding the relative position of points, with reference to their distance from the center of the earth.

The difference of level of any two or more points, is the difference of their distance from the center of the earth. The operations performed in finding this difference is called leveling.

The instruments used in leveling are the level and leveling staff. An engineer's level is provided with a fine telescope, with which figures, one-half inch in length, can be read a distance of thirty and forty rods. The quality and power of the telescope adds very much to the cost, which, for first-class levels, is about $110. The leveling, however, is done with a little bubble, entirely similar to that of a common level; the chief advantage being the telescope.

A carpenter's square hung on edge and the vertical blade plumbed will bring the other level. Other appliances might be suggested, but for this work we have adopted the common spirit level; such as are used by masons and carpenters. It is both simple and cheap, and will answer well the purpose. The most convenient way of using it will be on a tripod.

TRIPOD NO. 1.

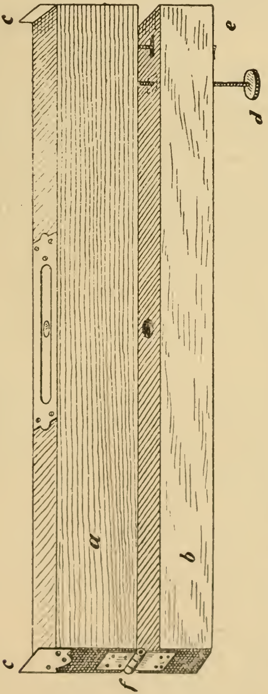
This can be easily made as follows: Take a block of wood 4 inches long and cut it in shape of a triangle, each side of which should measure 6 inches. Cut on one end a round tenon, 1 inch in diameter and 2 inches long. Then attach to the other end of the block, three legs 5 feet long, by means of hinges. The lower end of the legs must be sharpened to stick in the ground. Trim off the corners of the triangular block, and the tripod will be finished.

To fit the level for this tripod: Take a piece of hard wood 2 by 2 inches, the length of the level; and at a point equally distant from each end, bore an inch hole through, smooth and true, at right-angle to the sides. Then, with a 5-16 bit, bore another hole through from the same side, about 3 inches from one end. This is for a leveling-screw. Then, from the same side and between this hole and the end of the stick, with a ¼ inch bit bore two holes through, 1½ inches apart, and cut out the wood between them. This is for a clamp screw. Now lay the stick with the holes perpendicular and place the level on. In this position the two are to be attached by a hinge, at the opposite end from the small holes. Place the hinge open on the two ends, using a hinge that will allow a space between, of at least half an inch. A table-hinge will, perhaps be the best.

The leveling-screw is to be 4½ inches long, having a thread cut nearly its entire length.

On one end is to be a round head, 1¼ inches in diameter and half an inch thick. This screw must fit the hole tight enough to cut a thread in the wood. Or better, a square tap let in the wood at the upper end of the hole.

LEVEL.



a, level; b, base; c c, sights; d, leveling-screw; e, clamp-screw; f, hinge.

The clamp screw is to be 3 inches long, with a thread cut on one end and a T, one inch long made on the other. This is to be put through the long hole and screwed into the bottom of the level. Its use is to keep the level and its base together when being carried.

To clamp; turn the "T" across the hole and tighten by the leveling-screw.

THE SIGHTS.

The level should be provided with sights, which may be done by tacking to each end a thin piece of wood or tin, letting one edge of each come ¾ of an inch above the surface of the level. The insides should be painted black and the outsides white.

TO SET UP THE LEVEL.

Spread out the legs of the tripod and crowd them into the ground. Place the level on, unclamp it, and by the leveling-screw, bring the bottom of the level parallel with the base. Now bring the bubble to the center, or nearly so, by changing the position of the tripod legs in the ground. Then turn the level on its spindle one-fourth around, and bring the bubble to the center again as before, by forcing the legs into the ground. Then turn the level again in the first direction and if the bubble is much out, repeat the operation until it will remain in the center, or nearly so, with the level turned in any direction. Then after directing the sights toward the staff, bring the bubble to the center and keep it there by the leveling-screw.

Remark.—It is not expected of this level that the bubble will remain in the center during any part of a revolution of the level, but it should approach to that point as near as possible. It is expected the leveling up done by the tripod to be done hastily and approximately; but the correct leveling is to be done by the leveling-screw after the sights are turned in the required direction. The first process may be obviated by using tripod No. 2.

TO ADJUST THE BUBBLE.

Spirit levels that are adjustable have a screw by which one end of the tube containing the bubble-vial may be raised or lowered. The bubble is adjusted to the bottom of the level when made; but for our purpose it must be adjusted to the sights. If the sights are exactly the same hight from the bottom they will, very likely, be correct. This may be ascertained as described after the following preparation.

Take a board about ten feet long and drive a large wire nail through the middle, near one end. Then drive the nail into a post or corner of a building, about three feet from the ground; and let the other end of the board rest on something solid, with its lower edge about level. Now tack on two pieces of tin, the lengh of the level apart; letting one edge come half an inch below the lower edge of the board.

We are now ready to make the adjustment. Hold the sights up against the edges of the tin, and let the end of the board be raised or lowered until the bubble will stand in the center. Then with the sights held against the tin, give the bottom of the level a swinging motion of about one inch and, while moving it slowly to and from you, notice if the bubble runs toward either end; if so, the points in contact with the tin are not parallel with the bubble-tube. Shift the sights a little on the edges of the tin, and repeat the operation until no change in the position of the bubble is seen. Then mark the points on both the tin and sights where they come in contact; which is to insure the same position upon reversing. The bubble may not now stand in the center, if not, bring it back by the board as before. Then reverse the ends of the level, and if the bubble runs to the center, the adjustment is correct; if not, one-half of the adjustment is made by the adjusting-screw, and the other half by raising or lowering the end of the board.

Suppose that, upon reversing, the bubble runs toward the moveable end of the board, you will bring it back half way by lowering that end of the bubble-tube, or raising the other; and the other half by lowering the end of the board. The whole operation should be repeated until the adjustment is perfect.

If the edges of the tin were level, to begin with, the bubble could be adjusted in much less time. This may be done after the side adjustment is made, as follows: Bring the bubble to the center by the board; then measure exactly the hight of the end of the board from some point below. Then reverse the level and again bring the bubble to the center and again measure the hight of the board from the same point. Add the two measurements together and divide by 2; which will give the hight that the board must be, to bring the edges of the tin level.

THE LEVELING STAFF.

This should be made of a straight strip of wood 1 by 1½ inches, and not less than 10 feet long. Begin at one end and measure accurately, and mark each foot. Number them 1, 2, 3, etc. with the largest number at the top of the staff. Then divide each foot into 10 equal parts, called tenths. The first one from the bottom of the staff, and above each foot mark, you will number 1; the next two; and so on up to 9. Then divide each tenth into 10 equal parts, called hundredths. These need not be numbered, but will be read as though numbered the same as the tenths. The first one from the bottom of the staff, and above each tenth, will be read 1; the next 2, etc. up to 9. Let the foot marks extend across the staff, with a large red figure in center. The tenth marks extend one-half inch from both edges of the staff toward the center; with a black figure between the ends of the marks. The hundredth marks extend from the right hand edge of the staff ⅜ of an inch toward the center, with a dot at the end of the fifth or middle line.

Next; place on the staff a sliding target, to be made as follows: Take a piece of wood 2 by 2 inches, 4 inches long and cut a place in the middle of one side that will just take in


9
8
7
5
4
3
2
1
9
9
8
7
6
5
4
3
2
1
8
9

the staff the broad way; fasten to this, in front of the staff, by small screws, a piece of wood 5 inches long, 3 inches wide and a quarter of an inch thick. Paint the upper half white and the lower half black or red. Where the white meets the color will be for the line of sight, or point of observation. Now cut out from the lower half 1¼ inches wide, and up exactly to the line of sight. Then bevel from half an inch above the notch down to an edge. From this edge the readings of the staff, when leveling, are to be taken. The target will need a thumb-screw through the back part with which to clamp it to the staff. A stick about three feet long will also be needed with which to slide the target to points beyond reach of the hand. This can be attached by a screw to the back part.

HOW TO READ THE STAFF.

First; notice what foot the target stands at or above. Second; what tenth it stands at or above. Third; what hundredth it stands at or nearest to. Suppose it standing above 4 feet, and above 7 tenths, and to 5 hundredths; the reading would be 4 feet and 75 hundredths. Again; suppose it standing above 6 feet and to 1 tenth; the reading would be 6 feet and 10 hundredths. The staff readings are expressed the same and calculated the same as U. S. money; the foot being answerably to the dollar; the tenth the dime and the hundredth to the cent.

The above readings would be set down thus: 4.75 and 6.10.

The Principles of Leveling.

Leaving out the more scientific and theoretical, the practical principles of leveling are few and simple.

Case 1.—To find the difference of level of two points at one setting of the level.

Set up the level about an equal distance from the two points, though not necessarily in line between them. Then let an assistant hold the staff upon one of the points and move the target up or down until its center line falls in line with the sights of the level. Take the reading, and then let the staff be held on the second point, and note the reading. The difference between the two readings will be the difference of level. Suppose the first reading to be 4 feet and the second 5 feet; it is plain that the difference, which is 1 foot, is the difference of level. It is also plain that the first point is the higher, since a shorter staff was required at this point than at the second.

PRINCIPLES OF CASE 1.

Principle 1.—The difference between the readings of the staff will be the difference of level of any two or more points at the same setting of the level.

Principle 2,—The longer the staff the lower the point, and the shorter the staff the higher the point, at the same setting of the level.

Case 2.—To find the difference of level of two points requiring more than one setting of the level.

The points we will designate as point 1 and point 2.

Let the staff be held upon point 1 and take the reading; this reading is called a Back-Sight. Then let the staff be held on some point as far in the direction of point 2 as the target can be distinctly seen, and take the reading; this is called a Fore-Sight. Now pull up the level and go forward and set it up about the same distance beyond the staff, and take a second reading of the staff upon the same point where the last reading was taken; this reading is called a Back-Sight. The staff-man will now pass by the level and hold the staff on some point about the same distance on the other side; the reading taken at this point is called a Fore-Sight. And so continue until point 2 is reached; the last reading or that upon point 2 will be a Fore-Sight. The difference between the sums of the Back-Sights and Fore-Sights will be the difference of level. A form for keeping the levels is given in the following example:

EXAMPLE.

	Back-Sight.	Fore-Sight.
1 setting,	8.50	5.25
2 "	5.10	4.80
3 "	5.00	3.65
4 "	4.05	6.70 on point 2.
	22.65	20.40
	20.40	
	2.25	

Since point 1 belongs in the column of Back-Sights, and there being the most staff required for the Back-Sights, this must be the lower of the two points.

PRINCIPLES OF CASE 2.

Principle 1.--The difference between the sums of the Back-Sights and Fore-Sights will be the difference of level.

Principle 2.—That point which is in the column whose sum is the least is the higher.

Suppose point 1 in the above example to be in the bottom of a ditch or water course which is an outlet for a pond of water some distance away, and point 2 to be in the pond; we find the fall to be 2.25 feet.

EXPLANATION OF SIGNS, ETC.

Before going further it will be necessary to explain the mathematical signs and terms used by engineers.

This sign + plus, means that the numbers between which it is placed are to be added together.

This sign — minus, means that the numbers between which it is placed are to be subtracted one from the other.

This sign = equality, placed between two numbers mean that they are equal to each other.

This sign × multiplied by, denotes that the two numbers between which it is placed are to be multiplied together.

This sign ÷ placed between two numbers means that one is to be divided by the other.

This sign √ placed before a number indicates that the square root is to be extracted.

A Back-Sight is denoted by B-S. A Fore-Sight by F-S. The hight of the level above the Datum by H. L. The hight of the point or station above the Datum by H. The numbers of stations by Sta. Bench Marks by B. M.

Case 3.—To find the difference of level of several points or stations requiring more than one setting of the level.

First, an imaginary level plane called the Datum Plane, or simply the Datum, is assumed below the surface of the ground, and the hights above this Datum of all the stations to be leveled are found; consequently the difference of their levels becomes known.

The Datum is assumed below the starting point far enough to be beneath the lowest station likely to occur on the work; which, for local work, is usually 50 or 100 feet.

We will first give an example, then use it to illustrate the three general principles which shall follow.

EXAMPLE.

Sta.	F–S.	H. L.	B–S.	H.
1		54.20	4.20	50.00
2	6.32	54.20		47.88
3	5.15	54.20	4.15	49.05
4	2.80	53.20		50.40
5	3.10	53.20		50.10

PRINCIPLES OF CASE 3.

Prin. 1.—The reading of the staff upon any point added to the hight of the point above Datum will give the hight of the level above the Datum.

Sta. 1 in the above example is made the starting point and the Datum is assumed 50 feet below, which is placed in the column H. hence the hight of the point is known. A reading is then taken upon station 1 and set in column B-S., which is 4.20. Then 50.00+4.20=54.20 is the hight of the level above the Datum at this setting.

Prin. 2.—The reading of the staff upon any point subtracted from the hight of the level above Datum will give the hight of the point above Datum.

With the level setting in the same position, if readings are taken upon one or more stations in any direction and each subtracted from the hight of the level above Datum the results will be the hights of the stations above Datum. Let the reading upon station 2 be 6.32, and upon station 3, 5.15; then, the hight of the level being 54.20, we shall have

54.20—6.32=47.88 the hight of station 2; and
54.20—5.15=49.05 the hight of station 3.

In the above example the position of the level is now supposed to be changed, the hight of which must again be known; this will involve the first principle. The hight of station 3 being known a second reading is taken upon that station and set in the column B-S., which is 4.15. Then 49.05+4.15=53.20 is the hight of the level above Datum at this setting. Readings are then taken upon stations 4 and 5, and by Principle 2 their hights found. 53.20—2.80=50.40 is the hight of station 4, and 53.20—3.10=50.10 is the hight of station 5.

Prin. 3.—The difference of their hights above the Datum will be the difference of level of any two or more points or stations.

Since the figures in the column H. show the hight of each station above the Datum, by simply inspecting that column we find that station 5 is .10 of a foot higher than station 1, and that station 4 is the highest and station 2 the lowest.

Under the principles of case 3, almost all leveling is done; Case 2 may be brought under this case.

DRAINAGE LEVELING.

Since the best and quickest way to learn the art of leveling is to ievel, let us make a practical application of the foregoing principles in leveling for a ditch.

Take for example a ditch of 16 stations. Begin at the head and measure and place stakes regular distance apart, which is usually 100 feet, and number them 0, 1, 2, 3, etc., down to the outlet. About 4 inches from each stake drive a peg, called a hub-ped, down to the surface of the ground; from these the levels are to be taken.

Having first provided yourself with a field-book in which to take down your levels, a convenient form of which is given on page 23; and having secured an assistant you are now ready to begin leveling.

Set up the level near sta. (2), as you will not be able to see the target to set it correctly more than 200 feet each way. Then proceed as in Case 3; and write down the results as shown in the example of field-notes. The Datum which is assumed 50 feet below sta. (0) is set in column H. A reading is then taken upon sta. (0) and set in column B-S. This reading is added to the Datum, which gives 50.00+3.00=53.00 feet for the hight of the level above Datum. (Case 3, Prin. 1.) Readings are then taken upon sta. 1, 2, 3 and 4, which are set in column F-S; and each subtracted from the H. L., which gives the hight of each station above Datum. (Case 3, Prin. 2.)

The level is now removed to between sta.(6) and (7), and a back-sight taken upon sta. (4). This reading added to the hight of the station gives 50.65+3.60=54.25 feet for the hight of the level above Datum at this setting. Readings are then taken upon sta. 5, 6, 7 and 8, and the hight of each found as before. Proceed in like manner with the balance of the stations. Observe that at sta. (6) a Bench is established. The reading of the staff upon the Bench is subtracted from the H. L. which gives (54.25—2.53)=51.72 for the hight of the Bench above Datum. (Case 3, Prin. 2.) The point where a Fore-Sight and Back-Sight is taken, is called a turning point; this is usually made upon a station, but not necessarily so. In the example given, after a reading was taken upon sta. [12], because of some obstruction between it and sta. [13], the staff was held upon some point off to one side and the F-S. and B.-S. taken from it. It does not matter where this point is, nor how high or low; the only object in a Back-Sight being, after the level has been reset, to get its hight again above the Datum.

THE GRADE LINE HOW ESTABLISHED.

1. Having first determined the depth of cut necessary to be made at the head or sta. [0], subtract it from the hight of the station, the remainder will be the hight of grade of that station; which set in the column Grade. Also set the hight of the lower end station in column Grade.

In the example let the cut at sta. [0] be 2.35; then 50.00—2.35=47.65 will be the hight of grade above datum; and 45.25 the hight of the other end, or station 16. Then

2. Find the total fall of the grade line.

The difference between the hights of the two ends in column Grade will be the total fall. [Case 3, Prin. 3.]

In the example, 47.65—45.25=2.40 is the total fall.

3. Find the average fall per station.

Divide the total fall by the number of stations.

2.40÷16=.15 of a foot per station.

4. Find the hight of the grade line above datum at each station.

Beginning with sta. [0] the grade hight of each station is decreased by the average fall which gives the hight of the station below it; or, beginning at the other end, the hight is increased by the average fall for the hight of the next station above it.

Beginning with sta. 16, the hight being 45.25, you will proceed as follows:

45.25+.15=45.40	grade of	station	15.
45.40+.15=45.55	"	"	14.
45.55+.15=45.70	"	"	13 etc.

Beginning with sta. (0) we will establish the grade line of the entire ditch.

47.65	grade of	station	0.
47.65—.15=47.50	"	"	1.
47.50—.15=47.35	"	"	2.
47.35—.15=47.20	"	"	3.
47.20—.15=47.05	"	"	4.
47.05—.15=46.90	"	"	5.
46.90—.15=46.75	"	"	6.
46,75—.15=46.60	"	"	7.
46.60—.15=46.45	"	"	8.
46.45—.15=46.30	"	"	9.
46.30—.15=46.15	"	"	10.
46.15—.15=46.00	"	"	11.
46.00—.15=45.85	"	"	12.
45.85—.15=45.70	"	"	13.
45.70—.15=45.55	"	"	14.
45.55—.15=45.40	"	"	15.
45.40—.15=45.25	"	"	16.

CHANGE OF GRADE.

In long ditches it frequently occurs that one or more changes of grade is necessary, in order to avoid too deep cutting in some places and not deep enough in others. The points along the line where changes in the grade should be made can be determined best by drawing a profile of the surface, the method of which will be hereafter described.

Taking the above for an example, suppose that on reaching sta. (9) the ditch should be found running too shallow; to prevent this the fall must be increased, say to .20 of a foot per station. Then,

46.30	grade of	station	9.
46.30—.20=46.10	"	"	10.
46.10—.20=45.90	"	"	11. etc.

If the grade is found running too deep the fall per station would have to be decreased.

TO FIND THE DEPTH OF CUTTING.

To find the depth of cut at each stake it is necessary only to subtract the figures in the column Grade from those in the column H.

BENCH MARKS.

Bench Marks, denoted by B. M., are established at convenient distances apart along the line of work by cutting a notch on the root of a tree, when timber is near, or by taking some object as a large stone, corner of a building, or any stationary object on which the staff can be held. Their use is to enable an engineer to retrace a grade line either while the work is being done, or years after its completion.

To establish a bench: Take a reading of the staff upon the bench and subtract it from the hight of the level above datum; (Case 3. Prin. 2.) and mark the object on which the bench is made with the letters B. M., followed by the number corresponding to that of the station to which it is nearest, as B. M. 6.

TO FIND THE GRADE LINE FROM A BENCH MARK.

Take a reading of the staff upon the bench and add it to the hight of the bench above datum; the sum will be the hight of the level above datum. (Case 3, Prin. 1.) Then the difference between the hight of level and hight of grade at a given point will be the reading of the staff when held on the grade at that point. (Case 3, Prin. 2.)

Let us take for example the B. M. at sta. 6 of our example ditch, and find from it the grade at sta. 4 and 8; supposing the reading of the staff upon the bench to be 3.23.

Example.

Hight of B. M. above datum	51.72
Reading of the staff on B. M.	3.23
Hight of level above datum	54.95
Hight of grade at sta. 4	47.05
The required reading	7.90

Hight of level above datum	54.95
Hight of grade at sta. 8	46.45
The required reading	8.50

The principles of Case 3 are the principles under which street grades are established. Some permanent point is chosen for a bench mark from which to begin leveling, and a datum assumed, usually 100 feet below it; then levels are taken at street crossings, alleys and other bench marks, all of which are referred to the same datum. The method of finding the grade line at any point is the same as that given above. The engineer after he has finished leveling and made out the grade, files his notes of such grade in the office of the town clerk who places the same upon record, and all street improvements thereafter are made conformable to said grade.

EXAMPLE OF FIELD NOTES.

Sta.	F. S.	H. L.	B. S.	H.	Grade	Cut.	Remarks
0		53.00	3.00	50.00	47.65	2.35	
1	2.50	53.00		50.50	47.50	3.00	
2	2.10	53.00		50.90	47.35	3.55	
3	1.50	53.00		51.50	47.20	4.30	
4	2.35	53.00	3.60	50.65	47.05	3.60	
5	2.80	54.25		51.45	46.90	4.55	
6	3.00	54.25		51.25	46.75	4.50	Oak
B.M. "	2.53	54.25		51.72	46.75		2 rd. n.
7	3.20	54.25		51.05	46.60	4.45	e. of 6.
8	5.50	54.25	3.25	48.75	46.45	2.30	
9	4.50	52.00		47.50	46.30	1.20	
10	4.40	52.00		47.60	46.15	1.45	
11	4.75	52.00		47.25	46.00	1.25	
12	4.90	52.00		47.10	45.85	1.25	
Turn	5.00	52.00	4.50	47.00			
13	4.15	51.50		47.35	45.70	1.65	
14	5.00	51.50		46.50	45.55	.95	
15	5.50	51.50		46.00	45.40	.60	
16	6.25	51.50		45.25	45.25	0.00	

DRAWING THE PROFILE.

After any work has been leveled the surface of the ground and grade line may be represented upon paper in the following manner:

Take ruled paper and draw a line crossing the ruled lines, and let it represent the datum line, and let the ruled lines represent the stations. Also let one inch represent a certain number of feet for the vertical scale. Then if the hight of each station in the column H. is measured by the same scale, and their distances set off from the datum on the perpendicular rulings, a line drawn through those points will represent the surface of the ground. The grade may also be represented by drawing a line through two points measured by the same scale.

The instruments employed in drawing profiles are dividers or compasses, drawing pen, ruler and a diagonal scale having one inch divided into 100 equal parts.

Suppose that you wished to draw a profile of the foregoing ditch to a scale of 5 feet to an inch. Draw the datum line near one edge of the paper and place below it on the ruled lines the number of the stations from 0 to 16. Station 16 being the lowest, subtract its hight from the hight of each of the other stations; then the distances to be set off on the perpendicular rulings will be found by dividing the hights thus found by 5 feet. The hight of sta. 0, 50.00—45.25=4.75 and 4.75 ÷5=.95 of an inch. Now spread the dividers so that when applied to the scale of equal parts they will embrace 95 parts or hundredths of an inch. Place one arm of dividers on the datum at sta. 0 and the other above on the ruled line, and mark the point by a small dot.

The hight of sta. 1, 50.50—45.25=5.25, and 5.25÷5=1.05. Take one inch and five hundredths between the points of the dividers and with one arm on the datum at sta. 1, dot the point above to where the other reaches. The hight of sta. 2, 50.90—45.25=5.65 ÷5=1.13 inches. Measure and mark this distance above the datum on sta. 2, as above.

In like manner measure and mark the hight of each station; then a line drawn, off hand, through all of those points will represent the surface of the ground. The grade line may now be drawn under the surface line. The grade hight at sta. 0, 47.65—45.25=2.40÷5 =.48; measure 48 hundredths of an inch from the datum on sta. 0, and with a ruler laid at sta. 16, draw a line from 0 to 16.

The points where changes in the grade should be made, if any should be necessary, can be determined by stretching a fine black thread under the surface line.

Paper called profile paper is made for the above purpose, and is ruled in such a manner that no drawing instruments except a drawing pen is needed in drawing profiles.

GRADE STAKES AND THEIR USE.

The use of grade stakes, when once understood, will not be abandoned by any ditcher.

By their use no water for grading is needed and each foot may be tiled, if need be, before entering upon the next. The stakes may be prepared and arranged for use, all within a few minutes, as follows: Take three small stakes and split one end of each, and place in each split a thin piece of white wood about 5 inches long by 1 inch wide, so as to form a "T," and sharpen the other end to stick in the ground. The length of one should be 5½ feet; the length of the other two will vary, one will be longer and the other shorter. We are now ready to arrange them for use; and for this purpose let us use our example ditch.

1.—Place the 5½ foot stake perpendicular at sta. 16, with the "T" five feet above the hub-peg.

2.—Place the shorter stake at sta. 15, so that the "T" will be five feet above the grade line. To do this subtract the depth of cut from five feet; the remainder will be the hight of the "T" above the hub-peg. The cut at sta. 15 is .60; then 5.00—.60 =4.40 will be the required hight.

3.—Place the third stake about 100 feet below sta. 16 and range the "T" horizontally with the other two.

Now having the grade stakes set parallel with the grade line, five feet above it; and having provided yourself with a 5 foot measuring stick, you are ready to begin work. As you dig from sta. 16 toward 15 the depth may be tested at any time by holding the measure perpendicular on the bottom; if cut the proper depth the upper end of the measure will range with the tops of the grade stakes below you.

When the diging is completed up to sta. 15 the stakes must be reset. Take up the stake at sta. 15 and set it at 14; the cut at this point being .95 the hight of the "T" above the hub-peg will be (5.00—.95=) 4.05 feet. Then bring the stake from sta. 16 and place it at 15, with the "T" 5 feet above the grade line.

Then set the third stake at sta. 16 and range it with the other two as before.

When the depth of cut at any point is more than 5 feet, cut out until less than 5 feet before setting the grade stakes.

If the grade stake to be used ahead was provided with a sliding target it would save the trouble of having frequently to make new ones. The reason why is plain; at sta. 15 the hight required above the hub-peg is 4.40, while at sta. 6 it will be only (5.00 – 4.50 =) .50 of a foot.

THE GRADE STAKES AS A LEVEL.

If two grade stakes are set up say 50 feet apart in a pool of water with their T's exactly the same hight above its surface, a straight line connecting them or extended beyond will be a line of apparent level, and will answer for leveling ditches not more than one mile in length; but if longer than one mile the curvature of the earth should be taken into consideration.

The principles for this method of leveling are the same in all respects as those already given, except that no back-sights are taken.

A datum is assumed and the hight of the level line above the datum is kept the same as when using a level.

To illustrate, let us employ the grade stakes in leveling our example ditch. First let there be a shallow trench dug 40 or 50 feet long, some where between sta. 0 and 1 or 1 and 2, and allow it to fill with water or until the bottom, at least is covered; and when not in motion place in it two grade stakes as above stated. Then let the staff be held upon sta. 0 and the target brought in range with the tops of the stakes and take the reading, which we will suppose to be 5.00 feet. Then, the datum hight of sta 0 being 50.00 feet, we shall have 50.00 + 5.00 = 55.00 for the hight of the level line above datum; which enter in column H. L.

Now extend this level line by setting more stakes about one hundred feet apart and ranging them horizontally with those in the water and with each other until the end of the ditch is reached, or as far as the rise or fall of the ground will admit; taking a reading of the staff upon each station as you go, which you will place in column F-S.

Suppose that at some point, as near sta. 9, a fall of the ground makes it necessary to lower the level line say 2 feet. Set the target at 2 feet on the staff, then let it be held on a grade stake about one hundred feet from the last stake set or near sta. 10, and force the stake into the ground until the target comes in range with the two last set; then the one on which the staff is being held will be 2 feet below. In like manner set another near sta. 9.

Two feet must now be subtractrd from the datum hight, leaving it 53.00 feet; then you will proceed as from the beginning. The level line may also be raised or lowered by setting two stakes an equal distance above or below two already set. The datum hight must be changed accordingly.

The accuracy of work done by this method of leveling depends upon careful measuring and setting of the grade stakes, as the level to begin with is a good one.

A further explanation of this method of leveling is deemed unnecessary, as it will be understood on becoming familiar with the foregoing principles.

WIDTH OF DITCHES HOW COMPUTED.

Ditches are of two kinds, open and covered. The width at top of bank of an open ditch is governed by its depth, slope of banks and width on bottom. The banks should have a uniform slope of not less than one foot horizontal to each foot perpendicular.

RULE.—Multiply the depth of cut by double the slope of one bank and add the bottom width.

For example let us compute the width at sta. 0 and 1 of our example ditch; supposing the bottom width to be 2 feet, and slope of banks to be 1 to 1.

Depth of cut at sta. 0	2.35
Double the slope of one bank	2
	4.70
Bottom width	2.00
Width at top of bank	6.70

At sta. 1 the depth of cut $3.00 \times 2 = 6.00 + 2.00 = 8.00$ feet at top of bank.

EXCAVATION HOW COMPUTED.

The unit of measure for measuring excavation in cutting ditches, road making, etc. is the cubic yard.

A cube is a figure, having six equal sides, which are squares. A box measuring three feet square inside will hold a cubic yard.

TABLE.

1728 cubic inches make 1 cubic foot (cu. ft).
27 cubic feet " 1 cubic yard (cu. yd).

In order to find the cubical contents of a solid it must first be squared, if it is not, then apply the following:

RULE.—Multiply the length, breadth and thickness together and divide by the unit of measure.

Now let us find the number of cubic yards in sections 1 and 2 of our example ditch; supposing the slope of banks to be 1 to 1.

1. Find the average depth of the section.

Depth of cut at sta. 0	2.35
" " " 1	3.00
	2) 5.35
Average depth	2.675

2. Find the top width.

Average depth	2.675
Double the slope of one bank	2
	5.350
Bottom width	2.00
Average width at top of bank	7.35

3. Square the section.

Width at top of bank	7.35
Width on bottom	2.00
	2) 9.35
Average width	4.675

4. Apply the above rule.

Average depth	4.675
Average width	2.675
	23375
	32725
	2 8050
	9 350
Cu. ft. per foot	12.505625
Length of section	100
	27) 1250.5625 (46.31 cu.yds.

When the slope of banks is 1 to 1, add the bottom width to the average depth; which will give the average width or square of the section. In the above case, let the bottom width be added to the average depth, and we shall have 2.675+2.00=4.675; the same result as at 3. Therefore the operations at 2 and 3 are unnecessary except when the slope of banks is other than 1 to 1.

Computation of section 2.

Depth of cut at sta. 1	3.00
" " " 2	3.55
	2) 6.55
Average depth	3.275
Width on bottom	2.00
Average width or square	5.275
	3.275
	26375
	36925
	1.0550
	15.825
Cu. ft. per foot	17.275625
Length of the section	100
	27.) 1727.5625 (63.98 cu. yds

GENERAL RULE

For computing the contents of a section:

1. Add together the depth of cut at each end of the section and divide the sum by 2, which will give the average depth.

2. Multiply the average depth by double the slope of one bank and add the bottom width, which will give the average width at top of bank.

3. Add the top and bottom widths together and divide by 2, which will give the average width or square of the section.

4. Multiply the average width by the average depth and this last by the length of the section, which will give the contents in cubic feet.

5. Divide by 27 for the cubic yards.

FOR DITCHES THAT ARE TO BE TILED.

No definite rule can be given for calculating the width. The bottom should be just wide enough to receive the tile, while the top must be wide enough to allow free use of the body in casting out the dirt. An average width of two feet will, ordinarily, be a fair estimate.

RULE.

1. Add together the depth of cut at each end of the section and divide the sum by 2, which will give the average depth.

2. Multiply the average depth by the average with, 2 feet, and this result by the length of the section, and divide by 27.

THE WORK OF EXCAVATING HOW ESTIMATED.

This will depend upon at least two conditions. First, the nature of the ground. Second, the distance that the dirt will have to be removed. The nature of the ground in many places varies all the way from muck to hardpan. A common spade can be put down its length into muck, soil or soft clay by one or two exertions, while in hard clay six or eight exertions will be required; and hardpan will require a pick and shovel.

Now, suppose the above varieties of earth are to be cast from a ditch not to exceed five feet in depth nor more than twelve feet wide.

An ordinary ditcher, in ten hours, will cast from this ditch 20 cubic yards of muck or soil, or 15 cubic yards of soft clay or 10 cubic yards of hard clay, or from 6 to 8 cubic yards of hardpan. If the price allowed for 10 hours labor is $1.50, then will

$1.50÷20 cu. yds. = 7½c. for muck and soil.
1.50÷15 " " " 10 cts. " soft clay.
1.50÷10 " " " 15 " " hard clay.
1.50÷7 " " " 21 3-7 " hardpan.

In the above estimate no allowance is made for adhesive clay, stumps, roots, etc. If such occur due allowance should be made.

PART SECOND.

Hints on Land Surveying.

In connection with the foregoing work on leveling, a few suggestions upon the subject of land surveying will not be considered out of place, as the two go together.

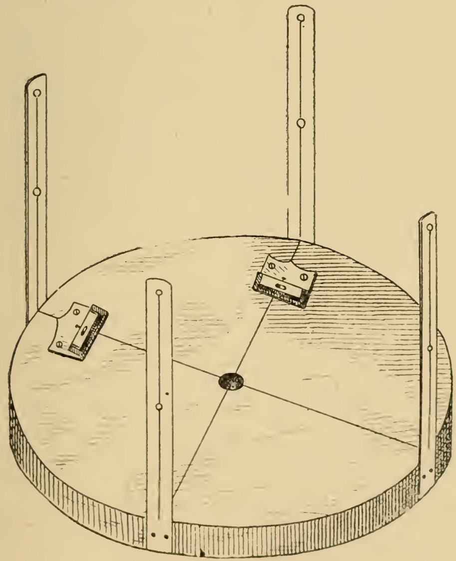
The principal instruments used in surveying are the transit or compass, and chain.

The compass is strictly a magnetic instrument, while the transit is not. The transit is provided with a telescope, while the compass may or may not be. The price of transits range from $130 to $200, and compasses from $30 to $75.

A very good substitute for the compass can be made by a mechanic, with which lines can be surveyed and right-angles set off with as much precision as with a real compass, as follows:

THE COMPASS.

Make two wheels of well seasoned wood, 16 inches in diameter and half an inch thick. Put them together with screws, their grain crossing each other. Then make another wheel 3 inches in diameter and 1 inch thick, and fasten it in the center of the other wheel with nails or screws. This will be the under side of the compass wheel. Draw two lines on the upper side, crossing the diameter exactly at right-angle to each other. At the intersection of these lines bore an inch hole through, smooth and true. Next take four



thin pieces of wood, 1 inch wide and 8 inches long, and make a slit 1-32 of an inch wide through the middle of each, to within one inch of each end. These being for the sights they must be fastened to the edge of the wheel or let in their thickness, so that their slits will be parallel to the hole through the center and coincide with the lines drawn across the wheel.

This may be done in the following manner: Lay the wheel on something solid, with the hole unobstructed, and suspend a fine line through the hole, with the bob in water to keep it from swinging; then fasten the wheel in such a position that the plumb-line will center the hole clear through. With the wheel in this position the sights, when made fast to it, must all be parallel to the plumb-line and each pair exactly in range with it.

If a hole ¼ of an inch is bored through near the upper end and one in the middle of each slit, it will aid very much in catching a view of the flag-staff or other object through them.

SPIRIT LEVELS HOW ATTACHED.

The sights of the compass when in use must be perpendicular; for this purpose two spirit levels will be required. Pocket levels, which will be very good for the purpose, can be obtained from almost any hardware store at a cost of about 15 cents. They are made with a clamp-screw on one side for the purpose of clamping them to the edge of a carpenter's square; and in order that they may be attached to this compass, an edge must be raised on which to fasten them. Take a piece of heavy tin 2½ by 1½ inches, and bend it lengthwise in the middle, to a right-angle. Make two holes through one side for screws, and fasten it on the wheel about three inches from a sight, so the line drawn across the wheel will divide it in the center; the other side will then be vertical, on the edge of which the level may be clamped as on a square. In like manner place another across the line between the other pair of sights.

TO ADJUST THE LEVELS.

Place the compass on the tripod and suspend a fine line near by. After bringing the compass to a horizontal position, direct a pair of sights to the plumb-line and bring the slits of the sights parallel to it. With the compass in this position the bubble should stand in the center, but if it does not the edge of the tin at that end to which the bubble runs must be filed down until it will stand in the center. Then turn the other pair of sights to the plumb-line and in like manner adjust the other level.

TRIPOD NO. 2.

A tripod having a ball and socket joint, on which the compass and level may both be used, can be made as follows: Take a block of well seasoned wood and make a wheel 6 inches in diameter, by 2¼ inches thick endwise of the wood. Bore a 2 inch hole through the center and rout out one end, or what would be better have it turned out on a lathe, large enough and in shape to receive a ball 3½ inches in diameter, one-half its diameter; so the ball will be just a loose fit. This forms the lower half of the socket. To the lower edge of this socket is to be attached three legs similar to those for tripod No. 1. Flatten three places equally distant apart just enough to receive the hinges. The upper end of the legs will have to be beveled a little on the side opposite the hinges, or else they will come in contact with the under side of the socket and will not close. Next cut from a seasoned board, 1¼ inches thick, another 6 inch wheel

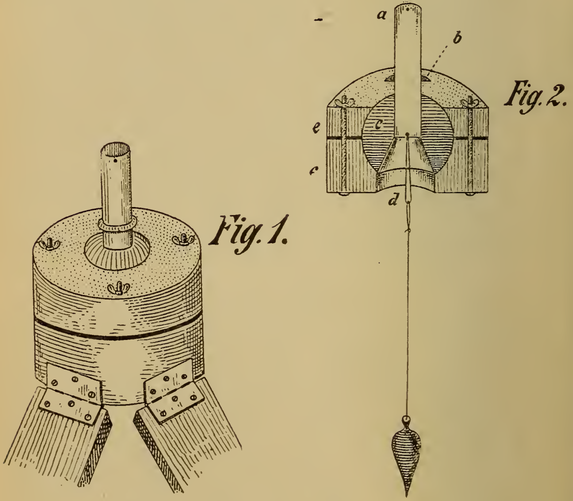


Fig. 2 represents one-half of Fig. 1. a, spindle; b, flange; c, ball; d, loop; e, upper socket; f, lower socket.

and turn or rout out a place in the center that will take in the 3½ inch ball, one-half its diameter. The hole through the upper side will be nearly 2½ inches. This will form the upper socket.

Having selected from a croquet set, a hard wood ball of the above dimensions, place it in the socket between the two wheels. Then, with a ¼ inch bit, bore three holes through both wheels about half an inch from the outer edge, and at points half way between the hinges. Put bolts through these holes from the under side, with washer and thumb-tap on the upper side. Then take the ball out and line the socket with thin, but good leather. The ball must have an inch hole bored through the center, which should be endwise of the wood. The points where the ball is finished in turning marks the axis or center; through this axis the hole should be bored. This is to receive the spindle which is to hold the compass wheel.

The spindle can be made of wood, but better made of tin. It must be 1 inch in diameter and 5 inches long. A flange 2½ inches in diameter, made of heavy tin, is to be soldered to the middle of the spindle, at right-angle to it. On this flange the compass wheel is to rest. One end of the spindle is to be inserted into the ball 1 5-8 inches or just to the center, and fastened in with glue. This end is to be capped and a small hole punched through the center of the cap from the inside. Through this hole a string is to be inserted and a knot tied on the end that will not pull through the hole; it should be about four inches long, with a loop on the lower end from which to suspend a plumb-line. A small hole should be made through the upper end of the spindle and a spring-pin put through to keep the compass from falling off while being carried. The ball should have about half an inch sawed off from its lower part and the hole flared, so that the plumb-line will have plenty of room. Before putting the parts of the tripod together the socket should be well rubbed with cold tallow.

In order that this compass may work well and true, it must be made exact in all its parts. The hole through the center of the wheel must be a right-angle to its under surface, and must fit the spindle so exact that there can be but one motion. The sights must be parallel to the hole through the center, and one pair exactly at right-angle to the other. The socket must be made in shape to fit the surface of the ball. The ball must be true, and the hole bored exactly through its center. The spindle must be perpendicular to the horizontal axis of the ball; and must be round. All of which can be done by an ordinary mechanic with the proper tools.

TO SET UP THE COMPASS.

Set up the tripod over the corner or point. Put the plum-string through the loop and tie it around the string below. Then force the legs in the ground so as to bring the point of the plumb-bob directly over the corner. Then, after turning the sights in the required direction, bring the bubbles to the center. Should the ball work too tight or too loose, regulate it by the thumb-taps.

THE CHAIN.

The chain used by surveyors is four rods or sixty-six feet in length, and consists of 100 links. This chain, once considered infallible, is now almost "a thing of the past." The steel tape, which is much lighter and a more accurate measure, is rapidly superseding it. They are of various lengths and graduations; for surveyors use they are made 66 feet long and graduated to links, though tapes which are only two rods or 33 feet long are often used.

A very good measuring line can be made of tin, as follows: Get a tinner to cut strips of tin 3/8 of an inch wide, and solder the ends together until 34 feet is made. Attach to the ends suitable handles, made of No. 9 wire, so they will turn in the end of the line. Take a piece of heavy tin 2 inches long by half an inch wide and solder it lengthwise on the line next one handle, with one edge even with the edge of the line. The shoulder formed by the projecture will be the rear end of the line proper – the points from which measurements begin. Measure from this point exactly 33 feet and solder on a similar piece of tin, with one end at the 33 feet and the other in the direction of the rear end; and let this shoulder be at the same edge of the line as the other. Trim off both rearward shoulders.

Graduate the line to suit your own convenience. When not in use coil it up and tie it.

This is not merely a toy line, but it possesses real merit. The author had one made

50.8 feet long for a special job, expecting when done to throw the line away, should it last that long. After two years use, upon testing it by a Chesterman steel tape, although somewhat kinky was found the proper length.

MARKING PINS.

These can also be made by a tinner. No. 9 wire will answer the purpose. They should be 14 inches long, sharpened at one end and a small ring bent on the other. Eleven pins constitute a set. Short strips of red flannel tied in the rings will render them more conspicuous in tall grass or weeds. An open ring made of wire will be most convenient on which to carry them.

Now, having all the necessary instruments for running lines, the next in order will be to learn to use them. So let us begin with the chain.

INSTRUCTIONS ON CHAINING.

In the operations of surveying, as much depends on correct chaining as upon any other part of the work. In fact, more skill is required to do correct chaining than to manipulate the instrument.

Let us proceed in regular order to measure between two points which are visible from each other. Place a flag-staff at the opposite end from which you wish to begin. Uncoil the line and stretch it out with the front end in the direction of the flag-staff. Let the rear chainman, called the follower, place the shoulder of the line against a marking pin put down at the starting point. The front chainman, called the leader, will now take the remaining ten pins, and after pulling the line taut, stick one down perpendicular against the other shoulder. The line will now be carried forward another length and the rear shoulder placed against the pin just put down, while the leader sticks another pin. The follower will see that the leader places the pins in line with the point to which they are running. When the leader has put down his last pin, he will receive from the follower the ten which he has taken up. The point where the leader runs out of pins is called an "out" and a stake called an "out stake" is usually driven at this point and the measurement continued as from the beginning. If the length of the chain or line being used is 33 feet, the distance between the "out stakes" will be twenty rods—five chains. This line being measured for practice, should be measured back again and the results compared.

In order to do correct chaining, the following suggestions should be observed:

Before starting to measure a line, the leader should see that he has the required number of pins. He should pull the chain always with the same tention. After putting down a pin he should stand erect and see that the pin does, then call out "struck." When the rear end of the chain comes up to the pin, the follower should call out "stick." He should guide the leader, and see that he puts the pins down in line with the point to which they are running. He should not allow the pin to be pulled over by the leader nor pull it up himself until the leader calls out "stuck." He should count the pins at each "out" to see that none are missing. Chainmen should make their backs bend, and not cut a "new moon" with the chain while sticking the marking pins. The chain should be held level no matter how irregular the ground. In chaining up or down hills, use a plumb-line or straight-edge in locating the points on the ground. When too steep for the whole length of the chain, use such equal parts of it at a time as can be reached, the leader being careful to leave a pin only for each entire length. Each chainman should be careful during a halt, or any interruption, to keep possession of his own pins and not allow them to get mixed, as they do the counting.

PRACTICE WITH THE COMPASS.

This compass, more properly called a cross, having no magnetic needle or graduated circle, is adapted only to rectanguluar surveying, as no angle less than ninety degrees can be taken with it. Though much surveying is done without using the needle, even with needle instruments; and aside from a telescope compass this one is as well adapted to running lines as a common compass.

Case 1. Let it be required to run a line which shall be a right-angle to a given line from a given point on that line.

Set up the compass at the given point, level it and turn one pair of sights on the given line; the other pair will then be in the direction of the required line. Let a flag-staff now be set up on the line as far as it can be distinctly seen through the sights, and another a short distance in the opposite direction, called a back-stake. Now take up the compass and go forward and set it at the point where the flag-staff stood, and after leveling it direct a pair of sights to the back-stake; when they will again be on the line. Thus the line may be extended at pleasure. When the line is being measured, the "out stakes" will serve for back-stakes; they should be four or five feet above the ground and their tops hewn so that they may be easily seen.

Case 2. Let it be required to run a line on which there are obstructions, such as a large tree, pond of water, buildings, etc.

Run the line up to a convenient point near the obstruction, mark this point and set the compass over it. Then with one pair of sights directed to a back-stake, which should not be less than ten rods away, measure from the point under the compass, in line with the other pair of sights, far enough to pass the obstruction and mark the point. Then go to the back-stake and measure from it in the same direction, exactly the same distance, and set up a stake. Now set the compass over the first offset point and direct a pair of sights to this stake; these sights will then be parallel to the required line. Now continue the measurement on this offset line far enough to pass the obstacle; mark this point, and another about ten rods farther on. Set the compass over the first point and then measure from these two points back to the true line in the same manner as when leaving it. Add the length of the offset line to that of the true line, up to the point where you left it.

In order to guard against error in measurements, the offset and offset line should each terminate with a whole chain.

There are other methods by which obstructions may be passed, but this one is, perhaps, the most simple.

Case 3. Required to run a line the ends of which are not visible from each other because of intervening hills.

Go to some point between, from which both ends of the line can be seen and set the compass on the line, as near as can be guessed, and direct a pair of sights to a flag-staff at one end of the line. Then turn and sight in the opposite direction, and if a flag-staff at the other end can be seen, the compass is on the line; but if not, the compass must be moved in the opposite direction from that side on which the line of sight falls. Then direct the sights again to the first staff sighted, and again turn and sight in the opposite direction; if still off of the line repeat the operation until both flag-staffs can be seen through the sights without changing the position of the compass. Stakes can then be set on the line in both directions as may be desired.

Case 4. Required to run a line through timbered land a distance of forty chains to a corner.

Suppose this to be the line dividing the east half and the west half of the south-west quarter of a section. Beginning at the south line of the quarter you will set the compass over the corner, which should be midway between the south quarter corner and the south west corner of the section. If a flag-staff placed at either of these corners can be seen from the compass, place one there and direct a pair of sights to it; the other pair should then be in the direction of the required line; but if neither of these corners are visible from the compass, then assume a bearing as near due north as can be judged, and run through according to instructions already given, driving a stake at each "out." The eighth stake will be at the corner, or terminus of your line. Suppose that upon reaching the north line of the quarter, you find that you have missed the corner to which you was running, which you will very likely do, and that your random line terminates to the left of the corner a distance of fifty-six links; the "out stakes" may now be placed on the true line by the following:

RULE FOR CORRECTING THE STAKES.

Divide the distance between the termination of the random line and true line by the length of the line surveyed, and multiply the quotient by the number of chains the stake is from the starting point. This will give the distance that the stake must be moved to the right or left as the case may be.

Taking the above case for example, the distance between the termination of the two lines, 56 links, divided by the length of the line surveyed, 40 chains, gives one and four-tenths link for the correction for each chain. The stakes being five chains apart the correction is make as follows:

lk.	ch.	lk.			
1.4×	5=	7=	Correction	for 1st	Stake.
1.4×	10=	14=	"	" 2d	"
1.4×	15=	21=	"	" 3d	" etc.
1.4×	35=	49=	"	" 7th	"
1.4×	40=	56=	"	" 8th	"

When, as in the above case, the line survyed terminates at a stake, it will be necessary only to divide the distance missed by the number of stakes. Then 56÷8=7 links for each stake, same as above.

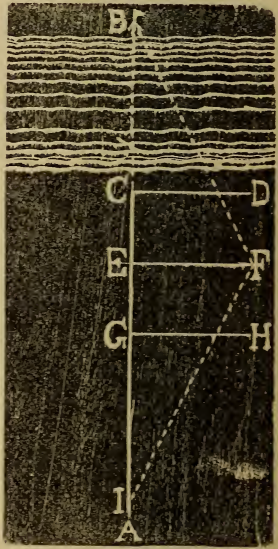
Case 5. Required to run a line which shall make an angle with another line a given number of degrees.

With a compass having no circle graduated to degrees, this requirement seems unreasonable. But what is the difference where the graduated circle is, so we get the angle?

Drive a peg at the point where the angle is to be made, and let one end of a 33 foot line be held at this point, and with a marking pin at the other end, describe an arc of a circle; beginning at the line with which the angle is to be made. Now, the length of an arc of one degree for a radius of 33 feet is .57596 of a foot. Multiply this decimal by the number of degrees in the angle to be made; which will give the length of the arc. Measure the distance on the arc described, and mark the point. With the compass set over the peg, direct a pair of sights to this point; then they will be in the direction of the required line. Suppose the required line is to bear north ten degrees west, and you have the north line. Drive a peg at the vertex of the angle, then with one end of the chain held at this point draw the other end westward from the north line a distance of about six feet, marking on the ground as you go. Now the length of an arc of 10 degrees will be $.57596 \times 10 = 5.75960$ feet, or 5 feet and about 9⅛ inches. Measure this distance on the arc from the north line. Then a line drawn from the peg through this point will be the required line. For angles less than a degree, divide the above fraction by the given fraction of a degree.

While the above method for setting off angles is correct in theory, it is not practical except where the ground over which the chain is to pass in describing the arc is horizontal, or level; and smooth enough that a fine line may be traced with a marking pin. The arc, which must be a true curve, should be measured with a cord or line that will not stretch, laid on the arc.

Case 6. Required to measure a line to a point which is inaccessible; as, for instance, to the opposite side of a river.



Let AB be the line and B the point. Then with the compass at C, let a flag-staff be set up in line at B. Mark the points CEG say, six rods apart. Make each of the lines CD, EF, GH a right-angle to the line AB and mark the points DFH about ten rods from it. Set up the compass at F and direct a pair of sights to B. Mark the point where the line of sight cuts the line CD and measure exactly its distance from C. Measure the same distance from G on the line GH and mark the point. Direct a pair of sights to this point and mark the point where the line of sight extended cuts the line AB, as at I. Then will the distance IG equal the distance CB.

For practice try the above where the point is accessible, then measure through and compare results.

Having now had instructions in the use of the compass and chain sufficient to cover all ordinary cases, before making use of them in dividing and subdividing sections, it will be necessary to know the manner in which the Government lands, or a greater part of them, were surveyed. This we will notice briefly.

ORIGINAL SURVEY.

The men who are authorized by the Government to do this important work are sent out under written instructions from the surveyor-general, setting forth the manner in which the work shall be done. The first thing the surveyor does is to select some permanent, imperishable object, which he establishes as the initial point from which to begin the survey. From this point he runs a line east or west, or east and west, to the limit of the territory to be surveyed; this is called the base line. He then runs another line north or south, or north and south, to the limit of the survey. This is called the principal meridian. These two lines, which are surveyed with fine instruments and with the utmost care, form the basis for the survey of all other lines within their limits. Each half-mile of these two lines is marked with a monument by setting a post, where there is timber, or where there is none by throwing up a mound of earth around a stake or stone. From each six-miles point on the base line, other meridian lines are surveyed, which divide the territory into strips each six miles wide. These strips are called ranges. The first one west of the principal meridian is called range 1 west, the second is called range 2 west, and so on; the first one east is called range 1 east, the second range 2 east, etc. These meridian lines are crossed by other lines run parallel to the base from each six miles point on the principal meridian. Thus the territory is divided into townships; each containing thirty-six square miles or sections. Each township is numbered or named with reference to its distance from the base and principal meridian; thus, township 23 north, range 10 east, means that it is the twenty-third township north of the base line and of the tenth range east of the principal meridian.

The law provides that east and west boundaries of townships are always to be run from south to north on a true meridian line, and since meridian lines all come together at the poles, it is plain that a township north must be somewhat narrower than the one south of it, and in order that they may all be about the same in area, lines called standard parallels are surveyed every four townships north of the base line and every five townships south of it and always parallel to it. Upon these lines the distances are set off anew as on the base line. Auxiliary meridians are also surveyed every eight townships east and west of the principle meridian, but descriptions are all referred to the base and principle meridian lines just as though these did not exist.

The townships contain thirty-six sections each, which are numbered beginning with number one in the north-east corner and numbering west to six, then with seven south of six, number east to twelve; and so on to thirty-six in the south-east corner of the township. From the time the surveyor begins until the townships are laid out in sections he marks every half-mile of true line he surveys, in the manner as before stated; and when timber is near he marks two or more trees as witnesses, giving the kind of tree, its diameter in inches and its course and distance from the corner; a copy of which is usually recorded in each county. These, together with similar notes taken by the county surveyor, make up the surveyor's records of field-notes in each county.

The manner in which the sections are surveyed are as follows: The surveyor begins at the south-west corner of section 36 and runs north, parallel to the east line of the township. At 40 chains he establishes the quarter-section corner between sections 35 and 36; he then runs 40 chains farther where he establishes the corner to sections 25, 26, 35 and 36. From this point he runs a random line east to the township line. If he misses the corner on the township line, he corrects back and sets the quarter-section corner on the true line between sections 25 and 36, an equal distance between the section corners. Returning to the south-west corner of section 25, he proceeds in the same way to survey that section;

and so continues until he reaches the north line of the township. He then returns to the south line, and beginning at the south-west corner of section 35, he proceeds to survey the next tier of sections in the same way; by running first north then east, closing each time on the section corners just previously established. The last two tiers of sections are surveyed together, by running first north then east, then west to the west line of the township.

There are two sets of corners established on correction parallels, one for sections south and one for sections north of the line. Besides these it is not uncommon to find two sets on other township lines; for the reason that in running the section lines north and west to the north and west boundary lines of the township, they were not made to close on the corners previously established on those lines; and therefore offsets frequently occur at every mile on township lines except at township corners.

For reasons already stated, townships can not be quite square, consequently some sections must fall short; therefore the law provides that the excess or deficiency shall fall on the last half-mile of the north and west tiers of sections. These are called fractional sections. There are many other things relating to the survey of the public lands, but the foregoing will be sufficient for our purpose. Subsequent surveys prove that many errors in the original have been made, but none of the lines or corners can be changed. It is therefore the duty of the county or other surveyor, when dividing and subdividing sections, to follow as closely as possible the original survey. If these surveys had been made on the ground as we see them represented on paper, it would be a comparatively easy matter to follow them. But to the contrary, we find that section lines seldom run east and west, north and south. That they bend at nearly every half-mile, and that the quarter-section corners are seldom equi distant between the section corners. By reason of this some quarters in the same section are made to overrun and others fall short. But they are all sold as containing one hundred and sixty acres each, except the fractional quarters in the north and west tiers of sections, which are sold as containing whatever the Government surveyors returns show.

SUBDIVISIONS OF SECTIONS AND METHOD OF ESTABLISHING CORNERS.

As before stated the four corners of a section, and the corners between them called quarter-section corners, are established by the county or other surveyor, in accordance with these corners. The principal lines to be surveyed in subdividing sections are those which divide the quarters into eighty, forty, twenty and ten acre tracts. The method of establishing the corners to these tracts will now be considered; presuming that all of the original corners can be found, and that the center corner of the section has been previously established. This, however, is done by running lines crossing the section each way from the quarter corners and placing the corner at the intersection of the lines.

To divide a quarter section into eighty acre tracts. 1. By a line running north and south. Suppose it to be the south-east quarter. Run a line from the east quarter corner to the center of the section, and place the corner on the middle of the line. Then run a line from the south-east corner of the section to the south quarter corner, and set the corner on the middle of the line. Then a line connecting these two corners will be the required line. 2. By a line running east and west. Run a line from the south quarter corner to the center of the section, and from the south-east corner to the east quarter corner, and set the corners on the middle of the lines.

To divide the quarter-section into forty acre tracts. Establish a corner on each of the boundary lines of the quarter by the above method, then run lines connecting these corners, crossing the quarter each way, and set a corner at the intersection of the lines.

To divide the quarter into twenty and ten acre tracts. This division is not likely to occur. But, having established the corners to the forty acre tracts, you will proceed to divide them into ten and twenty acre tracts in the same manner as the quarter was divided into eighty and forty acre tracts; by taking the middle of their boundary lines for the corners.

The same rules will apply to all the quarters in the township, except those bounded on the north and west by the township lines; and a few others made fractional by lakes, rivers, indian reservations, etc.

As there are frequently no quarter-section corners on the north and west sides of sections bounded on the north and west by township lines, and the work of dividing the fractional quarters being somewhat complicated, this work will be left to the county surveyor. The re-location of corners will also be left to experienced men. Nor is it advisable for any other person to make excavations in search for a corner, unless it is known that a stone has been deposited or a stake recently driven to mark the corner; for the reason that certain recognizable evidences of the location of a corner would be passed by unnoticed and perhaps destroyed by any other than an experienced person. If the witness trees and all traces of a corner have disappeared, it is impossible in most cases to re-locate an original corner; even the surveyor who established it would fail. It is therefore of great importance to land owners that these corners be perpetuated.

TABLE FOR LAND MEASURE.

7.92 inches	=1 link	marked	lk.	
100 links	=1 chain	"	ch.	=66 feet.
80 chains	=1 mile	"	mi.	
25 link	=1 rod	"	rd.	=16½ ft.
16 squrae rods	=1 square chain		sq. ch.	
10 " chains	=1 acre		A.	
160 " rods	=1 acre			
43560 " feet	=1 acre			

Chains and links are expressed the same and calculated in the same manner as dollars and cents. Five chains and six links, multiplied by three chains and sixteen links, would be expressed and multiplied thus: $5.06 \times 3.16 = 15.9896$ ch.

Any number of links less than one hundred are expressed as hundredths of a chain. One link is expressed thus, .01; ninety links thus, .90. Also the fractions ¾, ½, ¼, etc. for conveniency are expressed decimally thus, .75, .50, .25.

To reduce chains to feet.—Multiply by 66. How many feet in 3.16 chains?

$3.16 \times 66 = 208.56$ feet.

In 50 links? $.50 \times 66 = 33.00$ feet.

To reduce feet to chains.—Divide by 66. How many chains in 82½ feet?

$82.50 \div 66 = 1.25$ ch.

In 8 feet and 3 inches? $8.25 \div 66 = .125$ ch.

To reduce chains to rods.—Multiply by 4. How many rods in 3.25 chains?

3.25×4=13.00 rods.
In 4.22 chains? 4.22×4=16.88 rods.
In 12½ links? .125×4= .50 rods.

To reduce rods to chains.—Divide by 4. How many chains in 18 rods?

18.00÷4=4.50 ch.
In 7½ rods? 7.50÷4=1.875 ch.
In 3 rods? 3.00÷4=.75 ch.

COMPUTATION OF AREA.

In computing areas the work may be shortened by expressing the length of all the lines in chains and hundredths of a chain. In multiplying the lengths of lines containing hundredths of a chain one by another, point off from the right of the product as may figures for decimals as there are decimals in both multiplicand and multiplier. Divide by 10 for the acres by moving the decimal point one place to the left.

To find the area of a parallelogram or rectangle.

Rule.—Multiply the length in chains by the perpendicular breadth in chains for the square chains, and divide by 10 for the acres.

1. How many acres in a parallelogram; the length 30 chains, and the perpendicular breadth 21 chains?

Solution. 30×21=630 sq. ch.
630÷10= 63 acres.

2. How many acres in a rectangular field 8·75 chains long by 5 chains wide.

Solution. 8.75×·5=43.75 sq. ch.
43.75÷10=4.375 A.

3. In a square field, each side of which is 15.75 chains, how many acres?

Solution. 15.75×15.75 =248.0625 sq.ch.
248.0625÷10 =24.80625 A.

After finding the area of an entire tract, when as in the above example there are several decimal figures, we usually cut off all but two; adding 1 to the second figure when the third is more than 5. In the above area the third decimal figure is 6; adding 1 to the second figure, we have for the area 24.81 A.

To find the area of a triagle.

For right-angle triangles, or triangles whose perpendicular hight is given.

Rule.—Multiply the base by the perpendicular hight, and take half the product for the area.

1. How many acres in a triangular piece of land; the base 11 chains, the perpendicular hight 4.50 chains?

Solution. 11×4.50=49.50 sq. ch.
49.50÷10=4.950
4.950÷2=2.475 A.

2. How many acres in a triangular field; the base 20 chains, and the perpendicular, 16.75 chains?

Solution. $20 \times 16.75 = 335.00$ sq. ch.
$335.00 \div 10 = 33.50$
$33.50 \div 2 = 16.75$ A.

When the sides only are given.

Rule. 1. Add the three sides together, and take half the sum.

2. From the half sum take the three sides severally.

3. Multiply the half sum and three remainders together.

4. Extract the square root of the product for the area.

How many acres in a triangular field, the sides of which are 13, 14 and 15 chains, respectively?

Solution. $13 + 14 + 15 = 42$, sum of the 3 sides.
$42 \div 2 = 21$, the half sum.
$21 - 13 = 8$, 1st remainder.
$21 - 14 = 7$, 2d "
$21 - 15 = 6$, 3d "

$21 \times 8 \times 7 \times 6 = 7056$
$\sqrt{7056} = 84$ sq. ch.
$84 \div 10 = 8.4$ acres.

The area of a field or piece of land in any figure may be found by dividing it into triangles, and computing the area of each, separately. The sum of the areas of all the triangles will be the area of the tract.

DIVISION OF LAND.

To lay down rules covering all cases that might come up, would require more space than is allotted to this work; therefore only a few cases of most common occurrence will be given.

Case 1.—To divide a rectangle into any number of shares, by lines running parallel to a side, so that the shares will be to each other as their representative numbers, or parts.

Rule.—Divide the base lines by the numerators or numbers representing the several shares, and multiply the number representing each share by the quotient thus obtained. Or put the number of acres in place of the base line when the acres are required.

Problem 1.—Divide the south half of a quarter-section into 5 shares, by lines running north and south, so that the shares will be to each other as 1, 2, 3, 5 and 5; the length of the base line being 40 chains.

$1+2+3+5+5=16$, and $16=40$.

$40 \div 16= 2.50=$least part.

$2.50\times 1= 2.50$ chains, $=$1st share.
$2.50\times 2= 5.00$ chains, $=$2d "
$2.50\times 3= 7.50$ chains, $=$3d "
$2.50\times 5=12.50$ chains, $=$4th "
$2.50\times 5=12.50$ chains, $=$5th "

40.

Prob. 2.—Divide 66 acres between three persons; A, B and C; giving to A, 2-10; to B, 3-10 and to C, 5-10.

$$2+3+5=10.=66.$$

$$66\div 10=6.6=\text{least share.}$$

$6.6\times 2=13.2$ acres=A's share.
$6.6\times 3=19.8$ acres=B's "
$6.6\times 5=33.$ acres=C's "

66.

Case 2.—The area and one side of a rectangle being given, to find the other side.

Rule.—Divide the area by the given side; the quotient will be the other side.

Prob. 1.—One side of a rectangular field is 30.5 rods; what will be the length of the other side for 4½ acres?

$160\times 4.50=720$ sq. rd.=area
$720\div 30.5=23.6$ rd. Ans.

Prob. 2.—A field 24 chains long contains 21 acres; what is its width?

$21\times 10=210$ sq. ch.=area.
$210\div 24=8.75$ chains. Ans.

Case 3.—The area of a square field being given, to find its sides.

Rule.—Extract the square root of the area.

Prob. 1.—A square field contains 22½ acres; what is the length of each side?

$160\times 22.50=3600$ sq. rd.=area.
$\sqrt{3600}=60$ rods. Ans.

Prob. 2.—What will be the sides of a square field that shall contain 3 acres?

$3 \times 10 = 30$ sq. ch.

$\sqrt{30} = 5.478$ chains. Ans.

How many rods of fence will be required to fence in 1 acre?

If but 1 rod wide, it will require 322 rods; but if square, a little more than 50½ rods will fence it.

The above is given to show that there is economy in fencing ground in a square form when it can be done.

Case 4.—From a right-angled triangle, to cut off a given number of acres, by a line perpendicular to the base.

Rule.—1. Divide the perpendicular of the whole triangle by its base.

2. Take any length of base, less than the required base, and multiply it by the above quotient; which will give its perpendicular.

3. Compute the area of this triangle.

4. Multiply the square of its base by the required area, and divide the product by the computed area; which will give the square of the base sought.

5. Extract the square root of this square; which will give the base of the required area. Having the base, the perpendicular may be found by multiplying this base by the quotient obtained in the first above proceeding.

The base must be measured from the end opposite the foot of the perpendicular.

Note.—When the part to be cut off is next the perpendicular, subtract it from the area of the whole triangle, and find the base and perpendicular of the remainder.

Problem 1. From a right-angled triangle whose base is 8 chains, and prependicular 6 chains; to cut off 1½ acres.

(1) 6.00÷8.00=.75=equal perpendicular for each chain of base.
(2) 2.00 chains, assumed base.
(") 2.00×.75=1.50 ch.= perpendicular.
(3) 2.00×1.50=3.00 sq. ch.
(") 3.00÷10=.30=double area.
(") .30÷ 2=.15 of an acre in triangle.
(4) 2.00×2.00=4.00=square of assumed base
(") 4.00×1.50=6.00
(") 6.00÷.15=40=square of required base.
(5) $\sqrt{40}$=6.324 chains. Ans.

The area of the whole triangle is 2.4 acres. Now, if it was required to cut off .9 of an acre next the perpendicular, since the remainder would be 1½ acres the process, according to the above note, would be the same; and the length of the base would be 8.00—6.324=1.676 chains; and the length of the perpendicular would be 6.324×.75=4.742 ch.

ABSTRACT OF DECISIONS

OF

VARIOUS STATE COURTS,

WITH REFERENCE TO SURVEYS, ETC.

---

1. Visible monuments, control courses and distances.

The Buffalo, etc., R. R. Co. vs. Stigeler, 61 N. Y. 348.

Pitcher vs. Dove, 99 Ind. 175.

2. A grantor referred to a government corner as a monument in the description of land in a deed, but mistook the location of the government line, which he intended to mark the northern boundary of the land conveyed. The land laid off was marked by stakes and other monuments, and was conveyed with reference to such boundaries.

Held, that the grantee took the land according to the lines actually run and established, though they did not correspond to the line in the government survey.

Same. When a deed describes land by measurements, and at the same time by known and visible monuments, the latter will govern the call for courses and distances.

Same. The rule of applying descriptions of boundaries is (1) to natural objects; (2) to artificial marks; and (3) to courses and distances given.

Fisher and others vs. Bennehoff, (Ill.) 13 N. E. Reporter 150. Shepherd vs. Nave and others, 125. Ind. 226. Thomas vs. Patten, 13 Me. 329.

3. In construing a description of land conveyed in a deed, monuments control, then courses and distances, and lastly, in their absence, the designated quantity will prevail. Allen vs. Kersey, (Ind.) N. E. Rep. 557.

4. A line is to be extended to reach a boundary in the direction called for, disregarding the distance. Witherspoon vs. Blanks, 1 Taylor (N. C.) 110.

5. A survey of lands establishing corners and lines made in accordance with the statutes regulating the same is conclusive evidence of such corners and lines unless the survey is appealed from as provided by such statute. Herbest and others vs. Smith, 71 Ind. 44. Grover vs. Paddock, 84 Ind. 244.

6. The corners established by the original surveyors of public lands under the authority of the United States, are conclusive as to the boundaries of sections and divisions thereof, and no error in placing them can be corrected by any survey made by individuals or by a state surveyor. Arnier vs. Wallace, 28 Miss. 556

7. Where adjoining land owners cause the division line between them to be surveyed and established, such survey conclusively establishes such line, and is binding alike upon them and all who claim under them.

Same.—When such proprietors agree upon a division line, and one take possession and occupies the land to such line, peaceably and undisturbed, under claim of title, for more than twenty years, such possession divests the other of any title that he may have had to the land so occupied.

Same.—When parties agree upon such line, and each occupies to such line for more than twenty years, such agreement and occupancy give title to the line without reference to the true line. Main vs. Killinger, 90 Ind. 165. Smith vs. McKay, 30 Ohio St. 409. Fahey vs. Marsh, 40 Mich. 236. Whitman vs. Henneberry, 73 Ill. 109.

8. Where for more than twenty years a person and his grantors have continuously and uninterruptedly occupied land extending to a fence built by his remote grantor, claiming throughout that it was the dividing line, and using and cultivating such land, under a continuous claim of ownership, he becomes the owner in fee, and ejectment will not lie against him by one having the paper title. Riggs vs. Riley, (Ind.) 15 N. E. 253.

LANDS BOUNDED ON STREETS OR HIGHWAYS.

9. Conveyance of lands adjoining a public highway conveys the fee to the center of the highway, unless the deed otherwise provides. Cox vs. R. R. Co., 48 Ind. 178. R. R. Co. vs. Scott, 74 Ind. 29.

10. Where the lines of a deed calls for a public road, the owner is entitled to hold to the middle of the road, and the fact that the road is subsequently vacated will not deprive the grantee of such owner of his rights in the road. Ott vs. Kreiter, (Pa.) 1 Atl. Rep. 724.

11. A deed describing the granted land as lying "southwardly of a highway," and "excepting the road laid out over said land," must be construed as conveying the land to the center of the highway, subject to the public right of way. Wellman vs. Dickey, (Me.) 2 Atl. Rep. 133.

12. A deed of a lot bounded by stones "on the side of a road," and answering the call for quantity, without including the road, does not convey to the center of the road. Peabody Heights Co. vs. Sadtler, 63 Md. 533.

13. Where, in a deed, land is bounded on a street, or its boundary line runs to a street, and thence by the street, the grantee takes to the middle of the street, unless the deed, or the character of the locality to which it is to be applied, indicates a different intention of the parties. Hamlin vs. Pairpont Manf'g Co. (Mass.) N. E. Rep. 531.

14. The grantee of a lot bounded by a public street in a recorded town plat, whether the lot is designated by numbers, or described by metes and bounds, takes to the center of the street, unless expressly excluded by the grant. Kneeland vs. Van Valkenburgh, (Wis.) 1 N. E. Rep. 63.

15. The office of a description in a deed is not to identify the land conveyed, but to furnish the means of identification. Rucker vs. Steelman, 73 Ind. 396. Scheible vs. Slagle, 89 Ind. 323. Colcord vs. Alexander, 67 Ill. 581. Slater vs. Breece, 36 Mich. 77.