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PREFACE.

The Engineering Society of the School of Practical Science was founded in the spring of 1885, through the exertions of a few of the students in the Department of Engineering; Messrs. Herbert Bowman of the third year, and T. Kennard Thomson of the second year, being the principal promoters. Meetings are held every second and fourth Tuesday of each month during the session, at which papers are read and engineering questions discussed. In order to keep alive the interest of graduates in the success of the Society, some of the leading papers, contributed during the previous session, will be published annually. The majority of the writers are students, the greater part of whose time is necessarily spent in acquiring information already in possession of the profession, and who can ill afford to spend much of it in attempting original work. While this is true, it was yet felt by the publication committee that it would be useless to publish papers the information in which had been gathered chiefly by reading. No paper, therefore, has been printed in the present selection, the writer of which has not had some experience in the subject dealt with.

It is hoped by the general committee of the Society, that graduates of the School and former students, who are now engaged in active work, will make endeavors to contribute papers relating to their work to be read at meetings of the Society.

The present edition consists of one thousand copies, which will be widely distributed among Engineers and Surveyors.

Rodding on Railroad Work.

I. RODDING ON SURVEY.

Mr. President and Gentlemen :—.

In treating this subject I have divided it into what seem to be its two natural divisions, viz : Rodding on Survey and Location, and Rodding on Construction : and we will first consider Rodding on Survey and Location.

Before going into that, however, it may not be out of place to give a general description of the way in which railroad work is done.

We will suppose, then, that some company has decided to build a line from some one point to another. First, some of the company's engineers go over all possible routes, noting levels with an Aneroid Barometer, or some such instrument, and marking the lines over which they are travelling on maps of the localities. After making several such surveys, the engineer in charge compares notes of all the lines, and then decides upon the approximate locality of the line.

It is at this stage that the survey party goes out, and they first make what are called trial line surveys. In these surveys the line is run by transit, and the levels are taken with the instrument.

The object of trial lines is merely to get definite information regarding the various routes that may be taken, and so it is necessary to measure all horizontal angles, in order that the plan of the line may be plotted. The levels, showing the nature of the ground on each line, are also plotted, and such a drawing is called a profile.

Several trial lines are run, and then the information gained is compared, and one is selected as the line to be built. This line is then "located," that is, the line on which the centre of the track is to be laid is staked out on the ground, all tangents, curves, etc., being laid out exactly as they are to be in the finished line, the methods used being similar to those used on survey.

After the line has been located, plans and specifications are drawn up and the contracts let.

While this is being done in the office, the work has also been divided, first, in "divisions," as they are called, and each division put in charge of an engineer, who is called the "Divisional Engineer," and who has to oversee the general management of the work on his division. Each division is subdivided into "sections," and the sections are given in charge of a "Sectional Engineer," or, as he is more commonly called, an "Assistant Engineer."

Each assistant engineer is given a rodman and an axeman, and this party of three then go out on their section and proceed to lay out the work for the contractor.

For the benefit of those unfamiliar with the subject, it may be well to describe the method of running a line by transit.

At the point from which the line is to be started, a "hub" is driven and a tack put in it, the tack denoting the exact point. The instrument is then set up over this tack, and the bearing of the line to be run being known, it is set off by means of the compass on the instrument, and another hub is set as far away as the transitman can conveniently see. The instrument is then set up over this second hub and sighted on the first; the telescope is turned over and a third hub set, and so on to the end of the line. A "hub" is a piece of wood about 8″ long, 4″ or 5″ broad, and from 2 to 4 inches thick; pointed at one end and flat at the other. The method of setting a hub is as follows: The transitman sights on the back picket, turns the telescope over, and a picketman who has gone ahead and lined himself in as closely as possible, holds his picket plumb, and the transitman motions him to one side or the other until he is on line. He then makes a mark with his picket, and the axeman drives the hub until its top is about half an inch above the ground. The picketman holds his picket up again on the hub, and the transitman lines him in exactly. He then makes a mark in the hub with the shoe of the picket, and drives a tack in that mark. This tack will be seen to be exactly on line.

The chainmen then come along and set in stakes every hundred feet, that is every chain, for a 100′ chain is always used. They line themselves in by the instrument and the back picket, and as they go along number each stake, numbering the first "0" and the end of the first chain "1," and so on; so that, for instance, a stake numbered "23" would mean 2,300 feet from the starting point.

These stakes are called "stations" or "centre stakes." After the chainmen come the levellers, and this introduces us for the first time to the rodman on survey. The general method of running levels is as follows: The levels are started from some definite point, for which an elevation is assumed. The instrument is then set up and levelled, and by means of a sight at the rod held upon the starting point, an elevation is found for the instrument, corresponding to that assumed for the starting point.

Readings of the rod are then taken at every centre stake, and the elevations determined by subtracting the reading at each station from the elevation or height of the instrument.

When the rod gets too high or too low for the instrument, or cannot be distinctly seen by it, the elevation of a point is found, and the instrument is then moved and set up again, and the height of the instrument again determined from that point, by knowing the elevation and taking the reading of the rod held on it, thus finding how much higher the instrument is than the point. This process is repeated over and over again until the end of the line is reached. The elevations found in this way are of course comparative, and when plotted form a profile, which, of course, shows the comparative heights of points 100′ apart on the line, and thus gives a general idea of the surface of the ground.

It might appear from the above that the rodman's duties on survey are rather light and simple, and so they really are; but this is only an additional reason why they should be well performed; and this brings us to our subject proper—Rodding on Survey and Location.

The first, and perhaps most important, duty of a rodman is to hold his rod plumb. This is absolutely necessary in order that the levels may be correct, and although it would appear a very simple matter, it really requires a good deal of attention.

First, then, get a firm footing for yourself behind the rod, and then hold it lightly between the fingers and balance it until it feels plumb both sideways and forward and backward. Then call out the number marked on the stake. This calling of the numbers must never be forgotten, as the leveller always depends on it to find out whether any number has been repeated or omitted by the chainmen in marking the stakes, and thus to check the chainage, for an omission or a repetition would shorten or lengthen the line, respectively. If an error is noticed, be sure the leveller notices it also, when you call out the number of the station.

Besides giving a sight at every station, it is also necessary to give sights at all points where the surface of the ground changes abruptly. Such a sight is called a "plus," and derives its name from the fact that the rodman must find and call out the chainage of that point. The distance of the point from the last station may be either estimated by the eye, or what is better, paced off. In calling out a plus, call out the full station as well as the plus; thus "365 + 33."

In order to recover the levels at any future time, it is necessary to find the elevations of definite points all along the line, and note their positions and elevations, so that they can be found without difficulty, and the levels started from them if necessary.

These points are put in about every ten or fifteen chains, and are called "bench marks;" and as naturally hard, definite points are rare, bench marks must usually be made.

The most common method is to cut the bench mark on the root of a tree near the line, and this requires not a little skill and practice if the bench is to be a good one.

First, then, choose a tree which can be distinctly seen by the instrument, and which has a root projecting from the trunk on the side next to the line. Then with the hatchet, which the rodman always carries, make a vertical cut down on the root, then an inclined cut, so as to take out a "V" shaped piece of wood. Then cut away the sides of the piece thus left, so as to form a pyramid. The top of this pyramid is then cut off horizontally, so as to leave a square about half an inch in diameter. This is the bench mark, and to prevent any possible mistake it is a good plan to mark the point with a little chalk cross on top.

When the bench mark is put in, the elevation is always marked on something near it, and in case the bench is on the root of a tree, the elevation is marked on the same tree. To do this, the face of the tree must be blazed; that is, the bark cut off and the wood smoothed so that it can be written on. In blazing the tree be sure not to leave the bark in shreds or partly cut away at the sides, for it will grow over the cut very quickly if left in that way; and also cut well into the wood of the tree, or otherwise the blaze will become black and the figures on it cannot be seen.

On the blaze is then marked with red chalk the letters "B.M.," (bench mark), and the elevation thus:— B.M.,
886.74.

Sometimes also the levellers number their bench marks, and if so, it should be marked thus:— B.M. No. 23,
886.74, and not the following:—(B.M., No. 23, 886.74), for with the latter way a new rodman and leveller might in some way mix up the number of the bench and its elevation.

In marking a bench do not make the figures very large, but make them very distinctly and neatly, for nothing looks better in going along the line than to see well-cut, neatly-marked benches; the centre stakes all standing plumb and also neatly marked; and in fact this applies to every stake that has to be driven and every number that has to be marked—drive the stakes plumb and mark the numbers neatly.

But of course it is not necessary to cut a bench mark on a tree; any hard, definite point which is certain not to be moved will answer very well; for instance, the top of a boulder or a stump, or a long stake driven solidly into the ground; but in these cases especially it is necessary to mark the point used by a cross, or some such mark, so that there can be no possible mistake in finding the point again. In order that bench marks may be found at any future time without any delay, it is necessary that the rodman should be able to "locate" himself, that is, to recognize any part of the line on which he may be put, and then to remember approximately where the nearest B.M. is. Of course this is pretty difficult, but if a mental note is made of the neighborhood of every B.M. as i is cut, with a little practice one is able to locate oneself almost exactly and with comparative ease.

When the leveller can no longer see the rod distinctly enough, he finds the elevation of some point and moves the instrument as was explained before. The point on which the rod is held is called a "turning point," and any hard, definite point that will not be destroyed until the leveller has found his elevation again will answer very well; for instance, the top of a stake, if it is solid, the top of a hub, a point on a stump, etc.

But cases will occur when nothing of that kind can be found where the instrument can see it, and then a turning point must be made.

The usual plan is to make a little peg about an inch in diameter and about six inches long, and drive this solidly into the ground, leaving about ¾" or 1" sticking up.

Another trick is to drive the hatchet into a log of wood, or something, so that the back of it is horizontal, and then turn on that, but in this latter case be careful not to move the hatchet.

When a turning point has been chosen, before using it mark it with a small cross, and then if your attention is called off you will not be puzzled when you come back to know which of half a dozen points you thought of you really did use.

In case of accident, it is well to leave the turning points in the ground, so that they may be found and used again, and it is partly for this reason also that they are marked with a cross.

Of course one cannot go back and stick the hatchet in just exactly as deep as it was before, and therefore it should be used as a turning point as little as possible.

As readings at turning points must be taken with extreme accuracy, and as the rodman, no matter how careful he be, cannot judge when the rod is exactly plumb, it is customary to "swing" or "wave" the rod backward and forward on all turning points, for in one of the intermediate positions the rod must be plumb.

To do this, get a firm footing behind the rod, and setting the rod on the turning point lean it well forward, and then draw it slowly backward, bringing it well behind the plumb position, then wave it slowly forward again, and repeat this until the leveller signals you that he has the reading.

Beside these duties of the rodman in the field, he has also to "call" the profile in the evening; that is, he calls out the elevations of the stations, and the leveller plots these on paper prepared for this purpose. As different levellers like the profile called in different ways, no details of this part of a rodman's work would be of any use.

The points then, to which a rodman on survey or location has to give his attention are:—

First, to hold the rod plumb; always to call the number marked on the stake; to take "pluses" at all prominent points where the ground changes to any considerable extent; to choose solid points as turning points, and mark them in such a way that there can be no doubt as to the point on which the rod was held; to cut and mark all bench marks neatly, and if possible to put them in such positions that they can be seen from any part of the line near them; to inform the leveller of any error in chainage or marking of the stakes that may be noticed; and, lastly, to call the profile for the leveller in the evening.

II. RODDING ON CONSTRUCTION.

On survey we have been getting information to enable the engineer in charge to choose the best line. On location we have laid down the line chosen, the methods used being similar to those used on survey, and on construction we prepare the work for the contractors.

To do this, the work is divided, as was explained before, into "divisions," and these divisions sub-divided into "sections"; there being an engineer for each division, and an engineer with his rodman and axeman for each section.

The first thing an assistant engineer does upon going on to his section, is to run check levels over the whole of it; that is, he runs very carefully over the line, checking all the bench marks, and putting in new ones wherever he thinks they are necessary, and also checks the levels of the centre stakes if he thinks necessary.

If there be any doubt as to the alignment, he should also check it by running over it with the transit; but as the location is usually made with great care, this is very seldom necessary; but the cheek levels are usually run on account of the ease with which a mistake can be made in reading the rod, or in noting the reading in the level book.

As constant reference must be had to bench marks, both in running check levels and in the ordinary work on construction, a good plan is for the rodman, before going out on construction, to get a list of all bench marks from the engineer, and carry them with him constantly, so that no time will be lost in finding them.

For the same reason this might also be done in the case of hubs, for although the engineer usually has a list of bench marks and hubs with him, yet in case of the rodman's being some distance from him, or if by chance he has not his list with him, a good deal of time and trouble would be saved by the rodman's list.

After the check levelling and alignment are done, the real work of construction begins. This consists in first laying out the right of way, and the clearing in all bush on the line; then the amount of cut or fill at every station must be marked for the contractor, and stakes set to mark where the embankment or cutting will meet the natural surface of the ground; and, finally, stakes must be set to mark the openings to be left in embankments for culverts, drains, etc.

Plans come from the head office giving the width of each owner's land which the company propose to buy; this is called a plan of the right of way, and the widths shown on the plan must then be staked out in the field.

In staking out the right of way, stakes about $4\frac{1}{2}'$ or $5'$ long, $1\frac{1}{2}''$ broad and $1''$ thick are used. These stakes are set so close to each other that from any one those next to it on either side can be distinctly seen. They are usually set opposite a full station or hub, the distance of the fence line from the centre stake being measured with a tape, and the stake set in at right angles with a pocket sextant. When the stake has been driven solidly into the ground on the face next to the centre line the word "FENCE" is printed with chalk, and below it the distance of the fence stake from the centre line is marked thus, "FENCE, 50′ S."; the letter S standing for South, and meaning the fence line is fifty feet south of the centre line at that point. A similar stake is then set on the opposite side of the line, and marked similarly with the word fence and the distance and direction of the fence line from the centre line.

In cases of jogs in the fence line, two stakes are set at the station where the jog occurs, the one denoting the end of one line of fence, and the other the beginning of the other line.

When the line runs through bush, the right of way is cleared to its full width, of course; and so in marking the stakes, they are marked "CLEARING, 50′ S.," instead of "FENCE," etc., as in the open.

The right of way and clearing are usually staked out first, in order to let the contractor get his clearing gangs to work as early as possible, and while the clearing is being done the earthwork in the open parts of the line is usually laid out.

In laying out work, as it is called, it is customary to stake out only the full stations, but also to cross-section such "pluses" as the engineer thinks necessary; the cross-sections being taken to get the quantities as accurately as possible, and the stakes set to show the contractor where the edge of the cut or fill is. In some cases engineers prefer to cross-section every fifty feet, that is, the full and half stations; but unless there is some apparent change in the surface, this is hardly necessary, although in any case it can do no harm and may make the quantities more correct, at the expense of a great deal more work.

Since the quantities which the contractor moves are measured in the cuts, pluses will be much more frequent and necessary in cuts than in fills; in fact, they need only be given at pretty abrupt changes in fills.

The first thing to be done in laying out a station is to get the cut or fill, and as the surface of the ground is somewhat indefinite, it is customary to drive a small plug, about 5″ long and ½″ in diameter, behind the centre stake, and to hold the rod up on that. The rodman calls out the number of the station, and the engineer, reading the rod and knowing his height of instrument, finds the elevation of the top of the plug. He also knows the elevation of grade at that station, for he has given in his profile book the height of grade at the last point at which it changed, and also the rate at which it is rising or falling. He can then see the relative elevations of the ground and grade, and calculates the amount of the fill or cut by subtracting the elevation of the ground from that of grade for fills, and *vice versa* for cuts. This calculation is made to the nearest tenth and the result called out to the rodman, who marks it on the back of the centre stake, thus, "C. 6.9" (or) "F. 5.7," the numbers always being marked so as to read downward.

Here it may be said that it is always advisable for the rodman to repeat the number which the engineer has called to him, and thus prevent any mistake in his hearing the number.

If the instrument be above grade, a neat method of calculating a fill is for the engineer to subtract the elevation of grade from the height of instrument, and then when the reading is taken he has merely to subtract this difference from it, and he gets the fill. If, however, the instrument be below grade, the H.I. is subtracted from the elevation of grade, and then when the reading is taken, by adding this difference to it the fill is obtained.

In cuts it is evident that the H.I. must always be above grade, and the elevation of grade is then subtracted from the H.I., and when the reading is taken it is subtracted from this difference, and the cut thus obtained. These methods save a little time, for the difference between the elevation of grade and the H.I. can be found while the rodman is going from one station to another; whereas, in the ordinary method, nothing can be done until the reading is taken. The cut or fill having been found and marked, the next thing to be done is to "lay out" the station; that is, to put in the "slope stakes," which denote the point where the slope of the embankment or excavation will meet the natural surface of the ground, and there are two methods of doing this.

The first method is by cross-sectioning every station and plus, after having found the cut or fill; then going into the office and plotting the cross-sections on cross-section paper, and by drawing in the depth of cut or fill, the width of the roadbed and the slopes, finding the points in which those slopes intersect the surface of the ground and the distance of such points from the centre line. A list is then made of these distances, the section is gone over again and the stakes set in. This method saves some time and is perhaps less troublesome, for the cross-sections have all to be plotted anyway.

The second method is by staking out every station as it is cross sectioned; perhaps it is the slower and more troublesome method, but it is the proper method, and the way in which most chief engineers require the work to be done; for an error in the plotting, in the first method, would cause an error in the placing of the slope stake, and, besides this, it is not considered business-like.

In the first method the rodman gives the centre sight, marks the cut or fill as the engineer calls it, and the axeman, holding the tape at the centre stake, the rodman pulls out and gives a sight at every point where the ground changes even slightly, calling out in feet and tenths the distance from the centre stake of every sight he gives, and going out until the engineer stops him. He then does the same with the other side of the line, and between the stations watches for pluses, at which he puts in centre stakes, marks the cut or fill, and cross-sections.

The engineer and rodman go into the office, plot the cross-sections and take out the quantities; the axeman, in the meantime, being out on the line making stakes. When the plotting is finished and a list of all slope-stake distances made out, they go out into the field and put in the stakes at the given distances and always at right angles to the centre line.

In the second method the rodman gives the centre sight and calls out the number of the station; then marks the cut or fill, and the axeman holding the tape at the centre stake, he pulls out (giving sights as before) until he comes to the point directly over or under the edge of the roadbed, where he always gives a sight. The slope being given by the proportion of the horizontal to one vertical, the engineer calculates the horizontal distance corresponding to the cut or fill at the edge of the roadbed, adds it to the half width of the roadbed, calls out the result to the rodman, who pulls out to that distance—giving sights where necessary—and gives a sight. The engineer then makes a correction for the difference in elevation of this last point and that at the edge of the roadbed, and calls out the horizontal distance as before, with this correction added or subtracted, and the rodman moves to that distance and gives a sight. The engineer makes a similar correction to the first and calls out the corrected distance to the rodman, who moves again and gives another sight. These two corrections are usually enough, but in very rough ground more may be required; if so, they are made in exactly the same manner as the other two. When the required point has been found, a "slope stake" is driven in to mark it. These stakes should be 15″ to 18″ long, about 1½ inches broad and 1″ thick. The broadest faces of the stake are "blazed," and one side is marked the station and on the other the letters "S. S.," slope stake, and the distance from the centre line.

The stake should be driven in plumb, with the side bearing the letters "S. S.," etc., facing the centre stake. The next points that must be marked for the contractor are the "grade points"; that is, those points where the cut runs out and the fill begins, or *vice versa*.

These points are marked by putting in three plugs at grade; one on the centre line, and one on each side at the edge of the roadbed.

When the engineer finds that the cut is getting very small, he calls or signals to the rodman to find grade. The rodman, knowing the cut or fill at the last station, moves down or up the incline, (along the centre line) until he thinks he is about grade. He then calls out "grade," and gives a sight. The engineer motions him up or down until the rod-reading shows that the rod is resting on grade. when the rodman is signalled "all right." A "grade plug," as it is called, is then driven at this point. This plug is about $1\frac{1}{2}''$ square, from 6″-8″ long, and has a good, hard, unfrayed top. It is driven until it is slightly above grade, and then by means of successive sights and tappings, it is brought down exactly to grade. To mark this plug, a stake, called a "grade stake," is driven in in front of it, bearing on its face the number of the station and the plus, and on the back the word "grade," reading downward, and marked directly over the plug. The plus of this grade point is called to the engineer, and the axeman holding the tape at the centre, the rodman pulls out (at right angles) to the width of the roadbed, and choosing the point which he thinks is on the same level as the plug just set, he gives a sight. He is motioned up or down, as before, until he finds grade, where a plug is driven and set, as at the centre. Behind this plug a grade stake is driven, and on the front of it, above the plug and reading downwards, the words "GRADE ON PLUG" are marked, and a similar plug is then set on the opposite side of the line. If the plus of either or both of these points differs from the plus of "grade at centre," it must be found and called to the engineer. As the work is gone over it is customary to take the "hub stake" from its place at the side and drive it directly behind the hub; and then to put in stakes on each side at about 20′ or 25′ out, as "reference stakes." These stakes have their inner faces blazed, and marked with the word "HUB," the number and plus of the station, and the distance and direction of the hub from the reference stake, thus:— "HUB, 337 + 27.5, 20′ S." These stakes, of course, form no permanent reference for the line, but are merely useful to find the hub when the "hub stake" has been lost, and before the earthwork has been commenced.

For permanent referencing, the methods described in Mr. Kennedy's paper are the proper ones to use. The openings to be left for drains, culverts, cattle-guards, etc., must also be marked for the contractor; and small drains, such as tile drains, may be staked out in the following way:

The point on the centre line at which the drain is to be put in having been decided upon, a stake is driven in, having on the face the number of the station and the plus. A sight is then given on the ground behind this stake, and the cut is calculated and called to the rodman, who marks it on the back of the stake. Two stakes, blazed on opposite face, are then set in on the centre line, before and behind the stake already set, and having between them the width of the excavation for the tiles. On the outer faces of these stakes the word "DRAIN" is marked, and on the inner faces the cuts are marked, they having been found by sights given at each of the stakes.

Then, two stakes corresponding to the last and similarly marked are set at the side of the line beyond the edge of the embankment; and two other similar ones are set on the opposite side of the line; making a total of seven stakes for marking a drain.

All plans for culverts and cattle-guards are made up at the head office and sent out, but the engineer, in going over the line laying out, merely puts up a large stake with something like the following on it:—

"8′ OPENING FOR CULVERT."

the culvert being laid out afterwards when he has the plans.

Besides laying out work as he goes over the line, the engineer puts in hubs to keep the alignment. These hubs are set in the usual way (the rodman doing the picketing), about 8/10 below grade, and reference stakes, as described, are driven in on either side.

The hubs should be extra long, so that they will not be disturbed if kicked or tramped upon by the horses, and should be driven rather low so that the scrapers will not catch them.

Such, then, are the duties of the rodman in the field, but in the office he has also to assist in taking out quantities, checking the level book, and in the general work of the office.

On construction, then, the rodman has first to rod for the check levels and picket for the alignment, if it is run. In running check levels the greatest possible accuracy and care are necessary; but besides this, the rodman must be sure to check *every* bench that has been put in on location. Next comes the staking out of the clearing and of the fence line; the point in this being to get the stakes set at the proper distances, exactly at right angles, and driven solid and plumb.

In rodding for laying out work, the saying that one should "always give the contractor the benefit of the doubt," will convey some idea of the degree of accuracy necessary in cross-sectioning, and the number of pluses necessary between full stations. In the picketing, the main idea is to get the hubs where they will not be disturbed by the navvies, but as that is pretty difficult the line is usually referenced at the side and altogether away from the line of haul of carts, scrapers, etc.

In the office work the rodman cannot be too careful, for he is dealing almost altogether with numbers, and we all know how easy it is to make a slip in the simplest calculation.

GEO. H. RICHARDSON.

Explorations on the Battle River.

Mr. President and Gentlemen:

It was on the afternoon of July 17th, 1885, that our little party bidding farewell to the Calgary-Edmonton Trail, turned its back to the setting sun, and being assured that all our necessary outfit was securely stowed away in our canoe, started on our long voyage down the Battle River. It is so called, I was told, from its being many years ago the scene of one of the bloodiest battles between the two great Indian nations of the North-West Territories—the Crees and the Blackfeet. It takes its rise in that immense swampy region surrounding Pigeon and Battle Lakes, about 150 miles north of the Canadian Pacific Railway, and 80 miles from the Rocky Mountains. Between its source and the Rockies, flow the Saskatchewan to the north, and the Red Deer to the south, intercepting all mountain streams, and compelling the Battle to be purely of prairie origin. But the low-lying boggy district surrounding its head waters, into which the surveyor can penetrate only when winter's frost has formed for him a solid footing, is of itself quite sufficient to produce a large river.

After flowing through about 350 miles of valley, it enters the Saskatchewan at Battleford, and by way of Lake Winnipeg, and Nelson River, its waters flow into Hudson's Bay.

The object of our journey was to make a geological, as well as geographical examination of the river and surrounding country, between the limits of the fifth and fourth principal meridians. The upper half of this distance had, during the summers of 1883 and 1884, been traversed by Dominion Land Surveyors, but the lower part was as yet comparatively unknown. But notwithstanding the work already done in the two previous summers, on account of the recent government maps not being completed, we were obliged to keep a tract survey so as to be able to locate exactly where any minerals or fossils were found, or where a new geological formation occurred.

Before going further on our journey, it may be interesting to review the general method of work.

In the first place then, the instruments used were but few and simple. They consisted of a prismatic compass, with a three inch card, an ordinary watch marking western standard time, and an aneroid barometer. Note books, scale and protractor were also used, and the country plotted as we proceeded. The prismatic compass was preferred, for since a bearing is seldom taken to less than half a point, results just as satisfactory will be obtained, as if the instrument had been the regular surveyors compass. A watch also proved of great assistance, for since the average rate of our canoe was known—about 3½ miles per hour—distances could be estimated tolerably well. The note books supplied by the Government to their geologists, seemed to me especially suitable. They are of such a size as to fit into an ordinary coat pocket without difficulty, viz.: about 5 " x 8." The pages are divided into blocks ½" square, so that the paper itself is a scale. One page was used for the tract survey, the other for written descriptions of the geology of the country, so that every two pages indicated one days work. Now as the start was made in the morning, the plotting of the country would be commenced in the usual way at the bottom of the page. A bearing taken would be laid off with the protractor, and the estimated distance by scale. Neighboring hills, lakes, streams, etc., were noted in the same way, so that by evening the page of our note book would be an approximately correct map of the country passed over during the day.

On being sent to the government, the leaves are all cut out of these books and pasted together, and with a pantograph, reduced or enlarged to any desired size.

It is in this way that the maps of the geological survey are produced.

But let us return again to our original story.

At its crossing with the fifth principal meridian, and about twenty five miles from Pigeon and Battle Lakes, the river has gained a width of nearly two chains, a depth of eight feet, and has a flow of about two miles per hour. Its water is of a darkish color, owing partly to the muskeg country surrounding its head-waters, and partly to the large quantity of clay iron stone found in this region.

On the afternoon of the second day, as we floated down the stream, we noticed on the high right bank, a small log shanty, and from its general appearance its square fences etc., we concluded that its occupant was no Indian or half-breed, but a white man. On climbing the hill, and making our way to the door, we were kindly greeted by the missionary to the Stoney Indians, who was busily engaged in repairing and rebuilding his house after the Indian raid of a few weeks before. He had, we were told, only left a few days with his family for a place of safety, when Bob Tail and his band came along, pillaged his house, drove his horses and cattle away, and after exhausting their means of destruction, rode off leaving the place a total wreck. During our stay here, Samson, a friendly chief, came over to the missionary telling him to make no more repairs, for he believed, that later on in the fall there would be a general rising of the Indians in the North-West. It was talked of, he said, not only in their own tribe, but also among the Crees and the Blackfeet. Another Indian came a few hours later bearing the same startling intelligence. The prospect now of starting with so small a party after the news which we had just received, to penetrate the heart of a hostile country, did certainly not seem the most inviting.

Later in the evening of the 20th, we reached the shore of a small lake, in a cold and drenching rain. The night was dark and dreary, and the continuous howling of prairie wolves did not tend to make it any brighter. By the light of a small fire of wet wood, we pitched our tent, not, however, without some trouble; for hunting about in black darkness in a bush, now tumbling head foremost over a pile of logs; then running against a standing tree; at the same time wet and shivering, and as yet without tea, could hardly be called revelling in luxury and ease.

This lake is about two miles long, and although very shallow, acts as a settling pool for the river. So that the apparently dirty water which comes in, flows out again clear and sparkling. Six miles below this lake is Todd's crossing, a small half-breed settlement of some half-dozen families, all of whom depend for a livelihood upon fishing.

The method these Indians use for catching fish seemed to me at first, cruel and inhuman. Two lines of closely set stakes are driven into the river bottom forming the two sides of a triangle, vertex down stream. One of these sides is made shorter than the other, so that the point can be easily reached from the shore. At this vertex is a gap of about four feet, in which an inclined plane formed of poles is placed, the high end down stream, and about a foot beneath the surface of the water. Both the fence of stakes and the inclined plane are open enough to allow water to pass through without being much dammed, but all fish except very small ones are retained. Around this gap, on the outside, is worked a large basket of willow boughs, so that all fish coming down the river are forced through this gap, and caught in the basket. The night we were there this trap caught about a ton of fish, principally gold eyes, suckers, and jack fish, having an average length of about eighteen inches.

The valley of the Battle throughout its entire course, varies from half to two miles in width, and this distance is for the most part a low flat, overgrown with poplar, spruce and willows. In this wide valley the river meandered backward and forward in tortuous windings, so that often after hard paddling, we would find ourselves only a few rods from where we were an hour or more before. Wherever the turns in its course are sharp, the current-side of the bank is, of course, worn away, so that trees and bushes having their foundations swept from under them, fall into the river, forming a barrier there. When nearing just such a place as this on the evening of the 22nd, we paused for a moment, fearful of the boiling rapid ahead, but in a second were whirled on, and in spite of our exertions with the paddles, were carried down in the strong arms of the current and dashed a helpless wreck against a mass of projecting bushes; our all was lost. We could speak for nothing more than for ourselves. However, our position was a serious one, so that we immediately set about saving our baggage. Some of the lighter things which would float, we had secured before nightfall, the rest were we knew not where. Our supper that night, was novel, in fact it seems rather more so now than it did then. It consisted of oatmeal porridge, void of all seasoning or sweetening, served up in the pot—the only cooking utensil saved—and eaten with a flattened stick. Never before did a meal taste so dainty or delicious.

Without a dry stitch in our outfit, or a single weapon for protection, we laid ourselves down on the river's bank, and before long were fast asleep.

Next day, chiefly through the exertions of one of our party who was an experienced diver, many things were found, and the following day many more; so that on the third day after our misfortune, we were again started, to make the fastest time possible for the nearest village where we could procure more supplies.

On reaching Salvay's Crossing,—also a half-breed settlement,—we found most of the men away, among others the owner of the ferry. On inquiring we were told that he was visiting in Edmonton; visiting, however, rather from necessity than from choice, at the Edmonton jail, to account for his actions at Batoche during the late rebellion.

A little above the village is the mouth of the Pipestone River, and from the high bank the view we had was very interesting. The Battle although more than four times as large as the Pipestone, has a valley only a quarter as wide.

After their junction the narrow valley disappears, and the Battle continues in the valley of its tributary. From my position at the top of the hill, the little coulée entering away in the distance, looked as if some little stream might be running there instead of our mighty river.

During the past several days great numbers of geese and ducks had been seen, not a few of them being obliged to stay with us, which helped considerably to "vary the stereotyped fare of Government bacon."

Our latitude was now 53°, the highest point we had yet reached, being about 700 miles further north than Toronto. In June, at this place, ordinary print can be easily read at 10 o'clock in the evening.

During all this time, the peculiar appearance of "*buttes*" had been attracting our attention. These are great mounds of earth rising immediately from the valley, and formed by the continuous action of the river on a narrow isthmus, which in the end it succeeds in wearing a passage through, leaving what was before a high ridge stretching out into the valley, now a lonely mountain. As they are of different shapes and sizes, so also are they different in beauty. Some in the form of cones, tower up from the valley a height of from two to four hundred feet. Others, wedged shaped, are so prettily formed, that they look like the roof of the palace of some ancient god. One, my barometer showed to have a height of 450 feet.

At the Government "cache," at the most southerly bend of the river, the view we had was really entrancing. What land is to a weary sailor, or water to a traveller in the desert, so was the sight of the expansive prairie, after travelling for weeks in the narrow valley. Standing on the summit of an almost perpendicular wall of ground, 250 feet above the valley, behind us lay the prairie, flat and boundless as the ocean, and in front, the beautifully wooded valley of the Battle, the river winding tortuously among its knolls and buttes; appearing here and there like a silver band, and then fading away in the tree tops.

A picture with more beautiful contrast could not be imagined.

Passing on from here, in about twenty-five miles, we came to a narrow valley where, on account of being thus corraled, the river was obliged to straighten in its course. At one time we were able to take a sight of three quarters of a mile, and at another a mile, the latter being the longest we had yet taken.

The river still maintained its flow of two miles per hour, although its width had now increased to three chains.

After passing in succession Grizzly Bear, and Blackfoot coulées, both entering from the north, we reached the old Fort Pitt and Sounding Lake Trail, where our story closes.

It was now the 19th of August, and the first white man's voyage down the Battle River was at an end. We had been on the way thirty-two days, during which time we had come, including the river's diversions, over 700 miles.

H. G. TYRRELL.

Mortars and Cements.

Mr. President and Gentlemen,—

In this paper on Mortars and Cements, I shall not endeavor to dwell at any length on any particular part of their manufacture or use, but shall take up the subject as a whole.

The material generally used in the manufacture of lime is the carbonate of lime, which is the constituent of bone, shells, etc., and is the principal ingredient of all natural limestone.

It will be necessary here in the beginning to explain the processes employed in the burning of the lime, which is effected in (1) kilns ; (2) in mounds and ovens. There are two kinds of kilns in which the lime is burnt.

(*a*) The intermittent or ordinary way.
(*b*) The continuous kiln.

The first of these is the method usually employed in localities where the burning cannot constantly be carried on, and is too familiar to require any explanation.

In the continuous kiln the lime is burnt either in kilns in which the fuel (generally coal) and stone are placed in alternate layers, or in kilns in which the fuel and stone are not in contact.

In the first of these the actual burning space is in the shape of an inverted cone, wide at the top and narrow at the bottom.

In the latter the kiln retains its character as a perpendicular or shaft kiln, but the fuel instead of being interstratified with the lime-stone is burnt in separate hearths in the side of the shaft, and the flame is conducted into the latter, which in this case contains nothing but the lime-stone to be burnt. In burning in mounds, which is done in Wales and Belgium, the fuel and lime-stone are put in a circular kiln and covered with turf, making a pile of about 16 feet in diameter at the base and 12 feet at the top, the burning occupying from 6 to 7 days.

In the slaking of lime there are three methods in common use :—

(1) Drowning.
(2) Immersion or sprinkling.
(3) Spontaneous slaking.

The first and second methods will probably explain themselves, while in the third method the lime is slaked by exposure to the air, from which it absorbs moisture, for which the lime has great affinity. Mortar is a mixture of slaked lime with sand in different proportions, in which the lime is to be good, and the sand good, sharp, and angular.

The proper proportion of sand and lime is a most important point in preparing mortar ; as a general rule, the lime should be sufficiently fine to cement all the grains of sand together. The surfaces of the grains of sand, or the voids between them should be only just covered with the lime in a semi-liquid state, and therefore enough lime should be added to fill up the voids in the sand without increasing its volume.

Both the sand and water should be free from clay and salt ; sea-shore sand should not be used as it is almost impossible to get rid of the salt, and enough will generally remain to keep the work damp and to produce an efflorescence of nitre upon the surface of the brick, whether with lime or cement mortar. Common mortar exposed to moisture may be seen to be rotten or to have become useless, and if exposed to a constant moisture will never harden properly. Thus it becomes necessary to use some mortar which will stand the moisture, generally.

Hydraulic Mortar, which is made from a lime containing more than 10% of silica and alumina, which imparts to this mortar the peculiar property of hardening under water has thus very appropriately received the name hydraulic. Moistened hydraulic lime is at first a very soft friable mass, which is easily scratched by the nail, but when covered with water it acquires a hardness which is quite equal to and often exceeds that of the limestone itself, for which it is often used as a substitute. As a general fact the time in which the hydraulic limes become hard is very variable, and the chemical action which is the cause of the hardening, is consequently very unequal.

The degree of hardness which they acquire is also not the same, those that harden slowly being often more compact than those that harden in a short time. The time required for hardening varies from a few minutes to weeks and months, and bears some relation to the amount of aluminous matter present in the lime. The more the lime contains of this ingredient the more quickly it hardens ; thus, in a lime containing silicate of alumina in the proportion of from 6 to 8 or 12%, the lime becomes simply "moderately hydraulic," and sets in from 15 to 20 days ; when in the proportion of from 12 to 20% it is called "hydraulic," and sets in from 6 to 8 days, and hardens in about 6 months, while that containing from 20 to 30% is called "eminently hydraulic" lime, setting in from 3 to 4 days and hardening in 1 month, and at last slowly approaches the character of the cements.

Hydraulic mortars do not require sand, but it is used for economy as it does not seriously impair the value of the cement, if used in moderate quantities, and even 1½ of sand to 1 of lime does not impair its value.

The hydraulic mortar employed by Smeaton in building the Eddystone light-house consisted of equal quantities of lime slaked to powder, and pozzuolana, a product of volcanic origin used very much by the Romans in the manufacture of their mortars. Good hydraulic mortar should not show any tendency to crack when hardened under water, even when no sand is mixed with it.

If the mortar is not only required to harden, but also to bind well, it is necessary that the surface of the stone shall be moistened, when this is not done the surface of the stone (by the power of absorbing moisture) dries the mortar, and prevents proper adhesion from taking place. As in common mortars, the grain of the sand employed requires to be sharp and angular; and it is better to use a mixture of coarse with fine sand, than that the sand should be all of the same sized grain.

The hydraulic limes which we have been considering are those which slake with water and have the power of setting under water. Certain limestones when burnt will not slake with water, but when the burnt stone is finely ground and made into a paste, it also has the property of hardening under water, and to distinguish it from our hydraulic mortar is called hydraulic cement.

A few natural cements are found and may be considered as chiefly of volcanic origin, chief of these is the pozzuolana which has been already mentioned, and received the name from the village of Pozzuoli in Italy, near which place it is found.

The use of the natural cements is the exception and not the rule, for on account of their high price, consequent upon the smallness of the quantity found, the use of artificial cements has almost superseded their use.

The earliest known artificial cement is that manufactured by Parker, Wyatt & Co., who took out their patent in 1796. The cement prepared by them and still in use is known as English or Roman or "Parker's Roman," and was manufactured by burning clay nodules, known as "septarian nodules," found in a peculiar clay-shale, above the chalk formation of Isle of Sheppy and the Isle of Wight, and elsewhere. The composition of the nodules is approximately clay 33%, carbonate of lime 67%.

They are burned in the ordinary conical kiln with coal or coke as fuel, at an under heat, to prevent vitrifaction. They are afterwards pulverized, and as the resulting red-brown powder eagerly absorbs carbonic acid and water from the air, it is necessary to keep it in air-tight casks, in which form it is sold in commerce.

This cement has a close fine grain, pasty look and greasy feeling, and loses ⅓ by weight when burning. When made into a mortar it sets in from 15 to 20 minutes.

There are four kinds of artificial cements :—

(1) Twice kilned artificial cement.
(2) Portland cement.
(3) Artificial pozzuolana.
(4) Silicization cements.

In the first the process of making the cement is to take clay of 50% alumina, and 4 to 5% of carbonate of lime ($CaCO^3$).

The clay is first burned until every trace of moisture has been expelled and it is then thoroughly mixed with the lime. It is then dried in the open air in sheds; then made into balls of 2 or 3 inches diameter and burned at a red heat; then again ground into a powder, after which it is ready for use.

Portland cement is named from the resemblance to the Portland stone, and is a scaly crystalline powder of grey color.

This cement was first prepared by Mr. John Aspdin, of Leeds, England, and was prepared by him in the following way. A large quantity of limestone is taken and pulverized, then dried and burnt in a lime-kiln. An equal quantity, by weight, of clay is then added to the burnt lime and thoroughly kneaded with water until a plastic mass is formed. This is afterwards dried, broken in pieces, and burnt in a lime-kiln to remove all the carbonic acid. The mass, now in the form of a fine powder, is ready for the market, and is known in commerce as a grey, or green-grey, sandy, palpable powder.

This cement was manufactured by Paisley in 1826 by burning river mud from the Medway, impregnated with the salts from the sea water, with lime-stone or chalk, and at the present the mud from the mouths and delta formations of several large rivers is employed in the preparation of this cement.

In the manufacture of Portland cement the following mode is generally followed. The raw materials, limestone and clay or mud in equal quantities, are intimately mixed; the mixture dried in the air, and then burnt in a shaft oven, such as is used in burning the lime, which has already been spoken of. The oven is so arranged that a layer of cement stone and a layer of fuel alternate; the fuel being generally coke, as this has been found by experience to be the best adapted for the purpose. After the mass has been submitted to a red heat for one hour it assumes a yellow-brown color, and at a higher temperature becomes a dark brown. Gradually the lime enters more and more into chemical combination with the silicates, at a white heat or at a temperature of about 1600° C; the mass becomes grey in color with a streak here and there of green. If during the operation of burning, these colors are shown at the several stages, the resulting cement will be good and set hard. If the heating is continued above the white heat or 1600° C, the cement will become quite useless and is very similar to glass-powder.

The more lime the mixture contains the more durable is the cement, and the less it falls to pieces in burning, while a cement with clay predominating is a weak cement, falling in pieces readily or not binding well.

The more intimately the clay and lime are mixed the larger the amount of lime that can be incorporated, and hence the better the resulting cement.

The cement, if set in air, exhibits no change from the stiffening until the final hardening, but if in water, there is at first a small loss of the more soluble constituents—the alkalies.

Portland cement mixed with water to a pulp, stiffens in a few minutes, and after the lapse of a day sets tolerably hard. After a month the cement sets into a substance so hard and firm that it emits a sound when struck by a hard body, and has received the name of "artificial stone" from its capability of being cast into various architectural ornaments, etc.

The manufacture of true Portland cement is confined, by letters patent, to England alone, but various kinds of Portlands are manufactured in America, Germany, and other countries; but none of these are as good as the English Portland.

The comparative values of the different cements may be had from their costs, which are as follows :—

English Portland cement...	$2.80	to	$3.25	per bbl. of	400 lbs.
The German Portland......	2.70	to	3 00	" "	" "
Saylor's American cement..	2.50	to	2.75	" "	" "
Rosendale................	1.60	to	1.80	" "	" "
Other U. S. cements.......	1.35	to	1.60	" "	" "

The Portlands are generally sold in barrels of 400 lbs. gross, while the Rosendale and the ordinary United States cements are sold in bbls. of 300 lbs. gross.

Protection from moisture, even that of the air, is very essential for the preservation of cements as well as of quick lime. On this account the barrels are generally lined with stout paper. With this precaution, aided by keeping the barrels stored in a dry place, raised above the ground, the cement, although it may require more time to set, will not otherwise appreciably deteriorate for six months; but after 14 or 16 months, Gillmore says, it is unfit for use in important works. Restoration by reburning may be effected by spreading the injured cement in a thin layer on a red-hot iron plate for about 15 minutes, when its good quality will be in a great measure restored. If it has actually been wet or lumpy, or cemented into a mass, it should first be broken into small pieces and then ground, or these pieces may be first kiln-burned at a bright red heat for about 1½ hours and then ground. A barrel of cement, 300 lbs; and two barrels of sand, mixed with about ½ barrel of water, will make about 8 cub. ft. of mortar, sufficient for :—

192 sq. ft. of mortar-joint	½	inch thick	= 21½	sq. yards.
or, 288 " " "	⅜	" "	= 32	"
or, 384 " " "	¼	" "	= 43⅔	"
or, 768 " " "	⅛	" "	= 85⅓	"

The common (not Portland) cements when used as a mortar for brick work often disfigure it, especially near sea coasts, and in damp climates, by white efflorescences which also injure the bricks. This is usually a hydrous carbonate of soda or of potash, often containing other salts, and as a preventive Gen. Gillmore recommends adding to every 300 lbs. of the cement powder, 100 lbs. of quick lime, and from 8 to 12 lbs. of any cheap animal fat, the fat to be well incorporated with the quick lime before slaking it preparatory to adding it to the cement. This addition will retard the setting and somewhat diminish the strength of the cement.

Color is no indication of strength in hydraulic cements. The finer they are ground, however, the better, and at least 90% should pass through a sieve of 50 meshes per lineal inch or 2,500 meshes per square inch.

The term setting which we have been using does not imply that the cement has hardened to any great extent, but merely that it has ceased to be pasty and has become brittle. Slow setting does not indicate inferiority, for many of the very best are slow setting. The time required to attain the greatest hardness is many years, but after the first year the increase is usually very small and slow, and there seems to be a period (from a few weeks to several months after having been laid) at which the cement and its mortars, for a short time not only cease from hardening, but actually lose strength ; they then recover and the hardening goes on as before.

This phenomenon is rather strange, but is the result of experiment and has been confirmed by good authorities.

The fourth kind of artificial cement is the silicated, and consists of the silicates of potassium or sodium, with lime. It is formed by boiling flint with KOH, under pressure of 70 or 80 lbs, which gives a soluble glass or liquor of flint, and this on evaporation yields a scaly horny mass. When mixed with CaO, it forms a double silicate.

This cement constitutes the class of artificial stones used for mantles, table tops, etc.

Strength of cements. The methods used in testing the cements are as follows :—

(1) Testing their resistance to tension.
(2) Testing their resistance to penetration.

For this purpose the cement is made into blocks about the size of a brick, and for the first test they are drawn apart by a machine ; for the second test the blocks are rested on some stable body and a force is applied to break it in the middle, and the breaking force is recorded.

The strength of the cement is very much affected by the temperature of the air and water, as also by the force with which the cement is pressed into the moulds, and by the extent of setting before being put into the water. These causes, together with the degree of thoroughness of mixing or gauging, the proportion of water used, and other considerations, may easily affect the results 100%, or even more; hence the discrepancies in different experiments. After only 24 hours in water the strength of the common U. S. cements average about half that for 6 days. The London Board of Works require that Portland cement after 7 days in water shall have at least 35 lbs. transverse, and 350 lbs. tensile strength per square inch. Mr. Shedd, as Engineer of the Water Works and Sewers of Providence, R. I., rejected all Rosendale, which when mixed to a stiff paste, and allowed 30 minutes in air to set, and then put into water for only 24 hours, broke with less tension than 70 lbs. The Sewer Department of St. Louis required all Louisville, Kentucky cement to bear at least 40 lbs. tensile, after 24 hours in water. Some of it showed as high as 100 or more, and 60 or 70 would have been adopted as a minimum, but for the fear that it would encourage the making of too quick setting cement. Most of that sold will probably not exceed 30 lbs.

The following is the analysis of two modern cements :—

DESCRIPTION.	LIME.	SiO_2.	Al_2O_3.	Fe_2O_3.	ALKALI.	CLAY & SAND.
Roman cement used in Eddy-stone lighthouse	55	25	8	5	5	2
Portland cement. By Michaelis............	59—62	24—25	6—9	3—5	4—5	1—2

And again the analyses of some very old cements are as follows:—

LOCALITY.	AGE.	CO_2.	CaO.	SiO_2.	SAND.	WATER.	ALKALI.
Brandeburg Cathedral...	600	5.00	8.70	1.25	83.75	1.20	—
St. Peters, Berlin.......	600	1.75	9.25	3.75	78.50	6.75	—
Roman Well at Cologne.	1800	9.00	15.00	.27	68.00	4.00	2.75
Roman Tower at Cologne	1800	12.00	24.00	.25	56.00	5.00	2.75

The hardening of hydraulic mortars has often been the subject of investigation, and is generally considered under two heads; first the mere setting, the congealing of the mass from a fluid state to a moderate degree of hardness; and secondly, their hardening to a stony state. The cements when thus considered are divided into two classes. The first, of which the Roman cement is the type, embraces the mixture of caustic lime with pozzuolana, pulverized tile and brick; and those hydraulic mortars obtained by burning hydraulic lime and marl.

The second class are the Portland cements, these containing no fresh caustic lime.

Collecting the results of all the experiments on the Roman cement, the conclusion is that the setting is due to the combination of acid silicates or silica, with burnt lime, forming a hydrated silicate of lime, intermixed with the alumina and oxide of iron.

The hardening of Portland cements, which is effected by the mixture with water, consists in the hydration of the calcium and aluminum silicates which exist ready formed but anhydrous, in the cement.

Concrete or beton. These terms, by no means originally the same, have become almost strictly so by usage. As generally understood in modern practice, they apply to any mixture of mortar (generally hydraulic) with coarse material, such as gravel, pebbles, shells, or fragments of brick, tile, or stone. More strictly speaking, as originally accepted, the matrix or gangue of the beton possesses hydraulic energy, while that of the concrete does not. Concrete is daily growing into more extensive use and application, for it can be used in almost every combination of circumstances known in practice. It is superior to brick work in strength, durability, and economy, and in some cases is considered a reliable substitute for the best stone.

For submarine masonry concrete possesses the advantage that it may be laid without exhausting the water.

The size of the broken stone for concrete is generally specified not to exceed 2 inches on any edge, but all sizes up to 4 or 5 inches may be used, care being taken that the other ingredients completely fill the voids. The stone is either broken by hand, or by machinery ; and of the latter Blake's Stone Crusher is generally used. It will break from 6 to 7 cubic feet per hour.

The cement used should be slow setting, especially when the concrete is to be rammed.

The mixing of the concrete is effected by hand and by machinery ; if done by hand, the gravel and pebbles are first separated by screening, into different sizes, the concrete is then prepared by spreading out the gravel on a platform of rough boards, in a layer from 8 to 12 inches thick, the smaller pebbles at the bottom and the larger at the top. The mortar is then spread over the gravel as uniformly as possible, the whole is then thoroughly mixed, two turnings sufficing.

The concrete for the New York City docks consisted of 1 part of either English, or Saylor's American cement, 2 of sand, and 5 of broken stone.

That made of English Portland after drying a few days, and then being immersed for six weeks, required about 30 tons per square foot to crush it.

That used in the foundations of the Washington Monument at

Washington, was, English Portland 1 ; sand 2 ; gravel 3 ; and broken stone 4 ; this stood a crushing strength of 155 tons per square foot when 7½ months old.

Some of the concrete of Rosendale cement 1 ; sand 2 ; and broken stone 6 ; had become so hard at the end of a year that to remove some of it they had to drill and blast it.

The strength of concrete is affected by the quality of the broken stone, as well as by that of the cement, the degree of ramming, etc., and at the end of 1 year concrete should stand a crushing strength of 100 tons per square foot. Concrete is used for bringing up an uneven foundation to a level before starting the masonry. It may readily be deposited under water in the usual way of lowering it, soon after it is mixed, in a V shaped box of wood or plate iron, with a lid that may be closed when the box descends.

The consistency and strength of the concrete would of course be impaired by falling through the water from the box, and moreover it cannot be rammed under water without further injury. Still, if good, it will in due time become sufficiently strong for engineering purposes. Concrete in this way has been deposited a distance of 50 feet. The area upon which it is deposited must previously be surrounded by some kind of enclosure, to prevent the concrete from spreading beyond its proper limits, and to serve as a mould to give it its proper shape. This will usually be a close crib of timber or plate iron, without a bottom, and will remain after the work is done.

The concrete should extend out from 2 to 5 ft. beyond the base of the masonry and the soft mud should be removed before depositing the concrete. It has been used in very large masses ; as in the foundation of a graving dock at Toulon, France ; where it was deposited to a thickness of 15 feet over an area of 400 ft. by 100 ft., forming as it were, a single artificial stone of that size.

When concrete is deposited under water, especially in the sea. a pulpy, gelatinous fluid is washed from the cement, and rises to the surface. This causes the water to assume a milky hue, hence the term "Laitance," applied by French Engineers. When this precipitate forms on the cement it prevents it from setting properly, thus lessening the strength of the mass. It is usually removed from the enclosed space by pumps, and is supposed to be caused by the magnesia contained in the water.

The weight of good concrete is 130 to 160 lbs. per cubic foot dry, and it costs from $5 to $9 per cubic yard if roughly deposited, and from $9 to $15 if first made into blocks, depending on locality, size of blocks and quality of cement used.

A. L. McCulloch.

RAILWAY SURVEYS.

A SHORT DESCRIPTION OF THE WAY IN WHICH THE WORK IS DONE IN THE FIELD.

Mr. President and Gentlemen:

The object the writer has in view in this paper, is the presentation of the subject of railway location in a concise form, so as to give Engineers who have had no experience in this branch of the profession, an idea of how the work is actually done in the "field."

The subject then will not be taken up at the conception of the scheme; but at the time when the location Engineer receives instructions to locate the road.

These instructions will include a description of the general routes; a list of the places to be touched by the line; the maximum limit for curves, and for grades, and other instructions of a similar nature.

The first thing to be done is to examine the ground carefully. This is done by the Engineer in charge, who usually walks over the ground examining the different *possible* routes,—comparing one with another. Usually some of the routes have some very evident disadvantages when compared with the others, so that they can be abandoned; thereby saving the expense of running a line over them.

The work is now ready for the "party" to commence the "preliminary line."

Before describing the "preliminary line work," it may be well to say a few words about the "party."

The party, as it is generally organized, comprises—The Engineer in charge; the transit-man; two chainmen; one forepicket-man; one back picket-man; an axeman for making "Station-stakes," "Hubs," and "Hub-stakes,"—and from two to five or six axemen (depending on the nature of the country) to chop out the line. This completes the "transit party." Next is the levelling party—composed of a leveller, a rod-man, and an axeman—where sections are taken by the leveller; but when there is a topographer along with the party, he has this last axeman to assist in measurements, etc., required in taking sections.

The Preliminary Survey is now commenced. The Engineer in charge being acquainted with the ground, knows approximately where the 'location line" will be. His object is, then, to get the preliminary line as near as possible to this place. To accomplish this, he directs the transit man in what ever way may be necessary. If the country is flat, a general bearing is given; if it is undulating, and not covered with bush, the line is run from point to point, as they appear, or if the country is both rough and covered with bush, the Engineer in charge stays right ahead of the transit party giving directions as he sees fit. On side-hill work, and where it is evident that nearly a maximum grade will have to be used, the position of the preliminary line is determined by knowing the elevations of the stations, and allowing for the change in elevation due to grade. In this way it can easily be determined whether the preliminary line is above or below, where the location will be—by the grade assumed. These elevations are given by the levelling party, keeping close to the transit party.

Stakes are set on these lines one hundred feet apart, each hundred feet being called a "station," and on each stake is written the number of the station it belongs to. At angles, and wherever else necessary, "hubs" are driven and centered with tacks. "Hub-stakes" are placed a couple of feet to the left of the "hubs." On each "hub-stake" is marked the "plus" to the hub—and the number of the station stake, immediately preceding it. The chainage is continuous.

Closely following the transit party is the levelling party, taking the elevation of every station, and of as many "plusses," as are necessary to give a correct profile; and a few B.M.'s are also established to check the location levels.

Next comes the topographer, who with a hand level takes cross-sections, both to the right and to the left, as close together as is necessary to give every change in the ground, and long enough to include the limits of the proposed location line. After the ground has been gone over in this way, the next step is to plot the work.

The alignment is plotted on some convenient scale for working from. The closeness of the contours and the nature of the work determine the scale, frequently it is as large as $100' = 1''$, and varies to $400' = 1''$.

The levels are plotted on profile paper, and the cross-sections, on cross-section paper.

The next step is to put the contour lines that come within the limits of the cross-section, on the plan. Given for example that the contours are to be traced for each even five feet of elevation from datum.

Look along the ground line of the plotted cross-section and note where it intersects with the horizontal line on the cross-section paper, indicating the elevation of the contour under consideration; find the distance this point is from the centre line (from which the section was taken) and plot its position on the plan. Do this for as many sections as are intersected by the given contour. Now draw a line through these points, and this line will be the contour required. In a similar way the other contour lines are determined and plotted.

The next step is to place the location line on the plan.

The plan, with the preliminary alignment and the contours, now presents very plainly all the information taken in the preliminary survey, making the work of placing the location line comparatively easy.

Usually there are points which determine the position of the "location line" at certain places, such as river crossings, prominent bluffs, etc.

Now let us consider the location of the line between two of such points.

By examining the contours on the plan, and scaling the distance between the points, the minimum grade can be found.

Then, if possible, "sustaining ground" is found for this minimum-grade line; that is the line is so adjusted (on the plan), and such curves introduced that will make the ground line coincide as nearly as possible with the grade line as above determined.

This will in most cases introduce too much curvature, and generally on the other hand, by making the line straight, the cost of construction would be too great. To find a proper mean between these two extremes, is the problem that presents itself to every location Engineer.

The cost of operation of the road is increased by the curves and the grades. Experiments have been made to determine the resistance due to each kind of curvature, (*i.e.* 1° curve—2° etc.), and also due to grades.

This resistance requires the expenditure of more power to overcome it, therefore more expense. Also, there is more wear and tear on a curve than on a straight line. By determining this increase in cost of operation for a prospective traffic for one year, and by considering this amount as interest on a certain principal, the location Engineer knows how much more cutting or filling he can take (at a certain price per cub. yd.) in making improvements in alignment or in grades, and still have the saving in cost of operation equal to the interest on the increased cost of construction. In this way he determines the amount of curvature that it is wise to introduce. A trial location line is placed on the plan with the curves traced in; the stations are called off, then the elevations of the stations are taken from the contour lines, and a profile plotted. Then the grade lines are put on the profile, showing the amount of "cut" and "fill."

The effect of any change in lessening the curvature, or easing the grades by changing the location, is now considered, and an estimate made of the cost of the road (if required to compare with another proposed location or for any other reason). Some of the advantages of the [illegible] m of location by contours are very apparent from the foregoing; for a very close estimate can be made for any location line within the limit of the cross sections in the above way. The profiles made from the plan and contours compare very closely indeed with the one made from the level notes taken after the line has been finally run in.

After a line has been decided on from the notes on the plan, all that remains to be done is to trace it out on the ground.

Notes are taken from the plan showing the relative position of the location line compared with the plotted preliminary line; and then by using these notes, and the preliminary line on the ground, the location line is easily established. Then the levels are taken—"bench marks" established—plans and profiles plotted—and the work of location is finished.

A. R. RAYMER.

PETROLEUM.

Mr. President and Gentlemen:

This is essentially the age of progress. The arts and sciences have made wonderful advancement within the present century. Many newly discovered, or at least recently developed agencies, have been at work revolutionizing the old methods of manufacture, and rendering new and improved methods possible.

Among the foremost of these agencies is Petroleum, which within the last thirty years has brought cheerfulness and comfort into millions of homes throughout the world.

The name Petroleum, is a combination of two Latin words "petra" a rock and "oleum" oil, thus showing its source and character. The oil is not found everywhere on the globe, but seems to be confined to certain localities, the principal of which are in western Pennsylvania, and at Baku, Russia.

From wells in Sicily and in Burmah, the ancients used to obtain an oil which they burned in their lamps; but it is only recently that the trade has been fully developed. The oil is generally found by boring in beds of sand-stone at a great depth, where the oil, often accompanied by an inflammable gas, is under a pressure so great as to force it up through the bored hole, throwing the boring tools high into the air.

Generally where we find oil, strata of coal are also found, only at a higher level. Very often, as in Pennsylvania, the oil bearing strata have a decided dip in the same general direction.

Among many theories as to the origin of petroleum, the two following seemed to be the best supported by known facts:

1st. The oil has been formed by distillation from bitum nous coal by the action of great heat and pressure. In support of this theory is the fact that crude Petroleum can be made by distilling coal in iron vessels made for the purpose; and indeed this was done to a considerable extent before the great oil fields were discovered a few years ago; hence, the name "coal oil," was first given to the product. This theory would make it appear that the oil was formed in the strata of coal, and from them found its way to the strata of sandstone, or occasionally imestone, which, owing to their porous nature, caught and held the oil.

The second theory supposes that the oil was formed in the same strata in which it is found, by the action of great heat and pressure upon the sea-weeds and animal remains of which the rock was partly composed. The fossil remains found in the rocks, together with the fact (as I understand), that Petroleum can be formed from similar plants and animals to-day, are the arguments in favor of this theory.

Until the middle of this century, oil had been found on the water near springs at Seneca Lake, and at many other places, but in small quantities. In the year 1859, Col. E. L. Drake, tried to reach the oil by boring near Titusville, New York State, and at 70 feet he struck a rich vein from which was taken the first of the many millions of barrels which the great Pennsylvania oil region has supplied. Before a year had passed, 2000 wells are said to have been started, which number by 1885 had increased to 42,500.

The cost of a well is considerable :—$25,000 to $50,000 for the land, and also another $4,000 to $8,000 for the hole alone, besides other expenses, and then no oil may be struck. Previous to the sinking of a well, a tall frame-work derrick is erected upon a strong foundation of hewn logs; everything must be strong and solid to resist the great strain. The derrick is about 20 ft. square at the bottom, and 4 ft. square at the crown-block, the topmost part. The height is about 80 ft. The whole structure is built up piece by piece, and strongly braced, the corner posts being made of 2 inch hemlock planks spiked together at the edges, trough-shape, with the open part turned inside. Through the centre of the crown-block, a heavy square piece of timber, a hole is cut in which is fitted a small wheel, over which the heavy 2 inch rope used in drilling is run. A ladder is built up one side of the derrick, a floor is laid sloping to two sides from the middle to let water run off. In the centre of this where the well is tobe bored, a hole is left. On one side of the derrick are fixed the bull-wheels, two great wooden wheels on each end of a heavy windlass, upon which is wound the drill cable.

Upon a heavy post firmly braced, the walking-beam works. The inside end of which is directly over the hole in the centre, while the other end is connected by a pitman with a crank attached to the drive-wheel. This is connected with the engine by a belt, and with the bull-wheel by what is called the bull-rope. A small line run through a pulley near the top of the derrick is wound around the sand reel, which may be connected with the drive-wheel by friction gearing.

The drill itself, is made up of several pieces.

The rope-socket, to which the drill cable is made fast, is two or three feet long. Into the lower end of this is screwed the sinker-bar, a round iron or steel bar about 4 inches in diameter, and 12 to 14 feet long. Into the lower end of this go the jars, two strong steel links made to slide within each other like the links of a chain. The jars are about 7 ft. long when closed, and about 2 ft. longer when drawn out. Below these the auger stem, the longest and heaviest part is fastened. It is very much like the sinker-bar, but is from 35 to 40 feet long. Into the lower end of the auger stem is screwed the last piece, the bit. This is the part which cuts and breaks the hole down through the rock. It is 4 ft. long, the same thickness at the upper end as the auger-stem, but broadened and flattened toward the lower end ; about 4 inches thick, and from 4½ to 13 inches wide.

With all pieces screwed together, the drill is 65 to 70 ft. long, as firm and rigid as one piece, and weighs from 3000 to 3,500 lbs.

Besides the drilling tools there are the sand pump, the boiler and the fishing tools.

The machinery, and the lower part of the derrick are generally housed in, as work is to be carried on night and day, winter and summer.

Four men make up an oil-well "crew,"—two drillers, and two tool dressers, but only two (a driller and a tool dresser) work at a time. The day is divided into two " tours," of 12 hours each. From midnight till noon, is the morning tour ; and from noon till midnight, the afternoon tour.

The upper part of the well, say for 80 to 100 feet, is "spudded" down. A wooden conductor, or iron drive pipe is put down through the loose earth, to the first bed of rock. A short heavy spudding-bit is used instead of the long drill. And as the walking-beam cannot be used yet, a jerk-rope is fastened around the cable above the spudding-bit, and the end made fast to the crank, from which the pitman is removed. As each turn of the drive-wheel first tightens then slackens the jerk rope, the spudding-bit is raised and let fall heavily to the bottom of the hole, to cut and break the rock at each blow.

When sufficient depth is drilled in this way, to admit of the use of the long drill in connection with the walking-beam, the spudding is stopped, and the regular drilling commenced. The long drill with its parts screwed very tight together is swung over the hole and lowered into it. Then when all is clear, the brake is thrown off the bull-wheel, and the heavy drill drops down, each moment increasing its speed, until it is near the bottom, when the driller applying the brake slows it up before it strikes bottom. From a great iron hook fastened to the inside end of the walking-beam, hangs the " temper-screw," a heavy screw, four or five feet long, set in a strong steel frame ; while attached to this, below, are the clamps, two iron blocks or jaws hinged together, so that they can be opened and closed. The driller puts the clamps around the cable and screws them up tight so that it cannot slip. He then pulls two or three coils from the bull-wheel, which leaves the cable swinging loose above the clamps.

As soon as the other end of the walking-beam has been fastened to the crank by the pitman, the engine is started by a pull on one of the cords, running to the engine-house. As the inner end of the walking-beam flies up, it raises the drill a couple of feet, and on coming down the heavy drill drops back, cutting, or rather breaking and crushing through the rock.

In this way 40 or 50 blows are given every minute, and as the old proverb says, "constant dropping wears away the rock."

During this work the driller keeps turning the temper-screw above the clamps, thus gradually lowering and turning the drill in the hole, until it has been lowered the length of the screw, or as the driller says "one bit." It is by these "bits" they measure roughly the distance drilled through a certain rock, or during one tour.

The next thing is to get out of the hole the little pieces of rock just cut by the bit.

A pull of the cord stops the engine; the clamps are unfastened; the engine is again started, and the bull-rope from the drive-wheel turns the bull-wheel (which has been thrown into gear), thus winding up the cable and pulling the drill out of the hole. A long iron bucket with a valve, which opens to let in the muddy material at the bottom of the well, is now lowered by a light line called the sand line. When this sand pump, as it is called, is lifted again, the valve at the bottom closes, and the wet material is lifted out.

If the bit is much worn, it is removed from the drill, and a sharp one put in its place, and the whole thing lowered into the hole once more. The long screw is pushed up into the frame again, the clamps are put around the cable, and the drilling is resumed.

The tool dresser now attends to the engine and to sharpening the worn bit.

Water is always kept in the well when drilling is going on, to soften the rock and keep the loose material in a thin muddy state; but sometimes as the hole goes down through the rock, streams of water are tapped, which flood the hole often to overflowing. This greatly interferes with the drilling, as the water tends to bury up the drill and prevent it from striking as hard a blow on the rock as it would otherwise do. A heavy bucket like the sand pump, only much longer, called the bailer, is sometimes used to free the hole from water, but this cannot be done where there is a big flow. In that case it is necessary to put large iron-pipe casings in the well down to a point below where the water comes in, and thus shut it out. The separate pieces are screwed together at the ends as length after length is lowered, and when they are in the well, they form a continuous water-tight iron lining. If water is met with at different levels, smaller casings must be successively lowered inside of those already in place to stop the new leaks as the work goes on. Sometimes three, or rarely four strings of casings are needed in the one well.

One great difficulty in drilling wells is in tools breaking or coming loose while in the well. These parts have to be fished for, and thus a great deal of time and sometimes the well itself is lost; if the broken part cannot be grappled, and the well has to be abandoned, great loss falls upon the unhappy contractor.

In some instances the desperate effort has been made to drill past the broken tools; an effort which has occasionally been crowned with the success it deserved.

If a well has to be abandoned, the casing is first taken up if possible, and the derrick is then torn down and removed to another place. Suppose, however, that all has gone well, and the oil sand is at length reached, the boiler and forge are removed to a safe distance and all night-work is stopped, as there must be no lights burning near the well. Word is sent for the tank builder, and in an astonishingly short time a large tank with a capacity of several hundred barrels is built.

By certain signs the driller can tell about how fast the oil is rising in the well. The drill is drawn out and hastily swung aside. The driller, who has been listening over the hole, suddenly tells all to run back to the engine house, and he himself starts. Then comes the oil bubbling and boiling over the mouth of the well; up it goes, each spurt sending it higher and higher, a great fountain of golden-colored oil flooding everything. Still it rises—half-way up the derrick—a rush and roar up to the top of the derrick and out through it, and away above it, it breaks into drops, the spray falling back a golden shower in the bright sun-light. It soon declines, however, and in a short time the derrick is left dripping while the oil flows in a steady stream out of the ground. A large pipe is quickly run from the mouth of the well to the tank, and all the oil that comes now is saved.

Pipes are laid from a great many surrounding oil wells to the large tanks in the valley, which have a capacity of about 35,000 barrels each. These tanks are generally owned by some transportation company, which sees to the transportation of the oil either by rail or by immense lines of pipes.

Arrived at the refinery, the oil is allowed to stand in great tanks until the water, sand, etc., which have come from the well with it, have settled to the bottom. The oil is then distilled by boiling it in great iron stills.

In this process the vapors arising from the boiling mass, are condensed in the long crooked iron pipe, "the worm," and the distilled liquid is collected, while a thick black substance is left in the bottom of the stills. Sulphuric acid, caustic, soda and other chemicals, are added to the former.

and the distillation repeated several times, until the different products are thoroughly separated.

The principal of these is "kerosene" (coal oil), used so extensively for illuminating purposes. Then there is "gasoline," a fluid used instead of coal in the manufacture of gas for public and private use; generally for the latter.

There is also "naphtha," an exceedingly inflammable gas. This, if mixed with kerosene, causes it to catch fire very easily, and often explode, resulting in great damage.

Another product is rhigolene, an exceedingly light volatile fluid, used sometimes to prevent pain in surgical operations.

Besides these, are mineral sperm oil, several lubricating oils and paraffins.

Lastly, the thick tarry residuum also has its uses.

There are many interesting things connected with Petroleum that might be dwelt upon, such as the natural gas that accompanies it; the subject of blasting wells, and the further treatment of the transportation of the oil, etc., but the time allotted for this paper will not allow of their discussion.

W. J. WITHROW.

Notes on Iron Bridge Building.

Mr. President and Gentlemen :—

Though the limits of the present paper will not allow the writer to enter fully into the details of this important branch of engineering, he yet hopes that he may give some insight into the method adopted in bridge works in carrying on their operations.

Iron bridge building is properly classed under mechanical engineering. Besides designing bridges, viaducts, roofs and floors for buildings, etc., the bridge engineer must be able to plan the works, including machinery, which may be required for the making of any extraordinary piece of work.

Economy of construction in the shop, and facility of erection in the field, are the two most important considerations to be kept in view in getting up the plans for a structure. Of two bridges built to suit the same strains, one may be very much cheaper than the other, the difference being due to the style of the bridge and to the manner of making joints and connections. From practical considerations, bridge engineers have almost unanimously concluded that the most economical designs for various lengths, for R.R. bridges, are as under.

Spans up to 16 feet	Rolled beams.
" 16 to 60 "	Rivetted plate girders.
" 60 to 90 "	Rivetted lattice girders.
" over 90 "	Pin connected trusses.

Let us suppose, now, that a R. R. Company or some corporation require a bridge. Their engineer communicates with various bridge companies, sending them a copy of their specifications and the length of the span, asking for tenders accompanied by general plans and strain diagrams. These plans are examined by the R. R. company's consulting engineer, and the contract awarded according to his decision.

Very often the tender is for a lump sum, but sometimes at so much per pound. The latter is the better, since it does not create a tendency on the part of the contractors to " skin " the work.

Working drawings for the shop must now be made. These are generally drawn to a scale of $1\frac{1}{2}$ or 1 inch to the foot, or sometimes even full size for joints. Though they are drawn to scale, every dimension must be figured on the drawing, and repetition is by no means a fault. In some offices the drawings are made on white paper, and then traced so as to be capable of reproduction by blue printing; in others they are made directly on the tracing linen, on the unglazed side, a stout variety of which is made expressly for the purpose. Construction lines are drawn in with red ink, all others with India ink, and should be firm and black, no shade lines being used. Red ink takes very faintly on the blue print. The tracing is placed on file in the office, and the blue print sent to the shop.

It first goes into the template maker's hands who reproduces the structure exactly in wood, though the different pieces are not fastened together, but are made so as to be used in marking off the metal.

Wherever a rivet is to go a $\frac{3}{4}''$ hole is bored in template. In marking off the iron, these templates are simply clamped to the metal, the punch inserted into each hole where it is made to fit exactly, and slightly tapped with a hammer. A little mark is left which serves as a perfect guide in punching the holes.

When all the pieces are punched and cut to the right lengths, they are assembled together with bolts of sufficient number to hold them, and then brought to the rivetting machine. Machine driven rivets are always preferable to hand driven, and for this reason all rivets should be spaced far enough away from the backs of L's, T's, etc., to allow the jaws of the rivetter sufficient room.

After the work is all rivetted up, it is cleaned of scales, rust, etc., with a stiff brush, and then given first a coat of linseed oil, and next one of brown iron ochre paint. The different pieces are then marked so that when they are brought to the field they may be readily picked out.

The buyers generally send a man to inspect the work as it is being made. He must see that the rivets are well driven (sometimes they are quite loose and with imperfect heads, due to the jaws of the rivetter not being kept in good repair), that the pieces are of the dimensions called for in the drawings, and of the right length so as to cause no undue straining in the field, when the structure is being erected; that they are well and truly made, without warps, bends, etc., and that the iron used comes up to the requirements of the specifications. The following are among the chief requisites for good bridge iron, taken from Theodore Cooper's specifications for iron bridges :—

All wrought iron should be tough, fibrous and uniform in character, and should have a limit of elasticity of at least 26,000 lbs per square inch.

Finished bars must be thoroughly welded during the rolling, and be free from injurious seams, blisters, buckles, cinder spots, or imperfect edges.

For all tension members the bars should stand the following tests:

Full sized pieces, flat, round or square, not over $4\frac{1}{2}$ sq. in. sectional area, should have an ultimate strength of 48,000 lbs. per sq. in., and stretch

$12\frac{1}{2}$ per cent. Bars greater than $4\frac{1}{2}$ sq. in. sectional area, when tested in the usual way, will be allowed a reduction of 1,000 lbs. per sq. in. for each additional square inch of section down to a minimum of 46,000 lbs. per sq. in.

When tested in specimens of uniform sectional area of at least $\frac{1}{2}$ sq. in. for a distance of 10″, taken from the tension members which have been rolled to a section not more than $4\frac{1}{2}$ sq. in., the iron should not break at less than 50,000 per. sq. in., and stretch 18 per cent. in 8″. Specimens taken from bars of a larger cross section than $4\frac{1}{2}$ sq. in. will be allowed a reduction of 500 pounds for each additional square inch of section, down to a minimum of 48,000 lbs.

The same sized specimens taken from angle and other shaped iron shall have an ultimate strength of 48,000 lbs. per sq. in., and elongate 15 per cent. in 8″.

The same sized specimens taken from plates less than 24 inches in width, shall have an ultimate strength of 48,000 lbs. per sq. in., and elongate 15 per cent. in 8″.

The same sized specimens taken from plates exceeding 24 inches in width, shall have an ultimate strength of 46,000 lbs. per sq. in., and elongate 10 per cent. in 8″.

All iron for tension members must bend cold, for about 90°, to a curve whose diameter is not over twice the thickness of the piece, without cracking. At least one sample in three must bend 180° to this curve without cracking.

When nicked on one side and bent by a blow from a sledge, the fracture must be nearly all fibrous, showing but few crystalline specks

Specimens from angle, plate and shaped iron, must stand bending cold through 90°, and to a curve whose diameter is not over three times its thickness without cracking. When nicked or bent its fracture must be mostly fibrous.

Rivets shall be made from the best double refined iron.

Of late years steel has been considerably used in bridges. At present, however, the opinion of leading professional men is averse to using it altogether in place of iron, preferring the less strong but better known metal for the tension members, or those subjected to alternating stress, and using steel only in compression members and in webs of plate girders.

Steel may vary very much in character, and different specifications call for different standards. Below is given the specification for steel for the Harlem River bridge.

1. The steel shall be uniform in character for each specified kind. The plates, finished bars, and shapes must be free from cracks on the faces or corners, and have clean smooth surfaces.

2. All steel for the arch ribs, girders and tension rods, shall have an ultimate strength of 62,000 or 70,000 lbs. per sq. in., with an elastic limit of not less than 32,000 lbs. per sq. in., and a minimum elongation of 18 per cent., when measured on an original length of 8 inches.

3. All steel for rivets shall have an ultimate strength per sq. in. of 56,000 to 64,000 lbs., with a minimum elongation of 25 per cent.

4. Tests shall be made by samples cut from the finished material after rolling. The samples to be at least 12 inches long, and to have a uniform sectional area of not less than $\frac{1}{2}$ sq. in. All the samples must shew uniform, fine-grained fractures of a blue steel-grey color, entirely free from fiery lustre, or a blackish cast.

5. Samples cut from finished materials for the arched ribs, girders, or tension members, tested before or after heating to a low cherry red, and cooled in water at 82° Fah. must stand bending to a curve, whose inner radius is $1\frac{1}{2}$ times the thickness of the sample, without cracking. Samples of rivet steel, before and after being heated to a light-yellow heat, and quenched in cold water, must stand closing solidly together without sign of fracture. To check the uniformity of the material, the manufacturer of the ingots shall cause to be made from each cast sample bars of $\frac{3}{4}$ in. round, with a definite and uniform reduction equivalent to reducing a 4″ ingot to the sample size. They shall mark the same in a manner to identify the final product.

6. The usual chemical tests shall be furnished in connection with these samples.

7. No work must be put upon any steel at or near the blue temperature, or between that of boiling water and the ignition of hard-wood sawdust.

8. Any steel straightened or worked cold by use of the hammer or gag press, must be afterwards wholly unnealed.

Below are given the results of some tests made on 50,000 lb testing machine of the Passaic Rolling Mill Co., and also one made on full sized Eye-bar, on Fairbanks large 200,000 lb. machine.

E. W. STERN.

WROUGHT IRON.

Tested For.	Date.	Specimen.	Mark.	Size Inches.	Area in Square Inches.	Broke at Pounds.	Strain per Sq. Inch in Pounds.	Limit of Elasticity in Pounds.	Limit of Elasticity perSq. Inch in Pounds.	Elongation in 8 Inches.	Elongation Per cent. of Length.	Area of Reduced Section in Sq. In.	Per cent. of Reduction.	Test Made by.	Remarks.
	Jan. 3rd	$\angle 5 \times 3\frac{1}{2} \times \frac{7}{16}''$...	1	0.994 .585	.5815	29000	49870	16000	27500	1.60	20	.449	22.7	McKee..	All fibrous
	" "	9″ [Web......	2	.315 1.003	.3160	16000	50630	9800	30800	1.95	$24\frac{3}{8}$	.213	32.5	"	"
	" "	15″ [Flange....	3	.580 .997	.5782	30200	51430	17000	29400	1.60	20	.367	36.0	"	"
	" "	15 [Web......	4	.540 1.000	.5400	27000	50000	16000	29500	2.10	$26\frac{1}{4}$	.337	37.0	"	"
	" "	$10\frac{1}{2}''$ [Flange..	5	.342 .995	.3403	17800	52400	11000	32320	1.60	20	.267	22.0	"	"

MILD STEEL.

Tested For.	Date.	Specimen.	Mark.	Size Inches.	Area in Square Inches.	Broke at Pounds.	Strain per Sq. Inch in Pounds.	Limit of Elasticity in Pounds.	Limit of Elasticity perSq. Inch in Pounds.	Elongation in 2 Inches.	Elongation Per cent. of Length.	Area of Reduced Section in Sq. In.	Per cent. of Reduction.	Test Made by	Remarks.
	Jan. 16th	Boiler Plate...	37	.496 .996	.494	29550	59800	18600	37600	.78	39	.212	57	St. J. C.	
	" "	" "	38	.483 .993	.480	28700	59800	17900	37300	.80	40	.222	54	"	
	" "	" "	39	.502 .996	.500	28800	57600	17800	35600	.80	40	.206	59	"	
	" "	" "	40	.491 .996	.489	28700	58700	18100	37000	.83	$41\frac{1}{2}$	.201	59	"	
	" "	" "	41	.499 .995	.497	29550	59500	18100	36400	.81	$40\frac{1}{2}$	.220	56	"	
			42	.495 .996	.493	28950	58700	18000	36500	.87	$43\frac{1}{2}$	.196	60	"	

REPORT OF TESTS MADE ON FULL SIZED SPECIMENS.

		Material	Wrought Iron.	
		Mark	A.	
		Test No.	3872	
		Shape Original	Eye-Bar.	
		Shape of Test piece	Full Size.	
Dimensions.	Original.	Length in feet	17.13	Under Gauge 15 ft.
		Dimensions in ins	3.990	
		Thickness in ins	.873	
		Area in sq. ins	3.483	
	Final.	Length in feet	16.81	
		Dimensions in ins	3.345	
		Thickness in ins	.625	
		Area in sq. ins	2.091	
		Per cent. Elongation	12.07	
		Per cent. Reduction	39.97	
Stress in lbs. Tension.	On Spec.	Elastic Limit	96000	
		Maximum	159680	
	Per sq. in.	Elastic Limit	27562	
		Maximum	45846	
		Fracture	Fibrous.	

REMARKS.

Pin holes 3.50A, 4.90B. Sides of eyes 3.34A, 3.405A, 2.990B, 3.065B. Backs of eyes 3.525A, 3.205B. Elongation .18A, .34B. Thickness of metal around eyes .855, .923. Bar broke in body 19½″ from B end.

ANGLE BLOCKS.

Mr. President and Gentlemen,—

The shape of the angle blocks and the length of the braces for a Howe truss may be determined either graphically or analytically. The first method appears to the writer to be by far the most useful, being the quickest and least liable to error. The method used on the C. P. R., as seen in Fig. 2, was as follows :—

First plot the panel, AD being the distance between the upper and lower chords, and AB the distance between the centres of the vertical rods. The larger the scale of this panel the better. One foot to the inch answers well. Then cut two right angled set squares "E"—paper does well—and graduate them by the assumed scale. Now, if the width of the brace is, as in this case, twelve inches, all that is necessary is to place the two set squares closely against the T square and shift until the zero mark and twelve inch mark of both set squares are in contact with the edges of the panel. We have now got the position and length of the longest brace of the given breadth that can be inserted in the parallelogram ABCD, and we have merely to scale off the length of the brace and the size of the angle block necessary to support it. These last dimensions should be noted on a rough sketch (as G) for future reference.

It is often required that all of the braces of a Howe Truss shall be of the same length, but as the braces are not all of the same width there is some doubt as to the size of the angle blocks, which must all be of the same height and have the same inclination towards their base. For instance, suppose we find the angle block for the widest brace, then for narrower braces the blocks are merely cut off, but some engineers object to this plan because the brace does not touch the chords and consequently is more liable to slip. Others go to the opposite extreme and design the block for the narrowest brace and let the wider braces butt against the chords. A course intermediate between these two is probably the best.

Of the analytical solutions, none that I have seen appear worthy of replacing the graphical method. I will, however, indicate the simplest method that I have come across, lest some of you should waste your office hours, as I did, in trying to find a simple solution, when old engineers say there is none.

Prof. P. H. Philbrick published the following solution in the May number of *Van Nostrands* in 1881 :—

Let ABCD Fig. 3 be the shape of the panel and FGNM be the brace, the length of which is required.

Let $a = \frac{1}{2}$ width of panel given.
$b = \frac{1}{2}$ length of panel given.
α = angle BOE given.
$FG = 2c$ = breadth of brace given.
$b = \frac{1}{2}$ length of brace required.
γ = angle HOE = angle BFG required.

$$\sin^2\gamma + \cos^2\gamma = 1 \qquad (1)$$

$$\frac{\cos\gamma}{\sin\gamma} = \frac{b - c\sin\gamma}{a - c\cos\gamma} \qquad (2)$$

Now by putting α for γ in (2) and combining with (1) he gets

$$\cos\gamma = \frac{b - c\sin\alpha}{\sqrt{(a - c\cos\alpha)^2 + (b - c\sin\alpha)^2}}$$

and

$$\sin\gamma = \frac{a - c\cos\alpha}{\sqrt{(a - c\cos\alpha)^2 + (b - c\sin\alpha)^2}}$$

which results are sufficiently accurate.

Having now ascertained the sine and cosine of γ = angle HOE = angle BFG, it is easy enough to find FG and BG.

For $FB = 2c\cos\gamma$
and $BG = 2c\sin\gamma$.

Prof. Philbrick has the following rather long equation for finding the length of the brace or $2l = \sqrt{(a - c\cos\gamma)^2 + (b - c\sin\gamma)^2}$

It seems to me that it would be easier to find $2l$ as follows: It may be seen in Fig. 3 that $FD = \frac{EF}{\sin\gamma}$; that $\frac{c}{x} = \tan\gamma \quad \therefore \quad x = \frac{c}{\tan\gamma}$; and also that $EF = ER - FR = a - 2c\cos\gamma$.

$$\text{Now } l = FD + x = \frac{EF}{\sin\gamma} + \frac{c}{\tan\gamma}.$$

$$= \frac{a - 2c\cos\gamma}{\sin\gamma} + \frac{c}{\tan\gamma}.$$

$$= \frac{a - 2c\cos\gamma + c\cos\gamma}{\sin\gamma}$$

$$= \frac{a - c\cos\gamma}{\sin\gamma}.$$

$$= (a - c\cos\gamma)\operatorname{cosec}\gamma = (a - \frac{FB}{2})\operatorname{cosec}\gamma.$$

and $\therefore 2l = (2a - FB)\operatorname{cosec}\gamma$.

It is easy enough to see that it would be far more troublesome to figure out the values for $\cos\gamma$ and $\sin\gamma$, than it would be to go through the whole graphical process, and would be much harder to check. The easiest check on the graphical method is to find the shape of the block at both ends of the brace at the same time and if these agree the work is correct.

T. K. Thomson.

TRANSITION CURVES.

Mr. President and Gentlemen,—

A Railway Curve, as generally laid out, consists of a curve of uniform curvature connecting two tangents. Where the curvature is slight and speed of trains low, this arrangement does fairly well, but, under different conditions, is very defective. Let us consider the case where a train is approaching a 4° curve at a speed of 40 miles per hour. The engine on reaching the curve presses heavily against the outer rail (unless prevented by some means), tending to spread the track and mount the rail. To counteract this tendency, it is necessary to give the outer rail an elevation of about 4 inches for the gauge of 4′ 8½″. In order, however, to give this elevation at the B. C. it is necessary to begin the elevation on the tangent, some distance back from the B. C. With this arrangement then, either the portion of tangent near the curve, or the portion of curve near the tangent is subject to undue strains since trains in either direction, must press either against outer or inner rail.

These defects may, however, be avoided by the introduction of a curve leaving the tangent some di tance back from circular curve, with slight curvature, which gradually increases until at the point of junction with the circular curve it is approximately the same, the elevation of the outer rail being kept proportional to the curvature.

All such curves are known as "transition curves," and may be divided into two classes, trackmen's curves and calculated curves.

Trackmen's Curves join points each way from ordinary B. C., keeping within the points set by the Engineer, viz.:—centres on the tangent and circle, and are always lined by eye by the trackmen.

There is one defect common to all curves of this class, which is the unavoidable sharpening of the curve at its junction with the circle, and there may also be other errors due to wrong judgment on the part of trackmen.

Calculated curves are of two kinds, parabolic and multiform, compound or spiral.

A Parabolic Transition Curve is an arc of a parabola joining a tangent and a circle, having the end with the least curvature joining the tangent, and the end with the greatest curvature joining the circle with a common tangent, and approximately the same curvature at point of junction.

This curve although theoretically the better one, is seldom used as it does not admit of ready calculation in the field.

The Multiform Compound Curve consists of a number of arcs of circles of equal lengths but increasing degrees of curvature, each pair of arcs having a common tangent at their point of junction. The arc of least curvature joining the tangent and the arc of greatest curvature of approximately the same degree as the circle, and having a common tangent with it at the point of junction. Evidently the best way to regulate these successive changes of curvature from tangent, or 0° curvature, up to the full curvature of circle is to make them all the same. If this difference is made 10 minutes, then the degree of curvature of the first arc will be $0 + 10' = 10'$; that of the second, $10' + 10' = 20'$; that of the third $20' + 10' = 30'$, etc. Now suppose the degree of circular curve decided on to be $1° = 60'$, then evidently the sixth arc will have the same curvature as the circle and will coincide with it. The number of arcs in the transition curve is, therefore, five, similarly with a 2° curve, the twelfth arc would coincide with the circle, and the number of arcs in the transition curve would be 11; and, generally, if m = degree of circle, n the degree of first arc in the transition curve, and t the number of arcs, then $\frac{m}{n} - 1 = t$.

From this it will be seen that the degree of curvature of the $t + 1$ arc determines the number of arcs in the transition curve. With curves of uneven degree, the $t + 1$ arc should fall within, or very close to, the circle.

Thus far the curve has been treated as a multiform compound curve, and if one or more points on each arc, in addition to the compounding points be fixed, the curve must so remain. If, however, the only points fixed are the compounding points, then the curve may very easily be made to assume another and much better form.

This form is shewn in Fig. 4, where TT = tangent; S = beginning of curve; 1, 2, 3 = compounding points: A = compound curve; B = other curve; D = degree of first arc.

The curve instead of starting from the point S with a curvature D, may start from S with less curvature, and gradually increase until it passes through 1 with curvature intermediate between D + 2D; thence without abrupt change, but continuously increasing and passing through 2 with a curvature intermediate between 2D + 3D, &c., &c., these forming a true spiral.

As the track practically assumes this shape when lined by trackmen to centres given as above mentioned, the term "railroad spiral" applied to this curve by some Engineers is quite proper.

It must be kept in mind, however, that the spiral itself is not calculated, but that the calculated curve is a multiform compound curve, through the compounding points of which the spiral is constructed.

The proper elevation of outer rail for any degree of curvature depends on the gauge and speed of trains, and for any other degree (on the same line) the elevation varies directly as the degree. The use of the spiral admits of this condition being fulfilled at all points of curve, as the track may be level on the tangent for its full length, and also the circle may have proper elevation for the full length, without any misproportion in any part of the curve.

The ordinary method of running compound curves is evidently unsuited to the running of a spiral, as it necessitates the setting up of the instrument at each compounding point. It is desirable, however, to adhere to the method of deflection angles and chord measurement, with as few changes of position of the instrument as the nature of the ground will permit. In order, however, to use this method, it will be necessary to calculate special deflection angles for each point.

For purposes of calculation, let us assume the chord length to be 100′, and for the central angle subtending the first chord we will adopt the angle used in practice, viz., 10′. To find the inclination of chords to the primary tangent, suppose the chords on which the spiral is be constructed to be laid down as in Fig. 5.

Let T′T = tangent; S = beginning of spiral; S 1; 1 2; 2 3. = chords; S_1 S_2 S_3 = central angles; S = central angle of spiral = sum of S_1 S_2 S_3. Inclination of S 1 to T T = TS1 = $\frac{1}{2}S_1 = 5'$.

To find the inclination of 2 1, draw through 1 the auxiliary tangent a1b and produce 2 1 to intersect T′T in A. Now the inclination of 2 1 = $TA2 = TS1 + A1S = \frac{1}{2}S_1 + S1a + A1a = \frac{1}{2}S_1 + \frac{1}{2}S_1 + \frac{1}{2}S_2 = S_1 + \frac{1}{2}S_2 = 20'$, similarly by drawing the auxiliary tangent cd, and producing 3 2 to intersect T′T in B, we have the inclination of 3 2 = $TB3 = TA2 + A2B = S_1 + \frac{1}{2}S_2 + A2C + C2B = S_1 + \frac{1}{2}S_2 + \frac{1}{2}S_2 + \frac{1}{2}S_3 = S_1 + S_2 + \frac{1}{2}S_3 = 45'$. And generally, the inclination of any chord to the primary tangent, is equal to the sum of the central angles, subtending all the previous chords plus, ½ the central angle subtending that chord.

INCLINATION.			CO-ORDINATES.				DEFLECTIONS.
POINT.	CHORD.	i = INCLINATION.	100 SIN I	100 COS I	x	y	DEFLECTURE ANGLES INSTRUMENT AT S.
S		0° 0°					0° 00′ 00″
1	S.1	5′	.145	100.	.145	100.	05′ 00″
2	1.2	20′	.582	99.998	.727	199.998	12′ 30″
3	2.3	45′	1.309	99.991	2.036	299.989	23′ 20″
4	3.4	1° 20′	2.327	99.979	4.363	399.968	37′ 30″
&c.							&c.

The inclinations just found are given in the above table under the heading "inclinations."

To find the co-ordinates of extremities of chords. In Fig. 6 let T'T = tangent; a, b, c = chords; 1, 2, 3 = chord extremities; A B = perpendicular to T'T through 3.

Project a b and c on T'T and on A B.

Then evidently $a' = a$ cos inclination.
$b' = b$ " "
$c' = c$ " "
Also $a'' = a$ sin "
$b'' = b$ " "
$c'' = c$ " "
Now $SA = a' + b' + c'$.
And $A3 = a'' + b'' + c''$.

or, in words, the sum of the projections of all chords between any chord extremity and S, is equal to the co-ordinate of that point, when S is the origin of co-ordinates.

In the above diagram with S as origin of co-ordinates, let the distances on ST be y, and distances perpendicular to ST be x. The numerical values of x and y for given points will be found in above table under head "co-ordinates."

To find deflection angles at S. By referring to the last diagram it will be seen that d_1, which is the deflection for the point 1, is the angle 1SA, the tangent of which is $\frac{a''}{a'}$ or $\tan d_1 = \frac{a''}{a'}$. Similarly by joining S2 and S3 $\tan d_2 = \frac{a''+b''}{a'+b'}$ and $\tan d_3 = \frac{a''+b''+c''}{a'+b'+c'}$; and, generally $\tan d = \frac{x}{y}$.

The numerical values corresponding to values of x and y previously found for these points are given in the table above, under heading "deflections."

It may sometimes be necessary, owing to obstacles on the ground, to run part of the spiral from S, and the remainder from some other point. To do so it is necessary to find the auxiliary tangent at that point. It is also necessary, in every case, to find the auxiliary tangent at the point where the spiral joins the circle, in order that the circle may be properly located.

Suppose that it is required to find the auxiliary tangent at point 3, and to make the case general, suppose the backsight to be taken on point 1.

In Fig. 7 let T'T = primary tangent; S = point of spiral: 1, 2, 3 = extremities of chords; AB; CD; = auxiliary tangents; s = sum of central angles, subtending chords up to point 3 = inclination of CD to T'T. E = interstction of AB and CD. Required: Angle C31.

$$
\begin{aligned}
\text{Now angle } C31 &= BE3 - E13. \\
&= CEA - E13. \\
\text{But } CEA &= TC3 - CAE. \\
\text{Therefore } C31 &= TC3 - CAE - E13. \\
&= S - S_1 - E13.
\end{aligned}
$$

This result may be expressed as follows: At any point, the back deflection (or deflection from auxiliary tangent to back point) is equal to the *sum* of the central angles up to the forward point *minus* the sum of the central angles up to back point, *minus* the forward deflection from the back point to the forward point.

Having found the auxiliary tangent the circle may be located in the ordinary manner; or, if the spiral has to be continued farther, the deflections from this auxiliary tangent must be calculated from the inclination of the chords to this tangent as in the case of the primary tangent.

The inclination of the chords to the auxiliary tangent may be found directly from the central angles, as with the primary tangent, or if the inclinations to the primary tangent have already been found, then the inclination of the chord to the primary tangent *minus* the inclination of the auxiliary tangent to the primary tangent, is equal to the inclination of the chord to the auxiliary tangent. Thus far only one way of varying the curvature of the spiral has been shewn, viz. :—by varying its length. A moment's consideration will shew us that this method will not do in practice. Suppose a spiral has to join a 4° curve, then t = no. of chords = $\frac{4^\circ}{10'} - 1 = \frac{240'}{10'} - 1 = 23'$, or length of spiral would be 2,300 feet, a length never desirable and seldom available.

In order that this curve may be of any use in practice, the curvature must vary independently of the length, or in other words, the spiral must be made capable of being constructed on different scales.

Since curvature depends on the relation between an angle at the centre of a curve and the arc or chord subtended by it, it is evident that the curvature may be varied in two ways; either the central angle may be varied, the chord length remaining constant, or the central angle may remain constant and the chord length varied, the curvature varying, practically, inversely as the chord length.

By the first method, since the central angles are varied, therefore, the inclination of the chords and the auxiliary tangents to the primary tangent are also varied, and consequently the deflection angles are varied. By the second method the above mentioned inclinations remain constant, the only variation being the length of chord used.

As it is much easier in practice to vary the length of the chain than to make the calculations which have been shewn necessary to find the deflection angles, the second method is much the better one. It has also these advantages in practice, that the points are comparatively close together (from 10 ft. to 50 ft. apart), and that owing to the shortness of the chords, the available length for the spiral may nearly all be made use of in case curves are close together.

We have just found that when the central angles are kept constant, all the other angles about the spiral are also kept constant, consequently, we may calculate, once for all, and tabulate for each point, all deflections (whether forward or backward) to all other points. Tables so constructed including points from S to 20 will include all cases which will arise in practice, as S at point $20 = 35^\circ$.

As the curvature varies with the length of the chord used, the curvature corresponding to each chord may be calculated for any chord length. Consequently a table may be prepared, containing for each chord length used in practice the corresponding degree of curvature for each chord. In practice the chord length varies from 10 to 50 feet, with intervals of 1 foot.

Let us see what these tables will enable us to do.

Suppose the degree of the circular curve to have been decided on. In the table for chord lengths we will find several chords of different lengths corresponding to a curvature closely approximate to that of the circle, and from these we may select the one of length best suited to our particular case.

Having selected the spiral, the table of deflections will enable us to locate it, provided we know the position of S and the direction of the primary tangent.

The position of S or the distance from the intersection of the primary tangents, depends as with ordinary curves, on the inclination, or intersection angle, and must therefore be calculated for each particular case. It is found by the following method :

In Fig. 8 let T = intersection of primary tangents; R = radius of circle; S = point of spiral; s = central angle of spiral; SL = spiral; O = centre of circle; LH = $\frac{1}{2}$ circular curve; join OT and OL; draw GLI parallel to TS; draw GN; LM; OI perpendicular to TS. Required :—T_s

Then $IOL = S$; $IOT = \frac{1}{2}K$; $OL = R$; $SM = y$; $LM = x$.

Now $T_s = ST = SM + MN + NT$.

But $NT = GN \tan TGN = x \tan \frac{1}{2}K$.

And $MN = GL = OL \dfrac{\sin LOG}{\sin OGI} = R \dfrac{\sin(\frac{1}{2}K - S)}{\cos \frac{1}{2}K}$.

Hence $T_s = y + x \tan \frac{1}{2}K + R \dfrac{\sin(\frac{1}{2}K - S)}{\cos \frac{1}{2}K}$.

As x, y, and S are involved they should also be inserted in the tables, and as they have to be found in order to calculate the tables, no extra calculation is necessary. Tables such as have been here indicated, containing deflections and chord lengths of from 5 to 50 feet, have been prepared, by W. H. Scales, C.E.

FIELD WORK.

In nearly all cases the location of the line may be carried on in the usual way, but before cross-sectioning or construction is commenced the spirals should be located and the necessary changes made in circular parts. The curves should be made to "come out right" even if K and T_s have to be remeasured. The points S and L should next be carefully established or referenced.

As the spiral is constructed on a number of chords of equal length, it must be located irrespective of the regular stations. For convenience when cross-sectioning, however, it is well to have the regular stations located.

When it is necessary to interpolate a station it may be located with sufficient exactness by making the sub-deflection equal to the sub-chord. For general purposes, however, stations may be located by the eye.

When final track centres are given, no points but extremities of chords should be located. The points S and L should be permanently marked by monuments at the side of the track, lettered for future guidance of trackmen, shewing the distance to the centre, and the elevation of rail. If one or two intermediate points were fixed in the same way it would secure a proper adjustment of the track.

J. L. Allison.