Engineering Society.

1885-6.

School of Practical Science,

PROVINCE OF ONTARIO.

TORONTO:
IMRIE & GRAHAM, PRINTERS, 26 AND 28 COLBORNE STREET.
1887.

With compliments of
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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 Tuesday 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, it has been decided to publish annually some of the leading papers contributed during the previous session. The following papers have been selected for publication from among those which had been read up till the end of the academic session, 1885-6. The guiding principle in making the present selection may be briefly explained. In the papers read at the society's meetings originality is not considered a necessary condition. The main object of the paper is served if it furnishes the society with food for discussion, and the writer with experience in the collection of information, and in expressing his ideas with clearness and precision. To make originalty in matter *sine qua non* would practically do harm instead of good. 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.

If the present venture be financially supported by former and present members of the society, it will be followed next year by a similar selection from the papers contributed during the session 1886-7.

In order to keep faith with the gentlemen who have contributed advertisements, an edition of five hundred copies has been printed, which will be widely distributed among Engineers and Surveyors.

The following is a complete list of all the papers which have been read before the society from its foundation up till the end of the session 1885-86.

1884-5.

1885-86.

NOTES

ON THE

FIELD WORK OF RAILROAD CONSTRUCTION.

E. W. STERN.

In treating of this subject, the writer will deal chiefly with the work an Assistant Engineer will be obliged to do on railroad construction, merely pointing out that before the contractors come upon the ground, explorations, preliminary surveys, and finally the location, will already have been made, plans and profiles got out, and all the information gained in these surveys made use of to find the approximate cost of the building of the road, upon the strength of which, money is raised to cover the cost of construction.

Assuming all this done, the construction staff is then placed in the field. The Chief Engineer, who generally has his headquarters at the main offices of the company, has under him several Division or Resident Engineers, who supervise the construction of thirty or forty miles, and who take up their residence at some convenient point close to the centre of their division. Under each of these are three or four assistants, or Section Engineers, who have charge of ten miles or so, and who undertake all the instrumental work, such as cross sectioning, estimates, alignment of track, etc. Each assistant has usually two or three men—a roadman and two axemen. He is generally furnished with an office by the company, and this should, as nearly as possible, be in the centre of his section. We will suppose now that the assistant has been put in charge, and the contractors are on the ground ready to begin work. The first thing to be done is the clearing. This should be staked out by placing stout stakes about 5 ft. long, and blazed on three sides, opposite each station, at the limit of the right-of way, usually 30 or 50 ft. from the centre line, at the same time he should furnish the contractors with a note stating when *close-cutting* and *grubbing* will have to be done, as both these operations are much more easily performed while the clearing is going on, and the tree is standing. This information can readily be gained by inspecting the profile.

Close-Cutting (the cutting down of the tree close to the ground) is necessary where embankments are low, usually four feet and under.

Grubbing (pulling out of the tree by the roots) where the bank is so low that close cutting will not be sufficient. Grubbing is also allowed in low cuttings from 4·2 feet and under.

Slashing should be done at the same time as the clearing. It consists in cutting down all decayed or leaning trees outside the right-of-way allowance, which, if they fall, would fall across the track or break down the fence.

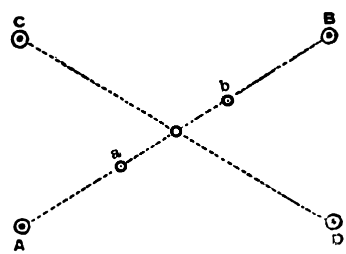
After the clearing, slashing, grubbing, and close-cutting have been done the contractor is ready to commence his earth-work, which must be cross sectioned and staked out beforehand. Before doing this the assistant will require to rerun in the centre line. On the location this is very often done carelessly, and moreover stakes may have been burnt out during the clearing. There should be a stake every 100 ft., and on deep, irregular cuttings, especially on curves, at 50 ft. or even at every 25 ft. Very often on tangents, especially over broken ground, the hubs (*i.e.* points, where, on the location the transit has been set up) which are stout chunks of wood driven into the ground with a tack put in to designate the point are found to be not quite in line. The tacks should be moved over into their correct positions; the same should be done to the "Points on Curves."

Hubs at the beginning, middle, and end of curves, as well as intermediates on long tangents, should be well referenced in, and extra points in the vicinity of important pieces of work such as trestles, culverts, deep cuts, etc., should be put in and referenced.

The most usual, as well as the most exact way of doing this, is by the method of intersections, as follows :—

The transit is set up over the point, say B. C. 2419 + 21, a stump a little inside the edge of the right-of-way chosen, a blaze cut on the face of it, and marked *Ref. Point B. C. 2419+21*, a notch cut in one of the roots and a tack inserted. This being used as a back point, the instrument after being set on it, is reversed, and a point put on another stump if it happens to be in line, or if not, on a hub driven in flush with the ground and marked by a post three feet long, driven well into the ground. The transit is then turned in another direction, nearly at right angles to its former position, and two other points thus placed. Stumps of trees are the best references for points, and should always be chosen when possible. The bearings of each of these lines should be noted. They are useful in finding the hub if the post be knocked out.

In putting in a point from these Reference Hubs, the reverse operation is performed.



Suppose A. B. and C. D. to be the Reference Points. Set up at A. and fix the transit on B.

Now at about two feet on each side of where you think the centre will be, put in two temporary stakes, *a. b.*, leaving them about 6 in. above the ground, and put a tack in each on line, about one-half sticking out. Stretch a thread from *a.* to *b.*, then set up at C., and after clamping on D., line up a picket held truly plumb, keeping it close against the thread *a. b.* The point is thus found.

Occasionally slight mistakes are made on curves during location. The angle of intersection of the tangents should always be checked, and the error, if any, distributed equally around the curve. A two degree curve may thus be made out of a 2°, 01′, or a 1°, 59½′.

Before cross sectioning, check levels should be run across swamps, and such places, where Bench Marks, even if put on stumps, may alter in elevation owing to the ground rising and falling; the writer has found a difference of 0.7 feet in a case where the Bench had been placed but two months before.

A considerable number of forms for cross section books for the field have been recommended by different authors. The subjoined one, although not different in theory from some that have been published, will be found much more compact.

LEFT PAGE. RIGHT PAGE.

Sta.	B. S.	I. S.	F. S.	Elev.	H. I.	Elev. S. G'de	CROSS SECTIONS. Left.	Centre.	Right.
B.M.	2.13			453.00	455.13	level	40′ left 2436 on		Tam. Stump.
2434						25.1 430.00	$\underline{11.1}=\left(+\frac{14.0}{32.0}\right)$ $\frac{7.3}{11}$	4.3= +20.8	$\frac{2.9}{11}$ $\underline{1.1}=\left(+\frac{24.0}{43.5}\right)$
+50						25.4 429.70	$\underline{11.5}=\left(+\frac{7.6}{22.4}\right)$ $\frac{11.9}{11}$	9.0= +16.1	$\frac{6.9}{11}$ $\underline{1.8}=\left(+\frac{23.6}{46.4}\right)$
T.P.	1.30		14.62	440.51	441.81	1.00			
2433						12.8 429.0	$\underline{2.6}=\left(+\frac{10.2}{22.5}\right)$ $\frac{3.0}{11}$	3.0= +9.8	$\frac{3.2}{11}$ $\underline{3.4}=\left(+\frac{9.4}{21.6}\right)$

In the column marked Elev of Sub-Grade, is copied from the profile the elevation of formation level at the respective stations, as well as the grades and the places where they change, *e.g.* at Station 2434, the elevation of sub-grade is 430.00, and from this point northwards the grade falls 1.00 foot per 100 feet, *i.e.* a 1.00 grade. While southwards the grade is a level one. The reference point denoting that the grade changes at 2434.

Suppose now we are ready to cross-section. The rod is held on a B. M., it reads 2.13 say—and the elevation of Bench is 453.00. H. I.—455.13. Then 455.13=430.00—25.1, and is the distance the grade line at 2434 is below the line of collimation of the instrument. This is called the "grade rod," in other words it is the reading the rod will require to have if its bottom is at grade elevation. The "grade rod" at this station 25.1, should be marked in small figures above the sub-grade elevation 430.00. The rodman now holds his rod at the centre peg at station 2434—it reads 4.3 feet. Put this down in the centre column of the cross section page, and immediately find the cut by subtracting it from 25.1. Thus—25.1 − 4.3=20.8.

This should be noted as follows :—4.3=+20.8, which interpreted means simply, a reading of 4.3 on the rods gives a cut of 20.8 feet.

This is then marked on the stake in plain, neat figures, with a piece of red chalk.

The rodman next holds his rod at the distance of the edge of road bed, which in this case is 11 feet from the centre, and a reading 7.3 is taken and entered $\frac{7.3}{11}$ in the note book. Since we don't require to use the reduced cut at this point just now, we need not make the reduction until we get to the office. The rodman next feels for the slope distance. We find that a reading of 11.1= + 24 feet gives the position of the slope stake = 32 feet, this is noted thus $\underline{11.1}=+\frac{14.0}{32.0}$. A stout stake 1½ inches square, and about two feet long, should be driven down firmly at this point, and on one side marked the station number 2434, and on the other the slope distance, thus, S 32.0.

It will be observed that in this system of note taking, every reading made in the field, and every operation performed is noted, so that at any time the reductions made, when a new G. P. is used, or the cuts and fills marked, may be checked.

The cross sections taken from day to day are entered in the field book as they occur, and there need be no especial pains taken to keep them continuous, since the contents of the book should be indexed; and, moreover, the cross sections should be copied every evening into what is called the "office copy," a separate book kept for the purpose.

These notes may be entered in ink, and the stations should be in continuous order. A convenient form of book is as follows, the left hand page being used for the cross sections, the right hand for quantities and remarks, such as positions of bench marks, notes of beginning of curves, etc., E. C.'s, Ref. Points, etc., and any information that may be useful.

Sta.	CROSS SECTIONS.					Elev. Grade	CUTS.		FILLS.		Remarks.
	Left.		Centre	Right.			Area.	C. Yds.	Area.	C. Yds.	
						level					B.M. 40'E 2436 on Tam St. El.=453.00.
2434	+14.0 / 32.	+17.8 / 11	+20.8	+22.2 / 11	+24.0 / 43.5	430.00	996.45				
+50	+17.8 / 22.4	+13.5 / 11	+16.1	+18.5 / 11	+23.6 / 46.4	0.00	757.50	1624.0			
2433	+10.2 / 22.8	+ 9.8 / 11	+ 9.8	+ 8.6 / 11	+ 9.4 / 21.6	429.00	312.40	99[illegible].6			

A very common way, in fact the most usual way, of calculating the quantities in the cuts and fills, is by averaging the end areas.

This method has been used in the above example.

A great convenience when one is setting slope stakes, is to have a table of slope distances written out in the back of his book, giving the distance of the slope stake out from the centre for cuts or fills, for every tenth of a foot. A convenient form is here given.

CUTS, WIDTH 22 FEET.

Feet.	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
0	11.0	11.2	11.3	11.5	11.6	11.8	11.9	12.1	12.2	12.4
1	12.5	12.7	12.8	12.9	13.1	13.3	13.4	13.6	13.7	13.9
2	14.0	14.2	14.3	14.5	14.6	14.8	14.9	15.1	15.2	15.4
3	15.5	15.7	15.8	15.9	16.1	16.3	16.4	16.6	16.7	16.9

After the first two columns have been computed the remainder can be interpolated. Since a difference in height of 2 feet = a difference of slope distance of 3 feet, for finding the distance for the depths 2.0, 2.1, etc., add 3 feet to each of the figures in the first line respectively, and for 3.0, 3.1, etc., add 3 feet to each in the second line.

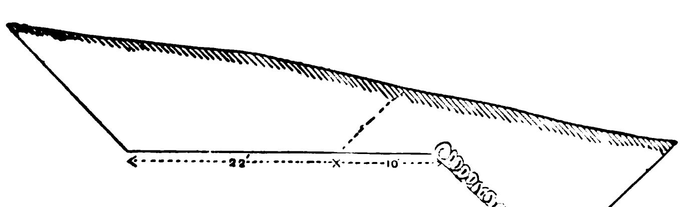
This little table, which should be worked out to a depth of 35 ft. will (with another for embankments) be found very useful, both in saving a great deal of time in the field and in preventing mistakes.

The cross sections are plotted generally on a scale of 20 ft to the inch. The measurements should be all marked on them as well as the area of each section, and the number of cubic yards between each pair. As construction is rushed very much now-a-days, and as the quantities are generally calculated from the excavation measurements, it is usual to plot only the cuts.

Before the grading has been commenced, the Division and sometimes the Section Engineer travel over the work and thoroughly examine into the way the road-bed is to be drained and kept dry. Creeks may have to be diverted where the road-bed follows the course of a winding one, ditches dug on either or one side of it, bridges or trestles built. He must ascertain as well as possible from the settlers or inhabitants, or from his own observation, what body of water may be expected at the time of greatest flood. He also ascertains what sort of foundations there are to be had where structures have to be built, and decides upon what style of structure is suitable for the different places. This information is embodied in a report and sent to the Chief Engineer, who designs his structures accordingly. The common way of testing for foundations is by means of "sounding" rods These are long iron rods about ¾ in. thick, and 8 or 10 ft. long, arranged so as to screw together into a continuous length of 40 ft. or more. The first length (which has a pointed end) is held vertically and pushed into the ground by two men, lifted up a little and pushed in again. When it has sunk sufficiently a new length is added, and the operation continued until sound bottom is reached, when the rod can't be sunk further. If rock is reached the rod gives the hand a sharp jar.

Sometimes a stratum of hard material occurs, under which there is a bed of quick-sand. To discover this, the ramming should always be persisted in for some time after good bottom is reached. Sounding rods cannot well be used on dry ground, then pits should be dug, and these will shew clearly what sort of foundation is to be had.

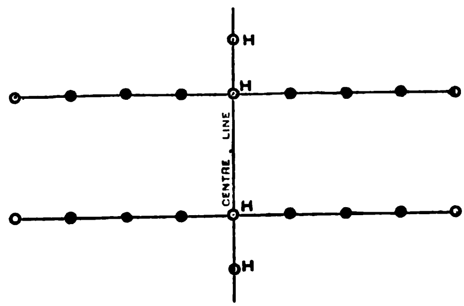
Very often, especially in a difficult country, the line follows a river or creek bed, which crosses and recrosses it several times. By cutting a new channel, as in sketch, very often a number of trestles can be cut out, which means a great saving to the railroad company. Small creeks crossing the line may be diverted down side ditches into larger ones, where culverts have been built to provide a crossing. The ground should always be most thoroughly examined to see if these divisions cannot be made, as time thus spent is not thrown away. These divisions should be cross sectioned and staked out much in the same manner as a line cut, an ample berme of 10 ft. or more being left between the edge of road-bed and creek, thus :—



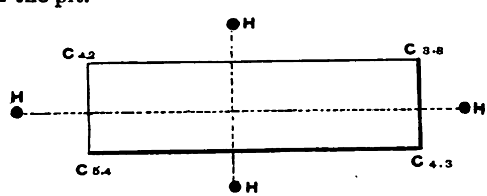
Very often rip-rap has to be thrown in along the bank in these places to protect it.

LAYING OUT PILING, CULVERTS, FOUNDATIONS, TRESTLES, ETC.

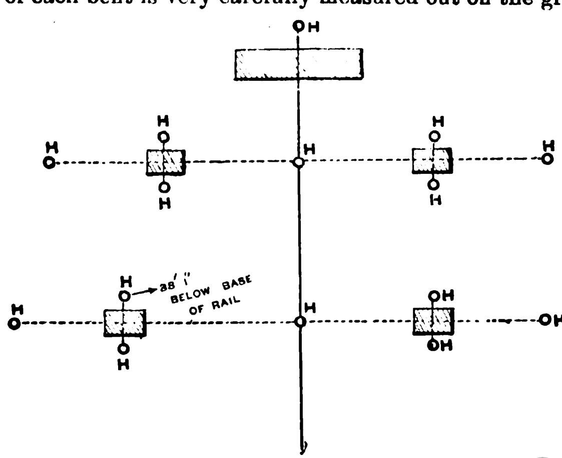
Where culverts have to be built upon treacherous ground, piling becomes necessary. The plans sent from the head office shew the disposition of the piles, and the assistant must lay them out accordingly upon the ground. Hubs must be put in on the centre of each bent, and two others at right angles, and some distance out, so that they will not become disturbed by the operation of pile driving. The foreman in charge of the driving should be furnished with the distances at which the piles are to be spaced.



Usually have a stake at each corner on which the depth of cutting is marked. Hubs are placed as at "H" on the centre line, and at right angles to the centre of the pit.



MASONRY WORK such as the abutments of a bridge, or pedestals of a viaduct are laid out as follows :—The distance along the centre line between the centres of each bent is very carefully measured out on the ground with a

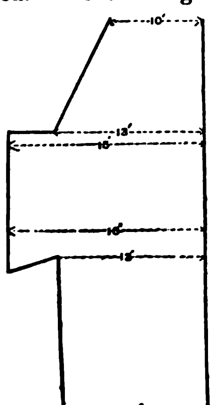


steel tape, and hubs put in with the tack precisely lined up with the transit, at these points. After these have been laid out, a thin steel wire is stretched from one end to the other, the difference of elevation of its ends noted by means of the level, and small marks made on the wire over each hub. It is then measured with a steel tape, and the distances reduced to the horizontal. A very effective check is thus obtained. At each of these hubs the transit is set up and right angle hubs put in as in the figure. The distance to the centre of the pins, taken from the plan, is measured along these, and hubs at right angles to these axial lines put in. The depth below base of rail or below top of coping stone, is also marked on one hub of each set. When the masonry has been brought nearly up to the right height, distances and heights should again be given to the foreman. The elevation of the bottom of the masonry as well as its size should be noted immediately it is started so as to be able finally to work out the quantities in each pair, which of course can't be done after it is finished and the earth filled in.

CULVERTS are laid out in much the same way as masonry. After they are built they should be watched carefully to ascertain whether there is any scour at either end. If there is, a couple of cart loads of rip-rap spread over the channel at the ends will effectually stop this.

ESTIMATES, ETC.

About the 27th of the month the assistant must start to take his monthly measurements for the estimate which consists in making a return of all the work done up to date on his section. He should commence at the bottom end of his work and go over the whole of it, noting what clearing, slashing, close cutting, grubbing, earthwork, rockwork, masonry, timberwork, etc., may have been done in a book kept especially for the purpose. About the most troublesome work to keep track of is ditching and side borrow. It is the easiest work to do, and for this reason it is generally sub-let out into small contracts of usually 100 ft. or so, hence the term applied to it—"Station Work." The writer thinks that by adopting the following method of keeping the notes, much confusion will be avoided. Use the centre line as a base for measurements, take sections every 100 ft., or less if the ditch demands it, noting most carefully what pieces have been finished, so that they need not be gone over again. The measurements of these finished ditches should be transferred at once to another book in continuous order, space being left for what is not yet finished. The following shews the method of noting a piece of ditch work.



	Rem'ks	Sta.	Dimensions.	Area.	C. Yds.
2402					
		2400	14+3.8		
+40					
		+80	13+3.8		
2401	Finished. Costello & Co.	+80	16+3.8		
+80		2401	16+3.6		
		+40	15+3.7		
2400					
		+40	13+3.7		
		2402	10+3.0		

A line drawn after a station number indicates that the ditch ends there.

LINE CUTS.

If line cuts are taken out down to grade with a face, they are very easily measured, finding the stations between which it is finished and working out the quantities from the original cross sections being all that is necessary ; but when worked from the top irregularly they are more troublesome, and the level may have to be used to get at the quantities.

The number of men a contractor has working for him should be noted several times during the month, as this affords a good rough check on the estimates. For unfinished work the estimate should be rather under than over the true amount, the aim being merely to put enough funds into the hands of the contractors to pay his men.

The computations should be worked out by the assistant and the roadman together, so as to check one another. While the office work is going on the axemen may be employed in making stakes at convenient points along the line Forms are provided for recording the monthly progress estimates in detail, there being a heading for each article mentioned in the schedule; other forms are supplied on which the estimate is put down in a more compact form, and sent to the resident Engineer, who examines them, fixes the prices, and forwards them to the Chief. The latter signs them and orders the amount to be paid out to the contractor.

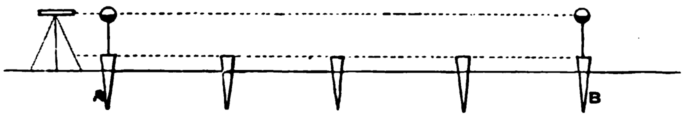
CENTRES AND GRADES.

When the grading is about being completed the assistant requires to go over the work and put in centre and grade pegs, according to which the contractor should be required to time his work up. These stakes if they are stout and well driven down will do for track centres, though a great many will require to be put in again, the distributing of ties and bridge timber by teams, etc., being fatal to them. When the grading has been finished, the ties are distributed along the line preparatory to being put under the rails. Now is the time to run in the track centres, these can be put in without using the transit from the slope stakes, and from the old centres, curves may be put in with the tape by chord deflections. After the track is laid, the ballast is put on in two or more lifts. Before the final lift is made the centres have to be run again most carefully over the whole line, stout stakes 2 in. square being driven down firmly every 200 ft. on tangents, and every 100 ft. or 50 ft. on curves, and a track placed exactly on line on each stake.

To run in a tangent 3 or 4 miles long, set up a very large picket at one end with a white flag on it. Set up the transit at the other end and run towards this picket, moving the instrument every twelve or fifteen hundred feet to keep up with the chainman.

BALLAST PEGS.

On the inside of curves opposite each centre stake, and on tangents, there should be a stout stake driven down at the end of the tie, so that its top shall be level with the *top of rail* when the ballast has been brought up to the required level. The following method of setting ballast pegs is to be recommended, both for its rapidity and accuracy :—



Set ballast pegs along the line at intervals of 2,000 feet or so, with the level in the ordinary way, also at the points where the grade changes, (where vertical curves have to be run in). Now to put in intermediates at 200 feet or so; set up the transit nearly, but not quite, over one of these points thus placed as at A. Place a target rod (the assistant can make one readily himself, it need not be longer than 5 feet) upon A.; lower or raise the sliding part until the centre of the target is on a level with the horizontal line of the transit. Now have the rod so adjusted, held at B.; set the horizontal thread of the instrument on the target, and clamp the axis of the telescope. Grade pegs are now readily set by driving a peg in, leaving it a little too high, holding the rod alongside and moving it up and down, till the centre of the target coincides with line of collimation. The rodman is motioned "all right." He then makes a mark on the stake at the bottom of the rod, and by means of a hand-saw, which he should carry, cuts it off. The top of the stake is, of course, on the grade line, A. B. In this manner a great deal more pegs can be set in a day, than by the old method, with just as great if not greater accuracy. The pegs are put on the inside of curve, because the outside rail has to be elevated according to the degree of curvature, which is generally one-half a tenth of a foot for every degree of curvature. This being the correct elevation for a speed of about thirty miles per hour. The "lifting gang" generally do this themselves, the foreman being furnished with a list of elevations, reduced to inches, for different curves. At all B. C.'s and E. C.'s, a stout post, 3 ft. long and 3 in. square, should be well driven down, and on it marked the Station number and the degree of the curve. This serves as a guide both to the liners and lifters.

INSTRUMENTS.

A great deal of walking has to be done when the construction is first under way, and in some countries where there are no roads fit to drive a buckboard over, this must of necessity be the only means of progression, until the welcome hand car makes its appearance.

Lightness of instruments is, therefore, an essential. If one has a transit with a good level tube on the telescope, he may often leave his dumpy or Y level at camp, a consideration worthy of notice.

According to the writer's experience, an American transit, though not so durably constructed as one of English make, and not finished as well, is by long odds the most handy instrument in the field, and saves a considerable amount of time. If an instrument were constructed with the English form of standards, telescope, and general finish, combined with the American form of tripod, shifting centre, leveling and tangent screws, divided circle, and compass, the result would be one which, for all ordinary purposes, would be practically perfect.

LEVELS.

For ordinary railroad work the dumpy, from its lightness and from the permanency of its adjustments, is to be preferred to the Y levels. Of course, for important structures, such as bridges and viaducts, the Y, from being susceptible of closer adjustment, is to be preferred.

SWELLING RODS.

For cross sectioning a single slab of wood shod with iron, 14 ft. long, 3 in. x 1½ in. at the bottom, and 2 in. x 1 in. at top, painted white, and divided into feet and half tenths, will be found much more handy and useful than a telescope rod. With a little practice $\frac{1}{100}$ ft. can be estimated with the greatest precision. A rod of this kind can be got up very cheaply.

TAPES.

Tapes used for cross sectioning should be in feet and tenths; computations being much more easily made than when in feet and inches.

A SYSTEM OF SURVEY
— IN —
BRITISH COLUMBIA.

A. M. BOWMAN.

The survey with which we were connected in British Columbia consisted chiefly of exploratory work. The main object was to obtain the best, most extensive, and most complete geographical information in the shortest time; and from the methods used, you will see that the information, though not so precise, was still obtained with a considerable degree of accuracy.

Our instructions were to procure topographical and geological notes of the country passed through, to note the kinds of timber and quality of the soil, and also to shew the boundaries between the different geological formations. Barometrical readings of both mercurial and aneroid barometers were also required to be taken. It was also necessary to state the character of the weather each day, and to gather botanical as well as geological specimens.

The kind of country surveyed was generally rugged and mountainous, and on the coast was well timbered. In the interior, however, timber was not so plentiful. It existed principally in the higher altitudes, the valleys being covered with what is known as bunch grass, and hence afforded excellent facilities for cattle grazing. Above a certain altitude no timber exists, The country is here and there dotted with mountain peaks, which may be seen one from the other, and the surveyor is thus enabled to carry on a system of triangulation by means of which he can check his work and make a more connected and exact survey.

Before going into new and unsettled quarters, the surveyor endeavors to procure from the old Indian hunters and trappers all the information possible regarding their trails, and the large streams in the district. If there are large streams and lakes he may travel by canoe into the country, but if not he provides himself with horses and axemen, and tries as much as possible to follow the Indian trails. A knowledge on the part of the surveyor of how to get through an almost impenetrable country with the least expense is one of the most important considerations in the eyes of the government in making their appointments.

The instruments used are a mountain transit, a sextant, a prismatic and a pocket compass, a hand level, also mecurial and aneroid barometers. A micrometer may also be conveniently used in measuring the distances across small lakes. The transit which has a vertical circle attached to it is principally used upon the summits of high mountains, to measure the exact angles between all prominent peaks, and also their angular elevations or depression above or below your horizon. This instrument has one of "Gurley's Solar

Attachments" which enables the surveyor to obtain the true meridian from the sun any time during the day.

The prismatic compass is used in taking bearings to mountains, only a short distance away, and also in ascertaining the general course of our trail, while the pocket compass is used in obtaining the smaller bends and windings of the course. The hand-level is used in connection with the prismatic compass to determine the angular elevation or depression of the object sighted upon with the compass.

In this work the distances are all estimated with a few exceptions, viz:—those obtained by the micrometer.

In travelling through the country the rate of travel is estimated, and the interval of time being known, our distance may be calculated, the result of which becomes a very close approximation to the true distance. In travelling in a canoe the average rate is about a 6 gait, and that of a pack-horse about a 4 gait.

The pocket compass, as was before stated, is used in making the track survey. This however is not sufficient to give us the true bearings of our course. By a judicious use of the prismatic compass a very admirable check upon the pocket compass is attained. It is done as follows:—Suppose we are travelling up a river valley having small mountain peaks on each side, we take bearings to each of these, at the same time, estimating their distances and noting their positions in our track survey sketch, but for the purpose of checking the survey, we must take at least three sights to the same point from different positions in our course. This is a very fair check upon our longitude. An excellent method for checking our northing and southing is by observing the sun's meridian altitude, from which we may determine our latitude. This is done with the sextant and mercurial horizon, and should be repeated every alternate day.

Notes of the country are also obtained by taking topographical sketches from some prominent point or mountain peak These are perspective sketches, and are similar to a photograph, but do not possess the same optical accuracy. Bearings are taken to the prominent mountain peaks, and to the heads of water-courses, the smaller streams and mountains being sketched in by eye; all the distances to these points are estimated and placed above their respective positions in the sketch.

These notes are made in a book 12x6 in., containing two hundred pages, which are divided into inch and a quarter blocks; these blocks are sub-divided into quarter inch blocks, each of these smaller divisions representing 2-10 of a mile, in the track survey sketches, and two degrees in the topographical sketches.

In the track survey sketches, a small arrow is placed in a corner of each page, showing the meridan, and the courses are drawn accordingly. The time when starting each morning is noted on the left hand side of the page, along with the barometrical reading in feet, directly opposite the station started from. Whenever a halt is made during the day to take notes, the time is first noted opposite the station, the position of which is ascertained in the manner already stated. The notes are then sketched, and as soon as they are completed, at that point, the time of starting is marked beside that of stopping, after which you are ready to proceed. The hills and mountains are denoted by contours, which also show the small streams and gulches in the mountain sides. The trail is shown by a dotted line, and the station by a dot surrounded by a circle. In this method each station is known by the time at which it was made and the geological specimens, gathered at any station, have written upon their labels the time and the date at which they were collected. The geological boundaries are marked with colored crayons, different colors representing different formations.

Camp readings of the mercurial and aneroid barometers are taken in inches every morning and evening, from which we ascertain the heights of our camps, and, since readings, in feet, of the aneroids are frequently taken during the day, we are enabled, after correcting for the weather, to make a complete profile of our track survey. The corrections for the weather may be obtained from some stationery barometer in the vicinity of the survey. In British Columbia we compared our readings with those taken at New Westminister and Spokane Falls.

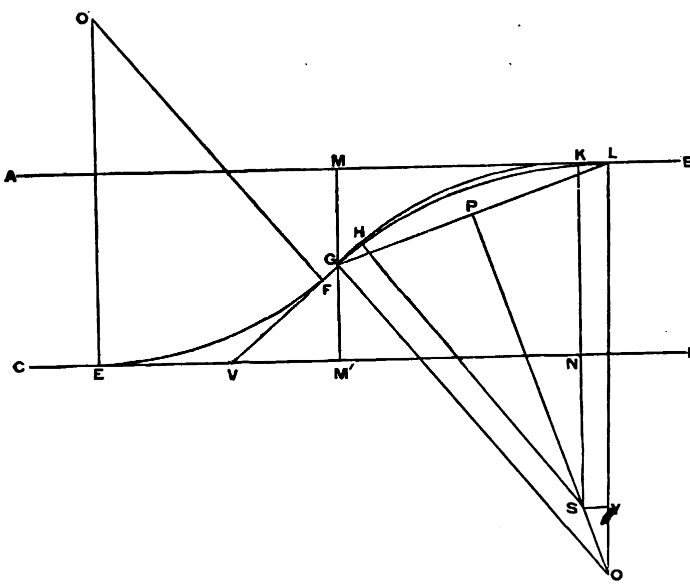
In plotting the notes obtained in the field, the track survey sheets are first cut out of the note books and pasted together, end to end, with all the arrows pointing in the same direction. This gives you the map as you have plotted it in the field from your pocket compass bearings. You now take tracing paper and trace only the trail from the notes so pasted together, at the same time swing it into the correct position as ascertained from the longer bearings taken with the prismatic compass.

The other notes of the track survey are then traced, relatively to the trail as changed. The bearings and distances of the topographical sketches are then plotted from the point on the track survey at which they were taken, showing the hills and valleys by means of contours. This map is then reduced to a smaller scale by means of the pantograph, and published.

PROBLEM IN RAILROAD CURVES.

It is required to connect two parallel tracks by a reverse curve, with a straight line of 500 ft. between the curves at the centre. The distance between the tracks being 2000 ft. = KN, and EN is to be 5000 ft., E and K being the beginning and end of the reverse curve.

B. A. LUDGATE.



GIVEN.—AB and CD, two parallel tracks, 2000 ft. apart, and the distance from E to N as 5000 ft. (for E and N see below).

It is required to connect these with a reverse curve, each part having the same radius, and having 500 feet of a straight line between the two curves at the centre. In the diagram the curve is to start at E and end at K. From K drop a perpendicular KN on CD; EN is to be 5000 feet.

1st Solution.—G is the centre between E and K, GH and GF, each = 250 ft. Make KL = 250. From L drop the perpendicular LO and find the curve whose centre is on LO, and which will pass through the two points L and G. This is got thus:—Join GL, and draw the perpendicular GM, and we have GM = 1000 ft., ML = MK + KL = 2500 + 250 = 2750, and GML is 90°, from which we find G L = 2926.18 ft. and the angle GLM = 19° 59′ nearly, or exactly, 19° 58′ 59.2″.

Bisect GL in P. Then in the △ PLO, we know PL, and ∠s LPO and POL. $PL = \frac{2926.18}{2} = 1463.09$ ft., and ∠ LPO = 90°. ∠ LOP = MLG = 19° 59′. From which we find LO = 4281.21 feet.

Now, a curve of this radius will touch AB in L and FH in G. From G draw FH ⊥ to GO, which will be the direction of the tangent or straight line of 500 ft.

Now, any curve drawn touching AB, as at K, having its centre on the line OSP will also *touch* the other tangent HF in some point as H. And it is the curve that touches AB at K, and HF at H that is required; wherefore, we want the radius KS = HS of such a circle. In the △ SYO we know SY = 250 ft. = KL, and SOY = 19° 59′, and OYS = 90°, from which we find OY = 687.47 ft.

Now, SK = OL — OY = YL = 3593.74 ft. ∴ the radius of the circles is 3593.74 ft. The other half of the curve is the same as this half.

This radius corresponds to a 1° 35′ 40″ curve, nearly.

2nd Solution.—

Produce HF to meet CD in V.
Then EV = VF = T, say.
Now, GM′ = 1000 ft.
VM′ = 2500 ft. — T.
VG = 250 ft. + T.
GM′V = 90°. ∴

$$(VG) = \sqrt{(GM')^2 + (VM')^2}.$$

$$(250 + T) = \sqrt{1000^2 + (2500 - T)^2}.$$

From which we find T = 1306.81 ft., and that the ∠ GVM′ = 39° 58′.
And ∴ the ∠ EO′F is = 39° 58′.
Join O′V. Then in △ EO′V we have

$$\angle EO'V = \frac{39.58}{2} = 19.79.$$

O′EV = 90°,
and side EV = 1306.81; from which we find that O′E, the radius of the required circle, is 3593.7 ft. as before.
And this radius corresponds nearly to a *1° 35′ 40″ curve.*

A RE-SURVEY IN ONTARIO.

A. E. LOTT.

In this Province re-surveys have been made in only a few cases. The necessity for such a proceeding may result either from the destruction of the posts put down on the original survey, and also of all traces of old lines by means of which they might be re-established, or from failure of the surveyor to do his work properly. In the instance with which the writer is familiar, the original survey was made or reported to have been made in 1821, by P. L. S. Elmore.

At that time lines were only partially run between Concessions V. and VI., VIII. and IX., and IX and X., and besides these no other lines were run, except the boundaries.

About thirty years after the above date, Elmore undertook to complete the survey, but owing to physical incapacity, was unable to either complete the original survey or to properly comply with the law in such cases. The township is about nine and a half miles wide from East to West, and about twelve miles in length, and was divided into eleven concessions running North and South or more nearly about N. 20° W. Ast.

Each concession was divided into 32 lots. These in the original survey were intended to be 30 chs. each, except the last, which was about 22 chs., while the length of the concessions was to be 66⅔ chs , except the eleventh, which was something over 40 chs. When Elmore came back, he gave Concession I., 20 chs., Con. II., 40 chs., Con. III., 60 chs., Con. IV., 210 chs.; V. 70 chs., VI., 60 chs., VII., 49 chs., VIII., 84 chs, IX X and XI., he left much as wood-rangers appointed by lumbermen had blazed them out. He began his chainage at the north and did not continue it to the south boundary, but stopped about lot 10.

Settlers took up lots by the second survey, the real original work never being known by them, except in one or two cases. Lumbermen in fighting in the courts found it necessary to have the lines properly run; and about fifteen years ago a surveyor was appointed to examine and report on the real condition of the township. He first obtained all the information possible from those surveyors who had done work in the township, and then proceeded with his examination.

By his report the only original posts which he could establish were a few of those on the V. and VI. concession line, as far north as No. 28 or 29, and a few of those on the VIII. and IX. line, as far north as No. 16 and 17. The en ths of the first five concessions as recognized by settlers varied from 20 chains to 210 chains, while the other concessions, although by no means correct, were more nearly so than the first five. This report was taken by the government as the basis of the re-survey, and instructions in accordance therewith were given to the surveyor who was appointed to do the work.

The average length of the concessions, excepting the eleventh, was about 70 chains, but according to instructions, the distance between the west boundary and the 5th and 6th Concession line, had to be divided into five equal parts. The distance between the 5th and 6th line, and the 8th and 9th line was to be divided into three equal parts as far north as the last post on the 8th and 9th line. The distance between the 8th and 9th line and the east boundary to the same point north was to be divided into three parts, but as in the original survey, the 11th concession was shorter than the others, the distance between the 8th and 9th line and the east boundary was to be divided in the same proportions;as the lengths named in the original survey. That part of the township between the 5th and 6th line and the east boundary, and north of the last original post on the 8th and 9th line, was to be divided into six parts in the same way as the last named part. The concessions had to be divided into 32 lots in the same way. In beginning the work, the southern boundary had to be established, and this was done in the following way: The point where the 5th and 6th line began was found, and a direction for the boundary was assumed, agreeing, as nearly as possible, with some blazes that were found in the swamp in which this point was located, and this line was continued through to the west boundary.

The original corner post between that township and the adjoining one to the west was then found by the aid of some old residents, and the distance from it to the trial line along the course of the west boundary as given by different surveyors. The length of the five concessions and the proper course of the south boundary was then calculated, and the boundary was then run out from the south-west corner, the concessions being laid off at the proper distances.

The west boundary and the 5th and 6th line were then run out, the boundary being established by posts of the adjoining township, and blazes at different places, while the 5th and 6th line was run so that the line between two consecutive original posts was a straight line. The length of the west boundary was taken from the notes of a surveyor who had chained it carefully and the posts were set accordingly. The 5th and 6th line was chained and the distance between each two consecutive posts was divided into the proper number of equal parts explained. Allowance was made for a cross road between lots 5 and 6, 10 and 11, 15 and 16, and so on. The courses of the several concession lines were then calculated so that the concessions should be of equal lengths at any point, and the lines were run. To ensure accuracy tie lines were run across the township every tenth lot, and the points at which the concessions crossed were noted. The lines were continued through to the north boundary, which being the south boundary of a comparatively new township was easily found. If the last lot had more than its proper width the excess was divided back among all the lots, either to the last original post or to the south boundary, each having its proper proportion The south boundary east of the 5th and 6th line was established in the same way as that part west of that line. On the 8th and 9th line the distance was divided, as on the 5th and 6th line. On the 6th and 7th, and the 9th and 10th lines some original posts were sworn to by the settlers and therefore had to be recognized as established posts in the resurvey. Where these posts were found the lines were run in this way: Suppose an original post to be found between 14 and 15 on the 6th and 7th line. The two concession lines, viz., 6th and 7th, and 7th and 8th were run on their proper courses to about the position of the side line between 13 and 14, but no posts were set. An observation was then taken at the original post to ascertain the direction of the side line, which being found was produced both ways to meet the 5th and 6th, and the 8th and 9th lines. The distance between these lines was measured and the point noted at which the side line crossed the concession lines. The distances between those points and the south boundary were then divided among the proper number of lots, and the posts were set up to those between 13 and 14. The course of the 6th and 7th from that point to the original post was calculated and run, and also the course of the 7th and 8th from the same point to a point half way from the original post to the 8th and 9th line.

Then supposing the last original post on the 8th and 9th line to be between numbers 16 and 17, a tie line was run across from the 5th and 6th line to the east boundary along the side line between numbers 17 and 18, and was divided into six parts, giving each concession its proper width and the concession lines were then run from the posts between numbers 16 and 17 through the proper points on the tie-line.

Traverses of clearings, rivers, lakes and roads were made by finding from the field notes the points at which the concession lines cross the several clearings, rivers, etc., and then building on the portions of the concession lines intersected between the two sides of the clearing, lake, road or river a system of triangles or lines from which the shape could afterwards be plotted.

The instruments used in traversing were the transit with stadia, or the micrometer and sextant, or micrometer and compass. Where the transit was used the angles measured were obtained either by finding the angle between each line and the concession line without reference to the real course of the concession line, or knowing the magnetic course of the concession line to find the magnetic course of the several lines by the compass on the transit. The distances were obtained by stadia measurements. The distances and angles or bearings were entered on sketches in the surveyor's field book. Where the micrometer and sextant were used, the angles were measured by finding the angle between each line and the concession line, and the distances were obtained in the ordinary way by the micrometer.

REFERENCE POINTS

—AND—

BENCH MARKS.

H. J. KENNEDY.

The object of the present paper is not to be technical in any sense of the term, but merely to call the attention of those who purpose engaging in railway work to a few matters of detail which so far have never been considered sufficiently important to be noticed in any published work known to the writer. At the same time, however, they are of sufficient importance to the young engineer to distinguish him among the older members of the profession as a "clever chap," or a "muddler." The latter reputation, being a very undesirable one, will be retained much longer than the former, and if the present paper succeeds in impressing this fact upon the attention of those who may peruse it, the writer's object will have been attained.

The subject proposed to be discussed is the best practical methods of keeping the original alignment and levels referenced while the work of construction is in progress, so that they may be readily replaced when the work is completed.

When the assistant engineer is alloted his section, his first work is to run check levels over it, placing benchmarks where necessary, and referencing the alignment in some way that it may be picked up at any time during construction if required. The necessity for these reference points must be apparent to all as the work is all cross-sectioned from the centre line, and if it cannot be replaced exactly, the quantities cannot be measured exactly, or the track laid to the proper centres. In a rock side-cutting an uncertainty as to the exact location of the centre line may possibly involve a difference of several hundreds of dollars, or even thousands, although the possible deviation may not be more than a foot. There is, therefore, a temptation to the contractor to dispute the measurements, and claim a remeasurement of his work after its completion if he thinks there is anything to be gained thereby. If he finds the centre has not been well referenced he is certain to think that the cuttings were taken out very wide on the high side.

The usual points to reference are the beginning and ending of each curve (B.C. and E.C.) which are no doubt the best points for convenience, when a suitable reference can be obtained. This, however, is not always the case. There are several methods employed, almost every engineer having some one favorite method to which he adheres in almost every case.

The following are a few of the more common methods :—

I. Having set the instrument over the hub to be referenced, turn off an angle from the line of about 60° to a stump, or some other object at a convenient distance out of the way, and sight to a point marked on the side of it. Now turn the telescope over, and set a hub on the other side of the road out of the way. Again turn to another stump having a point marked on its side, and, having reversed the telescope, set another hub. The point to be referenced will, therefore, be at the intersection of the two lines from the stump to hub respectively; and the distances having been measured to each the reference will be recorded in the book. Of course if there are no stumps convenient stakes may be driven instead; or, indeed, stakes may be driven instead of the hubs, if thought to be more convenient, the principle involved being the same in any case. There is no doubt of this being the most exact method, and the best in many cases, although it has its drawbacks. In the first place the instrument is necessary to re-establish the point; and secondly, there are four points to be kept, and if any one is disturbed the others are useless. Again if the point referenced is to be excavated to more than a few feet, the references are worthless, as they cannot be seen from the point, On the other hand if a high embankment is placed over the hub this method will be found the best that can be devised for replacing it.

II. This method is by measuring the distance to a stump or other permant object on each side of the point and noting distances. This is a readier although somewhat rougher way than the former. Although it is a poor method for either a deep cut or high embankment, it is more convenient and just as reliable as any other, when the hub is about grade elevation. It is preferable to measure the distances to three stumps where convenient, and the station and distance to centre should be marked on each stump.

III. Some prefer to measure the distance at right angles from the line to a permanent point, not only at the hub, but at several stations where convenient. This is a useful method as the stakes may be replaced without the aid of the instrument.

IV. Still another way is to place a hub at the point of intersection of tangents, generally called the PI. This is the best method that can be devised where practicable, but it is not always that it can be adhered to, as where a curve is placed there is always some reason for placing it there, and that reason being generally a hill or a ravine, the P.I. is often inapproachable. In such cases reference hubs are placed at any convenient place on the subtangents of the curve, where they serve just as well as if placed at the P.I.

The sole object of references being to keep the original alignment indisputable and easily found, there should be at least two points referenced in every tangent so that it can be replaced without the trouble of running a curve, besides in re-running a long curve the E.C. is liable to be badly out, the cause, of course, being due to a difference in chainage rather than instrumental inaccuracy. This is a source of annoyance to be met when the chain used on the original location has been stretched a little too long, as is sometimes the case. When, therefore, the B.C. and E.C. can be established independently there can be no difficulty in replacing intermediate stations when required.

The following rules may be laid down for referencing alignment, and if strictly adhered to when laying out work would be a great saving of both time and trouble.

1. Every tangent should have at least two points referenced, and those points should be the E.C. and B.C., if convenient for the purpose.

2. When convenient, a hub should be driven at every P.I. with a high picket behind it; but if not, hubs and pickets may be placed anywhere on the sub-tangents. And if a crosshead or piece of red cloth is placed on the top of each, it can always be seen, and is not likely to be disturbed by the workmen.

3. If the point to be referenced is to be covered by a high embankment, the first method described will suit best; but if in a deep cutting, another point on the tangent will be better suited for referencing.

4. Too many points cannot be referenced, and the transit book should show all information so clearly that a stranger can by it replace any of them.

It is very important that the book should give all information clearly, as it is liable at any time to fall into the hands of some experts whose business may be to search for errors and omissions.

The establishment of bench-marks is a subject needing some forethought, although it does not receive that attention in many cases, which its importance demands.

As previously stated, check levels should be run over the section, and benches established at the same time, where required. To guard against mistakes every bench should be made a turning point, as otherwise a bench might be given the wrong elevation, and cause confusion and loss before the mistake is discovered. A tracing of the location profile should be carried for reference; and a bench placed at each end of every cutting, choosing a stump or other object that will not be disturbed by the workmen; and if near a rock-cutting, a large stump should be chosen, as small ones are liable to be battered down by flying rocks.

It should not be forgotten, however, that every bench should be nearly about the same elevation as the grade, so that the level may be set up on the road-bed to give the workmen the grade elevation occasionally, without changing the instrument.

A bench that has been established either too high or too low for this purpose, will never be used after the work has been cross sectioned, as the first time the grade elevation is given to the workmen, the inconvenience will appear, and another bench will very likely be established in a better situation, so that it is here possible an error may be made if done hurriedly, and without checking back on the original bench. How much better it is, therefore, to place the original bench right at first, where it will be used to establish the grade at all times.

In recording the benches, great care should be taken to give such information that any one can with the book go directly to every bench and recognise it. Hunting for benches when one is in a hurry, and with incomplete notes, is the most disagreeable part of the engineer's work; and should he dub the one who established the benches a "muddler," the latter has only himself to blame. The writer can well remember a search made for a bench recorded as, "A point on white boulder on south side." But a few hours searching in snow about five feet deep, and an atmosphere forty below zero, revealed the fact that there were white boulders on the south side for miles around that locality, and no way of distinguishing the right one from the others.

A list of benches should be made out, and copied in each level book, giving the station where each is situated, its number, elevation, direction and distance from centre line; and also a full description, so there can be no doubt of its identification by anybody.

There are several reasons for taking this precaution, a few of which may be given for example.

If the snow is deep, how is the bench to be found without knowing the station and distance from centre; or, indeed, if it is a stump, and a bush fire blackens every stump alike, how can it be found, except by the recorded informations.

Again, suppose the number and elevation have been marked on each bench, and recorded, as is commonly done; but if the figures become blackened or burnt off, how can you know one from another, although you may know where to find every one.

These may seem unimportant matters to many who have not been confronted by them, yet they are the points every young engineer who engages in the work is supposed to understand; and cases could be cited where a disregard for them has caused the discharge of the engineer, besides giving his successor a great amount of unnecessary work.

In conclusion it may be well to call attention to the fact that we all make the same mistake in starting out. We get the idea somehow that, by reading the rod to hundredths in cross sectioning work we are getting it down pretty fine, while at the same time we may be neglecting the more important matters; and it is not till we come to calculate the quantities that we see the folly of creating extra work for ourselves for nothing. The rod should be read to the hundredths, of course, in taking foresight or backsight, so the height of instrument will always be correct; but for intermediate readings it is absurd, and goes to show the leveller's greenness.

In cross sectioning work the height of instrument should be checked from bench to bench, and the instrument should never be lifted without checking on a bench, or establishing a point to start from when the work is continued, so that any expert who may be employed to look over the books, may be able to see that every height of instrument can be traced to two bench marks. If this receives sufficient attention, the books must prove the correctness of the work, and no dispute can possibly arise upon that score.

CROSS-SECTIONING.

W. E. TYE.

In the following paper I will endeavor to illustrate the different methods actually used on the Canadian Pacific Railway in taking cross sections, keeping note books, calculating quantities, etc., both on the prairie and the mountain sections. The first case that I will illustrate is on the Emerson Loop Line, a branch of the C. P. R., running from Emerson to Rosenfeldt.

This road was over almost dead level prairie, and was entirely in embankment. The roadbed was 12 feet wide, and the slopes 1½ to 1. The alignment was good, there being only four curves in the twenty-one miles of line; one of them being the curve to connect with the Pembina branch at Emerson and another to connect with the South Western branch at Rosenfeldt. The work was all "short haul," that is, the material was all obtained within two hundred feet of the place it was to be used. This makes the simplest possible work for the engineer, though far from being the most pleasant, the work being done by grading machines, and almost impossible to make look well. The location having been run some time before, and stakes being set in at every one hundred feet, with number of station marked on each, the first thing to be done, was to run "Check Levels," to see if the location levels were correct.

The level books were all ruled in the following form :—

Station.	Back Sight.	Intermediate.	Fore Sight.	Height of Instrument.	Elevation.	Remarks.

And all records of levels were kept in this manner.

Bench marks were put in not more than half a mile apart; this being close enough for this kind of work. B.C.'s (beginning of curves), E.C.'s, and all centre line hubs were referenced in the following manner :—

Two hubs were driven, one on each side of the line at right angles to it, and exactly fifty feet from it.

Thus after the centre had been built over, by setting the transit over one point, sighting to the other and measuring fifty feet, would give you the centre again.

This method is simple and quick, but *not* accurate enough when curves are numerous or sharp. Besides the beginning and end of every curve, we referenced the centre line hubs, that is the points at which the transit had been set up on location.

Our party consisted of an engineer, a rodman, an axeman, and a cook.

Cross section books were kept in the following way:—

Sta.	Eleva.	Grade.	Rate of Grade.	Left Slope	Cent.	Right Slope	Area	Mean Height	Dis.	C. Yds.	Remarks.
324	1270.8	1274.00	LEVEL.	L	-3.2	L					
325	1269.4	1274.00		L	-4.6	L					
326	1270.4	1274.00		L	-3.6	L					
327	1271.2	1274.00		L	-2.8	L					

The elevations, or height of ground, were first transferred from level book to second column of cross section book.

The elevation of grade was calculated for every 100 feet. The rate of grade and points at which the grade changed being found from profile, and entered in third column. The rate of rise and fall per 100 feet being placed in fourth column. Then subtracting the ground elevation from the height of grade, or vice versa, gives the fill or cut at the centre. For instance, the ground elevation at station 325 is 1269.4. This subtracted from 1274.00, the height of grade, gives a difference of 4.6, and the grade being higher than the gradards shews that it is a fill, and is written —4.6.

The ground in this road was practically level. In no cross section was the fill at the slope stakes found to differ from the fill at the centre by more than two-tenths. This, of course, simplified the work of taking the cross sections, very much. A table was made shewing the distance of the slope stake from the centre for each tenth of fill.

For instance, if the fill be 4.0 ft., then the slopes being 1½ to 1, and the half width of the road bed being six feet, the whole distance of the slope stake from the centre would be twelve feet. In the same way the table was made up to ten feet, this being all that was required on this road. A sample of the table up to two feet is here given.

Fill.	Dist. out of Slope Stake	Fill.	Dist. out of Slope Stake
.0	6.0	1.1	7.7
.1	6.2	.2	7.8
.2	6.3	.3	8.0
.3	6.5	.4	8.1
.4	6.6	.5	8.3
.5	6.8	.6	8.4
.6	6.9	.7	8.6
.7	7.1	.8	8.7
.8	7.2	.9	8.9
.9	7.4	2.0	9.0
1.0	7.5		

The only implements used in taking cross sections here were one fifty-foot tape, one axe, and piece of red chalk for marking the stakes. The stakes for marking the slopes, had already been distributed; two being left at each station.

The duty of the rodman, was to mark on the centre stake the fill which the engineer gave him from the note book. The engineer and the axeman then measured out the distance found in the above table opposite this required fill. By using this table, no calculations were required to be made in the field.

In this description of ground, a good party could cross section a mile of line in very little over an hour.

When the ground was not level across, but only required a reading at the centre and at each slope stake, the cross sections were either taken with the level or a small hand level.

The instruments generally used were a hand level, a rod, a tape and an axe, a small sharp pointed stick about four or five feet long was carried to rest the hand level on when in use.

To cross section this, you would drive your stick into the ground, somewhere near the station. The rodman would hold at the centre of grade; sight through your level to the rod and note the reading. If it is a fill, substract the reading. Say the rod in this case read 3.2; this substracted from 6.0 gives a fill at the hand level of 2.8.

You see that the ground falls to the left about two feet, which would make a fill there of eight feet, which would require to be nineteen feet out, (the road bed being 14 feet and slopes 1½ to 1). The rodman and axeman measure out nineteen feet and give you a rod reading there—say the rod read 5.4, this added to 2.8 gives you a fill of 8.2. So you see you are not far enough out, so try 19.6. The rod reading here is 5.6, and the fill 8.4, which is the correct place. Sometimes three or four trials are necessary; but a good rodman will usually come very near it the second time. A stake is marked, the number of the station on the one side, and the distance out, in this case 19.6, on the other, and driven firmly into the ground.

Had station 716 been a cut, the rod reading 3.2 would have had to be added to the cut at the centre, to find the height of the hand level above the grade, and the reading at the slope stake subtracted to find the cut there.

At the beginning and end of every cut, three small grade hubs, or stakes about half a foot long and two inches in diameter, are driven so that their tops are exactly at grade, one at the centre, and one each at grade ten feet right and left of the centre. These are always put in with the level. Cuts are taken out with a twenty foot base; a road bed of fourteen feet and a ditch on each side three feet wide.

Where cuts are numerous it is best to put in a bench mark near the mouth of each.

On heavy mountain work, the party usually consisted of an assistant engineer, a rodman, chainman and axeman.

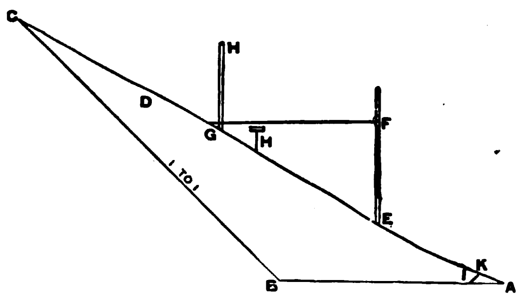
Each party was supplied with a transit, level, telescope rod, fifty foot chain and pickets. Hand level, one cedar rod, from 20 to 24 feet long, two of 15 feet each, and one light rod six feet long, two or three tapes fifty and one hundred feet long, and divided to tenths, and about two hundred feet of battery wire was found to be very convenient.

The rods were made of cedar, for lightness, and were each provided with small level-bubbles.

On the long twenty foot rod, and one of the fifteen foot rods, these were placed so as to shew when the rod was perpendicular, and on the other so as to shew when horizontal.

The locating party put stakes in at every fifty feet, and as the ground was very rough, the curves very sharp, 8°, 9° and 10° curves being numerous, and tangents very short, often not more than 200 feet long; all the plusses, or intermediate points, where cross sections were required, were put in with the transit.

On long earth slopes, where the slope of the ground was regular, and not many readings required between the centre and the slope stake, the best way to cross section was with the hand level and long rod.

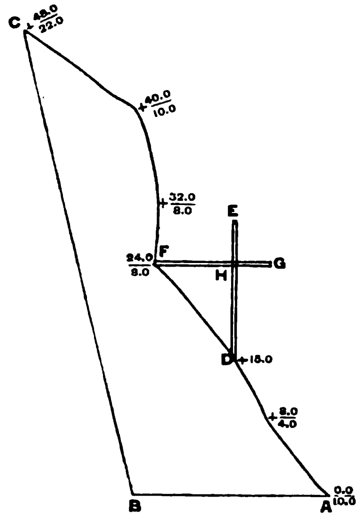


The rodman holds the long twenty-four foot rod perpendicular at the centre E, the cut at which is known from the cross section book. One end of the tape GF is fixed to the upper end of the rod by a hook or staple. The chainman takes the other end and goes up hill to G until he is about level with the top of the rod.

The engineer takes a pointed stick and drives it firmly into the ground at H on which he rests his hand level and sights to the rod EF, this reading added to the cut at E gives him the height of his level above the grade AB. The reading on the rod GH substracted from this height gives him the cut at G. The rod EF; is then moved to G and the process repeated up hill until a point C is found, at which the distance from the centre is just ten feet more than the cut, (the slope being 1 to 1 and the base twenty feet).

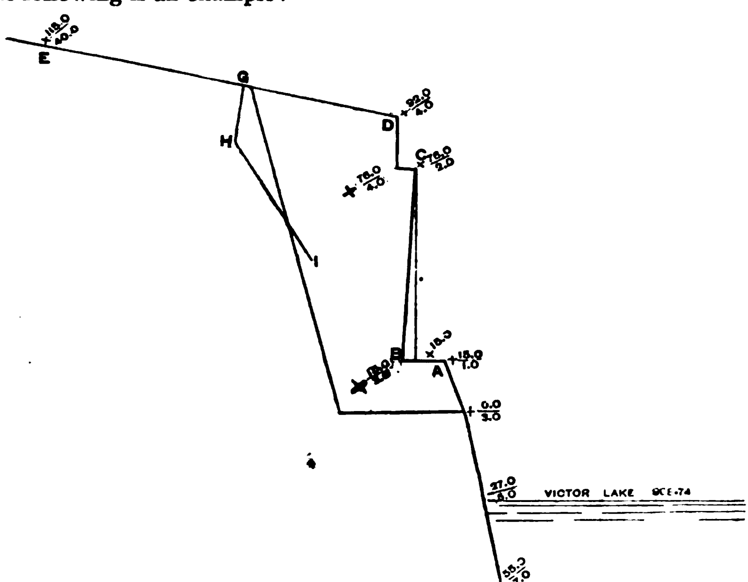
The different rod readings are kept on a small slip of paper, the necessary ones only being entered in the cross section book, these readings are necessary at the centre and at each slope stake, and also at each change in the slope of the ground as at D, or in general, so that the slope of the ground may be uniform between each reading.

On ground where the slope soon runs out to grade, the whole piece is taken out instead of leaving the small triangle AIK, K being the place where the lower slope stake would come with a 1 to 1 slope. On very irregular rocky grounds when changes of slope are numerous, as in the accompanying figure ABC, the fifteen foot rods are used. One rod DE is held perpendicular at the centre, while the other is held horizontal at F, the levels with which the rods are provided shew when they are perpendicular



and horizontal, and their intersection shew on the vertical one the height of F above D, and on the horizontal one the distance out from the centre. H D added to the cut at D gives the cut at F.

There are many cases in which the rods are not long enough to reach from one accessible point to another; some other device must then be adopted. The following is an example:

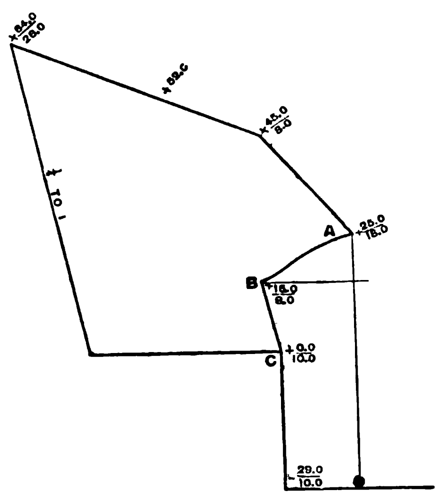


The centre A was accessible; and by going back on the line it was possible to climb up and get at D; the great difficulty here was to get the cut at C. A long rope was tied to a tree at E, and by this we could climb down and get to C.

A tape line with a heavy leaden plummet was first hung over the face of the cliff; but this was found to present too much surface to the wind, and was impossible to keep steady. We then got a quantity of battery wire made of the best copper wire, wound round with oiled cotton, and attached the plummet to it, which was marked at every five feet by pieces of flannel tied to it. It was then allowed to hang over the cliff, and lowered till the lower end was exactly level with the centre, and the height measured on the wire, this added to the fifteen feet cut at the centre gave the cut at C. The distance out was found by measuring from the centre to the plumb line. The height of D above C was found in the same manner. The water level of Victor Lake and the height of grade being known, the fill at the water's edge was easily determined. Soundings being then taken at F, etc., and the depth of the water added to the fill at the water's edge gave the total fill at F, etc.

This rock was badly broken at GHI, so that it was impossible that a ¼ slope would stand. We measured back to E and put in a stake to measure from and find the slope it actually did take.

The diagram below shews another place near Victor Lake. The cross sections as far as A were taken in the usual way, it being necessary in this case, as in a great many more, to have ropes to hold on by. A 100 foot tape was hung over the cliff in such a way that the fifty foot mark just touched A, the last point measured to.



The trouble was now to get to B, but by a combination of ropes this was managed. The horizontal rod was then held out from B, and the intersection read.

The cut and distance out to A could then be easily determined. When the rock was covered with earth to any extent, the earth had to be stripped off the rock, and the rock re-cross sectioned. When there was not more than a foot or two of earth, the depth of earth was often found by driving an iron bar through it till rock was found. Great care had to be taken in using this method, and it could only be used when the earth above the rock was entirely free from boulders. When the rock was covered with earth it was taken out in the following manner:

The rock was taken out to a slope of ¼ to 1, a berme of three feet being left on top of the rock, and the earth taken down to a slope of 1 to 1.

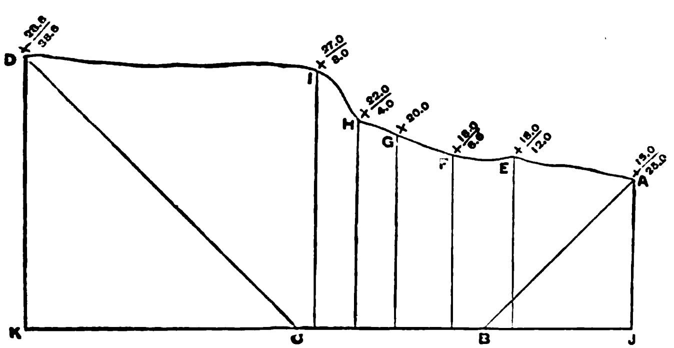
Cross section books were kept on the following manner :

Station	Elevat'n	Grade.	Rate	Left.	Centre.	Right.
729	1992.00	1940.0	$\frac{1}{.0}$	$\frac{+64.0}{26.0}$	+52.0	$\frac{+45.0}{80}$ $\frac{+25.0}{18.0}$ $\frac{+15.0}{8.0}$ $\frac{00}{100}$ $\frac{-29.0}{10.0}$

A separate book was kept for quantities, and all cross sections were plotted to scale, on paper specially made for that purpose. Great care has to be taken on this kind of work to get your B.C.'s and E.C.'s correctly referenced.

One end of each reference line should always be on a tree when possible as it is more easily found, when well blazed. The distances should also be measured to aid in finding the hubs.

The first thing to be done after the sections have been plotted is to calculate the areas.



Let ABCD be the sections to be calculated.

Some engineers first reduce this graphically to an equivalent triangle, and then calculate the triangle; others, again, divide it into a number of triangles scale the sides and calculate; but the best way, in my estimation, is to divide it into a number of trapeziums by dropping perpendiculars from AEFG, and all points at which the slope changes, on the base BC or BC produced. The different dimensions of these trapeziums being known, they can be calculated and added together, give the area of the figure AJKD, which is too large by the triangles, AJB and DKC. These can be calculated and subtracted and you have the required figure ABCD.

The calculation of the end areas should always be checked over before anything further is done, as the accuracy of all the following work depends on it.

To calculate the cubical contents, two methods were used by different engineers. The first by "average end areas." By this method the quantity book was kept in the following method:

EXCAVATION.						EMBANKMENT.					
Station	Area.	M. Area	Dis.	C. Yds.	C. Yds. per Sta.	Station	Area.	M. Area	Dis.	C. Yds.	C. Yds. per Sta.
618	2042.0										
+25	1896.6	1969.8	15								

To calculate the quantities by this method, you add the two end sections and divide by two, multiply this quantity by the distance or length and divide by 27. The result will be the number of cubic yards.

A table on the back of Trautwine's excavation tables gives you the number of cubic yards corresponding to every one-tenth of a foot of area, for 100 feet lengths.

To use this, you turn up the tables till you come to the required area; opposite this you will find the required number of cubic yards, if the mass is 100 feet long. If not, multiply by the length and divide by 100.

This gives results too large by a quantity represented by the formula $\frac{sld^2}{6}$, where s is the rate of the slope to unity, l the length, and d the difference in height between the end sections.

Another method is to deduce a mean area of the prismoid from the middle height, or arithmetical mean of the extreme heights, and multiply by the lengths. This method gives results too small by $\frac{sld^2}{12}$. (For demonstration see Gillespie's Roads and Railroads, appendix A, page 354).

For instance, if the difference in the extreme heights be 10 ft., the slope 1 to 7, and the length 25 ft., then $\frac{sld^2}{12} = \frac{1 \times 25 \times 10^2}{12} = 208.3$ cub. ft. $=$ 7.7 cub. yds.

One of the best books for railroad calculations is Rice's Excavation and Embankment Tables.

This contains, first, a table of areas of level, cross sections for every foot and tenth of a foot in height for the various widths of roadbeds, and rates of slopes. Second, tables of level cuttings for every tenth of a foot for prismoids 100 feet long, and also the correction to be added by the formula $\frac{sld^2}{12}$.

When using this method, the quantity book was kept in the following form:

EXCAVATION.						EMBANKMENT.					
Station	Area.	M. Hgt.	Dis.	C. Yds.	C. Yds. per Sta.	Station	Area.	M. Hgt.	Dis.	C. Yds.	C. Yds. per Sta

The areas of the cross sections were entered on the second column. From the first part of Rice's tables the height of an equivalent level sections was found and entered in the third column, the distance between the sections being entered in the fourth column.

To find the number of cubic yards in a prismoid, you add the two mean heights together and divide by 2. Find the number of cubic yards opposite this number in second part of tables, and to it add the number of cubic yards in correction table opposite the difference between the two mean heights, (column three.) Multiply by the length of the prismoid, (column four,) and divide by 100. The result being the number of cubic yards in the mass by the prismoidal formula.

When the ground is level across, it is not necessary to calculate the areas, the centre height being entered direct in the mean height columns.

When there are only three readings in the cross section, one at the centre and one at each slope stake, the area is calculated by Trautwine's rule. The extreme horizontal width multiplied by half the centre depth, plus the sum of the side heights multiplied by a quarter of the road bed.

ASPHALT PAVEMENTS.

E. F. BALL.

Before entering into the details of laying asphalt pavements, perhaps it would be advisable to refer briefly to the main features of their construction for the benefit of those who have not yet had occasion to study them.

Asphalt pavements were first constructed in France, in 1854, from a rock called asphalt rock, composed principally of carbonate of lime, saturated with a bituminous substance, somewhat resembling tar. Upon heating this rock it falls to a partially coherent powder, which when spread upon the foundation prepared for it, rammed, rolled, or otherwise compacted, assumes all the hardness and toughness of the original rock. It was found, however, that by mixing a suitable powder, as sand, carbonate of lime, etc., with a suitable cementing substance, such as asphalt obtained from the island of Trinidad, that a pavement could be made similar to that from the asphalt rock, possessing all its advantages, and when sand was used, having the additional one of not becoming slippery in wet weather.

A great diversity of opinion existed in regard to asphalt pavements, some upholding and others condemning them. The principal reason of their failure at first was owing to the fact that entirely unsuitable materials were used to take the place of the carbonate of lime and the asphaltic cement in the natural asphalt rock, as will appear from Mr. D. K. Clark's and Mr. Gillmore's works.

One of the principal points in the preparation of the matrix, or asphaltic cement, is to get it of the right consistency. For this purpose heavy petroleum oils are added to the refined Trinidad asphaltum in such proportions as will enable the mixture to maintain a proper degree of hardness, both summer and winter. Too much oil causing it to become soft and sticky in warm weather, and too little rendering it brittle and liable to crack in cold weather

In many cities in the States, especially in Washington and Buffalo, asphalt pavements have been laid very extensively and successfully. The method used in Buffalo at the present is practically the same as described by Gillmore.

Following are extracts from the "Inspector's copy of the specifications and description for grading, curbing, and paving of Linwood Ave., Buffalo, N.Y."

"Upon the sub-grade prepared as above mentioned, and between the curbstones firmly set as described, shall be laid a bed of Hydraulic Cement Concrete, six inches in thickness when compressed, to be made of one part best quality, freshly burned Rosendale, Buffalo, or Portland Cement, and two parts of clean sharp sand, free from clay, mixed dry, and then made into a mortar with the least possible amount of water. Broken stone not over two and one-half inches in their largest dimensions, thoroughly cleansed from dust and dirt, and drenched with water, must then be incorporated immediately with the mortar in such quantities as will give a surplus of mortar when rammed. This proportion when ascertained will be regulated by measure. Each batch of concrete must be thoroughly mixed, the mixing being continued on the board until each piece of stone is completely coated with mortar. It must then be spread, and at once thoroughly compacted by ramming until free mortar appears upon the surface. The whole operation of mixing and laying each batch will be performed as expeditiously as possible by a sufficient number of skilled men.

"No gravel must be used in the concrete," only pieces obtained by fracture.

"The upper surface must be made to conform to the contour of the roadway or pavement, and when finished must be protected from the action of the sun and wind until set" This is accomplished by spreading a little earth over it.

"WEARING SURFACE OR PAVEMENT PROPER.

"Upon the base above described the wearing surface is to be laid, two and one-half inches in thickness when compressed, and composed of,—

"1st. First Quality Refined Trinidad Asphaltum.

"2nd. Heavy Petroleum Oil, or the residuum of the same.

"3rd. Fine sand containing not more than one per centum of Hydrosilicate of Alumina.

"4th. Fine powdered Carbonate of Lime.

"The Trinidad asphaltum (so called) must be specially refined and brought to a uniform standard of purity and gravity. The heavy petroleum oils which may be residuum by distillation of the petroleum oils as found in the market, must be free from all impurities, and brought to a specific gravity of from 18° to 20° Beaumé, and a fire test of 250° Fahrenheit.

"By melting and mixing these two hydrocarbons, (petroleum oil and asphaltum), the matrix of the pavement, called asphaltic cement, is manufactured, which cement shall have a fire test of 250° Fahrenheit, and at a temperature of 60° Fahrenheit, shall have a specific gravity of 1.19. They must be mixed in about the following proportions by weight.

"Pure Asphalt	100	parts.
"Heavy Petroleum Oil	20	"

"The asphaltic cement being made in the manner above described, the pavement mixture will be formed of the following materials and in the proportion stated.

"Asphaltic Cement from	12 to	16
"Sand "	73 "	67
"Pulverized Carbonate of Lime	15 "	17
	100	100

"The carbonate of lime may be reduced or omitted entirely when suitable sand can be had. In order to make the pavement homogeneous the proportion of the asphaltic cement must be varied according to the quality and character of the sand.

"The sand and asphaltic cement are to be heated separately to about 300° Fahrenheit. The pulverized carbonate of lime while cold is mixed with the hot sand in the required proportions, and is then mixed with the asphaltic cement at the required temperature and in the proper proportion, in a suitable apparatus, which will effect a perfect mixture.

"The pavement mixture prepared in the manner thus indicated, will be laid on the foundation in two coats. The first coat, called the cushion coat, will contain from two to four per cent. more asphaltic cement than given above; it must be laid to such a depth as will give a thickness of one-half of an inch after being consolidated by a roller.

"The second coat, called the surface coat, prepared as above specified, must be laid on the cushion coat, being brought to the ground in carts at a temperature of about 250° Fahrenheit; and if the temperature of the air is less than 50°, iron carts with heating apparatus must be used in order to maintain the proper temperature of the mixture. It must be carefully spread by means of iron rakes, in such a manner as to give a uniform and regular grade, and to such depth, that after having received its ultimate compression of two-fifths, it will have a thickness of two inches. The surface must then be compressed by hand rollers, after which a small amount of hydraulic cement will be swept over it, and it must then be thoroughly compressed by a steam roller weighing not less than two hundred and fifty pounds to the inch run; the rolling being continued for not less than five hours for every thousand yards of surface.

"The powdered carbonate of lime will be of such degree of fineness that 16 per centum, by weight, of the entire mixture for the pavement shall be an impalpable powder of limestone, and the whole of it shall pass a No. 26 screen. The sand must be of such size grain that none of it will pass a No. 80 screen, and the whole of it shall pass a No. 20 screen.

"In order to make the gutters, which are consolidated but little by traffic, entirely impervious to water, a width of from twelve to eighteen inches next the curb must be coated with hot pure asphalt, and smoothed with hot smoothing irons, in order to saturate the pavement to a certain depth with an excess of asphalt."

DESCRIPTION OF IMPLEMENTS.

The hand roller referred to above, consists of a hollow iron cylinder about three feet in diameter, and three or four feet long, attached to a handle about twenty feet long. It is operated by two men wearing shoes without heels, to avoid making deep indents in the hot asphalt.

The steam roller consists of a boiler and engines mounted on three iron cylinders. The one forming the driving wheel, and bearing the greater part of the weight of the engine, is about four feet in diameter and four feet long. The hind roller is divided into two parts, placed side by side, and arranged to turn about an upright axis like the front wheels of a carriage, so that the whole machine may be steered in any direction. The engines consist of two cylinders with reversing gear, acting upon the driving roller by means of a beveled gear.

The sheet asphalt pavement, thus constructed, is impervious to water, smooth, noiseless, except for the clicking of the horses' hoofs, easily cleaned, not slippery, very durable, and capable of withstanding heavy loads. An instance is mentioned of a truck weighing four tons, carrying a boiler weighing twenty-one tons, passing over a sheet asphalt pavement without leaving a track. From the fact that it is entirely impervious to water and noxious liquids, promptly discharging them into the side gutters, it will be seen that it is a most healthy pavement; while its smoothness and noiselessness make it desirable for pleasure drives and for streets lined with residences. The effect of travel upon asphalt is to compact rather to wear it away, and if the foundation should settle, the sheet of asphalt will conform to it.