No. 6 1892-3

# PAPERS

READ BEFORE THE

# ENGINEERING SOCIETY

OF THE

## SCHOOL OF PRACTICAL SCIENCE

TORONTO

Published by order of the Society.

TORONTO:
THE J. E. BRYANT COMPANY
20 BAY STREET.

# CONTENTS.

# PREFACE.

The Engineering Society of the School of Practical Science was organized in the spring of the year 1885 by the students in the Department of Engineering of that year, assisted by Professor Galbraith.

Since that time the usefulness, size, and importance of the Society has been steadily increasing.

Meetings are held every alternate Wednesday in the academic year, when papers relating to engineering matters are read and discussed.

Up to the present time, our annual pamphlet has been published during the second term. Last session, however, it was decided to leave the publication of each year's papers over till the beginning of the following year. While this makes no material difference in the pamphlet, it gives more time to the committee to get the papers and advertising matter ready for the printers—a convenience which those connected with such work can well appreciate.

The papers in the present number have been contributed chiefly by students and graduates of the school.

The thanks of the Society are due especially to those graduates and other members of the engineering profession who have favored the Society with papers during the past year, and we trust that their example may be followed by others. Papers from men in actual practice are of special interest and value to students.

While the papers in this pamphlet are read and discussed chiefly for the benefit of stud nts, yet it is hoped that they may be not uninteresting to the profession at large.

The present edition consists of 1,000 copies, which will be widely circulated amongst engineers and those of allied professions.

DECEMBER, 1893.

## GENERAL COMMITTEE, 1892-3.

. . . . . .

**President:**
W. A. LEA.

**Vice-President:**
A. J. McPHERSON.

**Secretary:**
J. CHALMERS.

**Corresponding Secretary:**
JOS. KEELE.

**Treasurer:**
H. H. GIBSON.

**Librarian:**
WM. FINGLAND.

**Editor:**
G. L. BROWN.

**Graduates' Representative:**
E. B. MERRILL, B.A.

**Second Year Representative:**
A. T. FRASER.

**First-Year Representative:**
A. E. BLACKWOOD.

## GENERAL COMMITTEE, 1893-4.

. . . . . .

**President:**
J. D. SHIELDS.

**Vice-President:**
H. ROLPH.

**Secretary:**
J. C. ARMSTRONG.

**Corresponding Secretary:**
W. A. BUCKE.

**Treasurer:**
A. T. TYE.

**Librarian:**
H. F. BARKER.

**Editor-in-Chief:**
H. F. BALLANTYNE, Grad. S.P.S.

**Assistant Editor:**
A. E. BERGEY.

**Graduates' Representative:**
E. B. MERRILL, B.A.

**Second-Year Representative:**
F. W. GUERNSEY.

**First-Year Representative:**
H. B. POLIWKA.

# LIST OF MEMBERS.

## HONORARY MEMBERS.

J. Galbraith, M.A., M. Can. Soc. C.E.

E. J. Chapman, Ph.D., LL.D.

Col. Sir Casimir S. Gzowski, A.D.C., M. Inst. C.E., M. Can. Soc. C.E.

W. H. Ellis, M.A., M.B.

Coleman, A. P., M.A., Ph.D.

## LIFE MEMBERS.

Allan, J. R.
Allen, T. R.
Anderson, A. G.
Apsey, J. F., O.L.S.
Ashbridge, W. T.
Ball, E. F., A.M. Can. Soc. C. E.
Ballantyne, H. F.
Bowman, F. M., O.L.S., C.E.
Bucke, M. A.
Bucke, W. A.
Burns, D., O.L.S.
Canniff, C. M.
Carey, A. B.
Chewett, H. J., C.E., A.M. Can. Soc. C.E.
Clement, W. A.
Duff, J. A., B.A.
Dunn, T. H.
Fairchild, C. C.
Fraser, A. T.
Gibbons, J., O.L.S.
Goodwin, J. B.
Handy, J. B.
Haultain, H. E. T.
Irvine, J.
James, D. D., O.L.S., B.A.Sc.
Keele. J.
Lane, A.
Laschinger, E. J., B.A.Sc.
Lea, W. A., B.A.Sc.
Leask, J. D.
Lott, A. E.
Marani, C. J.
Martin, F. A., O.L.S.
McAllister, J. E.
McAllister, A. L.
McKay, O., O.L.S.
McMaster, E.,
McPherson. A. J.
McTaggart, A. L.
Merrill, E. B., B.A.
Mitchell, C. H.
Mickle, G. R., B.A.
Mill, F. X.
Moore, J. E. A.
Moore, H. H.
Newman, W. M., O.L.S.
Peterson, C. E.
Pinhey, C. H., O.L.S., D.L.S.
Raymer, A. R.
Richardson, G. H.
Rolph, H.
Rose, K.
Rosebrugh, T. R., M.A.
Russell, T. S., O.L.S.
Wright, C. H. C., B.A.Sc.
Stewart, L. B., O.L.S., D.L.S.
Silvester, G. E., O.L.S.
Shillinglaw, W. H.
Squire, R. H.
Symmes, H. D.
Thomson, T. K., C.E.
Thomson, R. W., B.A.Sc.
Wilkie, G.

## ORDINARY MEMBERS

Allison, T. H., B.A.Sc.
Allan, A. A.
Angus, R. W.
Armstrong, J.
Baker, H.C.
Bain, J. W.
Barker, H. F.
Beatty, H. J., O.L.S.
Bell, A.
Bennett, H. J.
Bergey, A. E.
Betty, H. K.
Beauregard, A.
Blachford, W. A.
Blackwood, C. K.
Blackwood, A. E.
Black, C. A.
Black, R. G.
Bolton, A.
Booth, F. E.
Boswell, E. J.
Brebner, G.
Boulton, W. R.
Bowman, H. J., O.L.S., D.L.S.
Bowman, L. M.
Bowman, A. M., O.L.S., D.L.S.
Boustead, W. E., B.A.Sc.
Boyd, D. G.
Boyd, J. L.
Brodie, W. M.
Brown, D. B., O.L.S.
Brown, G. L.
Brown, R. M.
Burton, F.
Bush, J. E.
Campbell, G. M.
Campbell, R. J.
Cant, G. F.
Carpenter, H. S.
Carrol, H.
Chalmers, J.
Chalmers, W. J.
Clark, J. T.
Clement, W. A.
Connor, A. W.
Corrigan, C. D.
Coltors, W. H.
Coyle, J.
Crews, H. R.
Cronyn, J.
Deacon, T. R., O.L.S.
DeCew, J. A.
Dill, C. M.
Dobie, J. S.
Douglas, G. M.
Duggan, G. H.
Dunbar, M.
Eamen, J. A.
Elliott, H.
Evans, J. W.
English, A. B.
Ewart, J. A.
Fairbairn, J. M.
Fawcett, A.
Fawell, J. H
Field, G.

Filion, G. A.
Fingland, W.
Fleming, J.
Forester, C.
Forward, E. A.
Fowler, C. P.
Francis, W. J.
Freeman, A. C.
Garland, N. L.
Gibson, H. H., O.L.S.
Goldie, A. R.
Gordon, B.
Gordon, J. P.
Graham, W. A.
Gray, R. A.
Gurney, W. C.
Guernsey, F. W.
Hale, W. B.
Hamilton, R.
Handy, E. F.
Hanning, G. F.
Harkness, A. H.
Harrison, J.
Harman, O. E.
Hartman, G.
Harvey, J. A.
Herald, W. J.
Hermon, E. B., O.L.S., D.L.S.
Hewett, C. H.
Hill, H. V.
Hinde, E. W.
Hull, H.
Hutcheon, J., O.L.S.
Innes, W. L., O.L.S., C.E.
Jackson, T. C.
Jameson, A. P.
Jameson, J. W.
Job, H. E.
Johnston, A. C.
Johnson, G.
Johnson, S. M.
Johnson, R. T., O.L.S.
Jones, J.
Karn, F. M.
Kennedy, J. H., O.L.S., C.E.
Kerr, R.
King, C. F.
Laidlaw, J. T.
Laing, A. T., B.A.Sc.
Laing, W. F.
Laird, R., O.L.S.
Langley, C. E.
Lash, F. L.
Lash, N. M.
Latimer, R. S.
Lawrie, R. R.
Lea, E. P.
Logier, D.
Macallum, A. F.
Macmillan, W. G.
MacFarlen, T. J.
MacMurchy, J. A.
Main, W. T.
Marani, V. G.
Martin, T.
Mather, C. D.
McAree, J., O.L.S., D.L.S., B.A.Sc.
McClellan, J.
McCulloch, A. L., O.L.S.
McCullough, A. W.
McDowall, R., O.L.S.
McFarlen, G. W., O.L.S.
McGowan, J., B.A.
McGregor, J.
McKay, F. G.
McKay, W. N.
McKechnie, R. S.
McLellan, R.
McKinnon, H.
McMaster, C.
McPherson, C. W.
Meade, H.
Meadows, W. W.
Millar, F. G.
Milne, C. G., B.A.Sc.
Mines, W.
Minty, W.
Mollins, C. B.
Moodie, G. W.
Moore, J. H., O.L.S.
Moore, I. E., B.A.
Morphy, E. J.
Morris, J. L., O.L.S., C.E.
Murray, D. B.
Murray, W.
Nairn, J.
Nicholson, C. J.
Patterson, G.
Parker, W. G.
Pedder, J. R., O.L.S.
Pease, H. C.
Playfair, N. L.
Poliwka, H. B.
Poussette, H. R.
Prentice, J. M.
Proudfoot, H. W.
Rees, J. L.
Rings, H. C.
Ritchie, N. T., O.L.S.
Robertson, C. G.
Robertson, J. M.
Robinson, F. J.
Roger, J., O.L.S.
Roberts, W. M.
Ross, J. E., O.L.S.
Ross, D. W.
Ross, R. A.
Ross, J. A.
Roy, A.
Russell, W.
Russell, R.
Sanderson, A. E.
Scott, W. F.
Shipe, E. F.
Shipe, R. R.
Shields, J. D.
Simpson, A. E.
Sims, H. B.
Sifton, E. J.
Smith, A.
Smith, A. D.
Smith, J. N.
Speller, F. N.
Spotton, A. K.
Stacey, G. E.
Stern, E. W.
Stevenson, D.
Stewart, J. A., M.A.
Stocking, F. L.
Sullivan, E. A.
Tate, E. F.
Troup, G. E.
Taylor, W. V.
Tucker, C. R.
Tye, W. F.
Tye, A. T.
Tyrrell, H. J., O.L.S., D.L.S., C.E.
Wade, H. R.
Walker, J.
Warren, E. C.
Watson, R. B.
Watson, J. W.
Webster, E. B.
Wells, J. R.
Wellington, E. S.
White, A. V.
White, G. W.
Whitson, J. F., O.L.S.
Wickett, T.
Wickson, T. R., O.L.S.
Wickson, R.
Wiggins, T. H., O.L.S.
Wilson, C. H.
Williams, J. C.
Withrow, W. J.
Wood, H. T.
Wright, R. T.
Wright, T. D.

# ENGINEERING SOCIETY

OF

# The School of Practical Science

TORONTO.

---

## PRESIDENT'S ADDRESS.

GENTLEMEN,—As this is not our first meeting I cannot open, as is customary, by bidding you welcome to another year of the Society's work. As most of you know, the president was duly elected last spring; but as he has left us for other spheres of labor, for a while his office was vacant, which vacancy you have seen fit to appoint me to fill. When I think of the ability and fluent speech of the gentleman I am called upon to replace, and when I remember those who have presided over these meetings for the past three years, I am made to feel my own incompetency and want of experience, and particularly does a consideration of the present importance and development of the Society force this upon me; so I feel that I have good reason to be grateful to you, gentlemen, for your expression of confidence in appointing me to this office, and I assure you that I am fully awake to and thoroughly appreciate the honor you have conferred upon me.

You have chosen a committee which will, during the coming year, fully sustain the Society's usefulness, and in whose care its progress is safe.

But here, gentlemen, I wish to remind you of the reason for the existence of your committee; that your officers are appointed to attend to business details and to procure the even working of the Society's meetings, so that its members may be free to carry out the purposes for which it was organized.

I think there is a tendency to overlook the fact that it is the members that constitute the Society, and that it is only by their active participation in its affairs that its continuance is justified. Your officers you have selected to be your servants, and the well-being of the Society lies as much in your own care as in theirs. And surely, gentlemen, they who systematically give up a portion of their time for our interests may reasonably ask for that sense of support that is felt from the vigorous manifestation by each member of his close interest in the affairs of the Society.

It may seem to be an expression of confidence to accept the work of your committee without comment, but surely it is evident that such a course of action will not work for the good of the Society; will be harmful to yourselves, in fostering a spirit of dependence and want of interest; will cost you many a valuable chance of learning readiness of speech and facility of sensible criticism; and will also be harmful to your officers, in encouraging hasty and careless work, and in diminishing their activity. I would, therefore, urge that each member would make a point of fully understanding the affairs of the society, make sure that full information is given upon every obscure matter, in the regular meetings, and see that no business pass without its rightful amount of discussion. Indeed, gentlemen, the progress of the Society will rest mainly with yourselves during the coming session. It is altogether too large a ball for your officers to keep rolling unaided. They only constitute its machinery. Its energy, its life, must come from you. I urge you, in your determination to make this year's meetings a success, and in your energetic interest and watchfulness, that you keep continually in advance of your committee, so that it may be encouraged in its labors, and roused to further efforts.

There are two good reasons for pressing this point upon you. In the first place, the Society has grown to proportions such that its affairs require careful handling. If you will consider how widely it is becoming known, the amount of money involved in its undertakings, and its rapid growth, you will be ready to admit that mistakes in its management may start a train of serious consequences, and, therefore, that your full knowledge and careful consideration will be needed. I have already mentioned the other reason, namely, the good to be gained by making use of the opportunities for speaking. Let me briefly remind you of this important matter. The time for our meetings is taken out of our regular working hours, and this means that these meetings are recognized by the Faculty as forming a part of the regular course—a necessary part of our education here. They do this in many ways, and as these are set out in the constitution, and in several numbers of our publications, I would refer you to these sources, and simply mention one item of our required accomplishments. In these days all professional men come to be concerned, sooner or later, with public meetings—in railway committees and boards; in civic committees; in various societies; in politics, perhaps. It is one of the tendencies of the time, and therefore it is advisable for us to learn the proper system of carrying on meetings, and to study the correct methods of procedure, while we are students and among friends. It may prove of greater value to us than we think, in our immediate future, that we have gained familiarity and readiness in the customs of public assemblies. And we have excellent opportunities for such practice; so let us endeavor to make full use of them. To do this we will require to be able to express our wishes or ideas in plain and simple language. We know that this art does not come readily to all, but it is a most needful accomplishment, and each one should spare himself no effort and heed no failure in his work to acquire it; for, like everything else, it is learned by successive attempts. I think we ought to look upon our Society as a field for doing practical work in these subjects, which are just as important to us as any other that we take up. It is said that the most important part of a man's education is that which he gains himself; and here, on these afternoons, the time is given to us for this very purpose of self-training. We are left to our own efforts.

This is taking a narrow view of the purposes of our Society, but I wish to confine myself to one or two contemporary matters.

There has now come about a tendency to separation between the four years that did not formerly exist, at least to the present extent. These meetings will give us an excellent counter-tendency, bringing us into better relations, and promoting a friendly knowledge of one another. Again, the four branches of the professions are now well established, introducing a division of a different nature—one that will affect the individual in his relation to his calling and general habits of mind, rather than the student body as a whole. We are compelled, more and more, to confine our attention to smaller regions in our work, becoming specialists, with the attendant risks of narrow sympathies and one-sided views. We are fully aware of the need of a wide general knowledge of engineering matters, as well as a narrow special one. But we have, as yet, hardly realized our power to limit our interests, to destroy our relish for the doings of our fellows, and to petrify us into a small daily routine, by the constant vigorous application of our energies along one channel. Now, here, while we are plastic, we can form habits of mind that will go far towards preserving us from the encroachments of this spirit of narrowness. If, in these meetings, we are accustomed to take an intelligent interest in and to discuss papers upon matters not belonging to our own chosen branch, it is very probable that the liberal-mindedness thus begun in us here will grow into a part of our mental furniture, and we shall see before us the possibility of becoming well-informed men as well as engineers.

Gentlemen, one of the objects of this Society is to give students the opportunity of reading a paper upon some subject of which they have practical knowledge, or in which they are interested. Let us remember this, that while we are grateful to and appreciate the kindness of those gentlemen who so often help us, yet one of the main objects of the Society is that we follow their example and write papers ourselves. The time will be well spent, the preparation itself is a valuable source of learning, and the information gathered will be of benefit to the Society ; and besides, apart from the subject-matter, the very processes of reading and discussion require practice, and will be of great benefit to you. It will be well, then, for you, by papers, to give yourself the chance of knowing what you can do, and where your faults lie, and your fellow-members the material upon which to exercise their attention and judgment, and the opportunity to practise discussion.

W. A. LEA.

# BRIDGE SPECIFICATIONS.

By T. KENNARD THOMSON, C.E.

The writer begs to submit some bridge specifications drawn up by himself last winter, with a few comments on the same, in hopes that they may prove of interest to our Society. It is hoped that these specifications will be thoroughly discussed by the members, for, as a rule, the discussion of papers is much more valuable than the papers themselves. Many members of the American Society of Civil Engineers read the discussion before the original articles. The writer will be only too glad to answer any questions or criticisms to the best of his ability, if the secretary will kindly advise him thereof.

These specifications are very much shorter than usual, as an attempt has been made to cut out much that is merely cumbersome. Bridge specifications are generally as lengthy, verbose, and vexatious as a lawyer's document. They are useless in the hands of the inexperienced, and too long for an expert.

**General Specification, Iron and Steel Bridges.**

## PROPOSAL.

### BIDS.

1. Bidders will submit sealed proposals on the basis of so much per pound in the finished structure.

### CONTRACT.

2. It is understood that when a tender is submitted, the contractor agrees to be bound by these specifications, and by the stipulation in the letter of invitation as to the time of completion.

### PATENTS.

3, Should the contractor make use of any patented device, he shall protect the railroad company against any or all claims on account of the use of such patents.

## DRAWINGS.

### APPROVAL.

4. As soon as possible after the contract has been awarded, the contractor shall supply the engineer with a complete set of all stress sheets, working drawings, bills of material, and cards of all pins, bars, rods, etc.

No work shall be done until these have been approved in writing by the engineer, and after their approval no change shall be made except with his consent or direction in writing.

### DRAWINGS FOR FILE AND INSPECTORS.

5. Three complete sets of drawings, bills, and cards shall be furnished the engineer free of charge, two sets being for his file and one set for his inspectors.

6. All necessary dimensions shall be given by plain figures.

## GENERAL DESIGN.

7. Masonry plans for each bridge will be furnished by the engineer, and, unless otherwise stated, for bridges of:

80 feet span and under, plate girders will be used.

80 to 120 feet, lattice girders will be used.

120 feet and over, pin-connected trusses will be used.

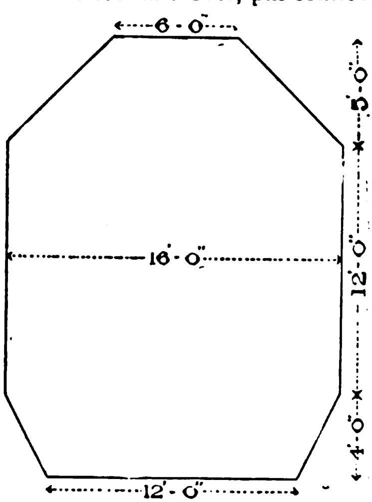



Fig. 1.

### SPACING OF TRACKS.

8. The distance from centre to centre of double tracks will be thirteen feet.

### CLEARANCE.

9. On a straight line a clear section as per diagram (Fig. 1) must be provided for single track bridges.

The width must be increased so as to allow the same minimum clearance when the bridge is on a curve or double-tracked.

10. Bridges on curves will have the outer rail elevated as follows :

| | | |
|---|---|---|
| For a 1° curve elevate the outer rail | | 1 inch. |
| " " 2° " " " " | " | 2 inches. |
| " " 3° " " " " | " | 3 inches. |
| " " 4° " " " " | " | 4 inches. |
| " " 5° " " " " | " | 4¾ inches. |
| " " 6° " " " " | " | 5½ inches. |
| " " 7° to 12° " " " | " | 6 inches. |

SPACING OF STRINGERS.

11. Deck girders and track stringers will generally be spaced not less than seven feet apart, centre to centre.

## CALCULATION.

### DEAD LOAD.

12. The dead load shall consist of the weight of the entire superstructure; the weight of the wooden ties, guard rails, and rails shall be assumed as 450 pounds per lineal foot of track.

13. Two-thirds of the dead load shall be considered as applied to the panel points of the chord supporting the floor, and one-third to the other chord.

### LIVE LOAD.

14. All plate girders and spans under eighty feet shall be designed to carry (in addition to the dead load) a live load of 4,000 pounds per foot, of which 136,000 pounds is liable to be concentrated on four axles thus:

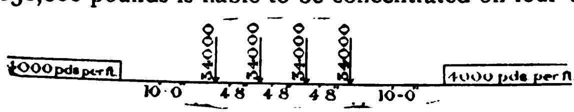



Fig. 2.

or 80,000 pounds to be concentrated on two axles thus: Fig. 3.

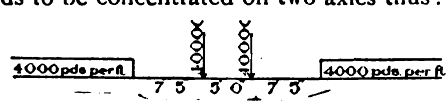



Fig. 3.

All trusses shall be designed (in addition to the dead load) for a uniform live load of 4,000 pounds per lineal foot of track, and also two concentrated loads of 20,000 pounds each, to be placed fifty feet apart.

### WIND.

15. The top and bottom lateral systems shall each be proportioned to resist a uniformly distributed lateral force of 150 pounds per lineal foot, and the lateral system nearest the floor shall (in addition to the above) be

proportioned for a moving lateral force of 300 pounds per lineal foot. For spans over 200 feet, add ten pounds per foot to each lateral system for every additional twenty-five feet of span.

### CENTRIFUGAL FORCE.

16. If the bridge is on a curve, the lateral bracing must be proportioned to resist (in addition to the wind stresses) a centrifugal force equal to three per cent. of the live load on all tracks for each degree of curvature.

### CO-EFFICIENT OF FRICTION.

17. The friction due to applying brakes shall be considered as equal to twenty per cent. of the live load.

18. Shipping weights shall in no case differ from the calculated weights by more than 2½ per cent.

## UNIT STRESSES.

### TENSION.

19. In tension members the unit stress caused by the dead and live loads shall in no case exceed the following:

### MATERIAL.

| | Stress per square inch | |
|---|---|---|
| | IRON. | STEEL. |
| For lateral | 15,000 | 18,000 |
| For "I" beams | 7,500 | 9,000 |
| For plate girder flanges (under 60′ span) | 8,000 | 9,500 |
| For plate girder flanges (60′ spans and over) | 8,000 | 10,000 |
| For lattice girders—bottom flanges | 8,000 | 9,500 |
| For bottom chords and main diagonal spans, under 150 feet—forged bars | 9,000 | 10,000 |
| For bottom chords and main diagonal spans, 150 feet and over—forged bars | 10,000 | 12,000 |
| For bottom chords and main diagonal spans, plates and shapes—forged bars | 8,000 | 9,500 |
| For counters and long verticals—forged bars | 8,000 | 9,500 |
| For counters and long verticals, plates and shapes | 6,500 | 7,500 |
| For floor beam hangers and similar members—forged bars | 6,000 | 7,000 |
| For floor beam hangers and similar members, plates and shapes | 5,000 | 6,000 |

20. Steel eyebars will be preferred.

COMPRESSION.

21. In compression members the maximum allowable unit stress due to the dead and live loads shall be determined by the following formulæ:

| | IRON. | STEEL. |
|---|---|---|
| For two square ends, | P = 9,000—30 l/r | P = 11,000—35 l/r |
| For 1 square end, | P = 9,000—35 l/r | P = 11,000—42 l/r |
| For 2 pins ends, | P = 9,000—40 l/r | P = 11,000—48 l/r |
| For lateral struts, | P = 12,000—50 l/r | P = 14,400—60 l/r |

Where:—

P allowable stress per square inch.

l length of member in inches.

r least radius of gyration in inches.

COMBINED STRESSES.

22. The unit stress caused by the dead and live loads and wind and centrifugal forces combined shall not exceed the above limits by more than twenty-five per cent.

ALTERNATE.

23. Members subject to alternate tensile and compressive stresses shall be proportioned for both kinds of stress. Each stress, however, shall be increased by an amount equal to $\frac{8}{10}$ of the other stress before determining the dimensions by the above unit stresses.

TRANSVERSE LOADING.

24. In case any member is subject to a bending stress in addition to its stress as a member of the structure, it must be proportioned so that the algebraic sum of the stresses per square inch on the outer fibre, due,

First, to the dead load;

Second, to the direct thrust or pull;

Third, to the maximum bending moment produced by the heaviest loading,

shall not exceed the before mentioned permissible working stresses in tension or compression.

SHEARING.

25. The shearing force on any member shall not exceed 7,500 pounds per square inch; on field rivets the shearing force shall not exceed 6,000 pounds per square inch.

BEARING.

26. The bearing on bolts, rivets, and pins, shall not exceed

12,000 pounds per square inch for iron;

15,000 pounds per square inch for steel.

### BENDING.

27. The bending stresses on the extreme fibres of pins shall not exceed
15,000 pounds per square inch for iron ;
20,000 pounds per square inch for steel ;
when the centres of bearing of the strained members are taken as points of application.

## MINIMUM SECTIONS.

### THICKNESS.

28 No iron or steel shall be used, except as fillers, of less than ⅜ inch thickness.

### WIDTH.

29. No iron in compression shall have an unsupported width of more than 40 times its thickness.

### LATERAL RODS.

30. No lateral or sway rods shall be used having a less section than one square inch.

### COUNTERS.

31. The minimum section allowed for any counter rod shall be 1½ square inches.

## DETAILS.

### TIES.

32. Cross ties shall be for
Deck bridges 8 x 10 inches x 14 feet.
Through bridges 8 x 10 inches x 10 feet.
Laid flat and dapped ½ an inch over supports and spaced 15 inches, centre to centre.

### STRESS ON TIES.

33. In no case shall the fibre stress caused by a load of 50,000 pounds on one axle carried by three ties exceed 1,000 pounds per square inch.

### GUARD.

34. There will be four pine or spruce guard rails, each 6 x 8 inches, laid flat, dapped one inch on ties, and bolted to every third tie by a ¾ inch bolt with a flat rounded headed and a square shoulder one inch long— the head to be placed upwards, and each bolt secured by two hexagonal nuts. The inner guard rails will have not less than eight inches and the outer guard rails eleven inches clearance between the timber guard rail and the metal rail.

The guard rails shall be continued for thirty feet beyond the bridge at each end—the outer ones being flared, and the inner ones brought to a point. The bolts through the outer guard rails will be connected to the stringer by means of lug washers.

### CAMBER.

35. Truss bridges are to be cambered by increasing the length of the top chord ⅛ of an inch for every ten feet.

### ANCHORS.

36. Bridges must be secured from side or vertical motion.

### ROLLERS.

37. All spans of seventy feet and over must have nests of turned rollers working on planed bearings.

The weight on rollers shall not exceed $500 \sqrt{d}$ pounds per lineal inch; $d$ being the diameter of rollers in inches.

### BEARING ON MASONRY.

38. Bearing plates shall not have a greater pressure on masonry than 200 pounds per square inch.

### CONTINUOUS BED PLATES.

39. Where two spans rest on the same masonry, a continuous wrought iron or steel plate shall extend under the adjacent bearings.

### RIVET SPACING.

40. Rivets shall not be placed farther apart in the direction of the strain than six inches, nor more than sixteen times the thickness of the thinnest external plate.

Where the ties rest on the top flange, the rivets in the vertical leg of the angle shall not be more than five inches apart.

### RIVETED LATERALS.

41. Riveted laterals will be preferred to adjustable rods. It is clearly uuderstood that the general and detail design shall be first class and satisfactory to the engineer in every respect, as these specifications are not intended to take the place of the bridge engineer.

## QUALITY OF MATERIAL.

### CAST IRON.

42. Cast iron will not be used without permission in writing from the engineer.

Except where chilled iron is specified, all castings shall be of tough gray iron, free from injurious cold shuts or blow holes, true to pattern, and of workmanlike finish; sample piece 1″ square, cast from the same heat of metal in sand moulds, shall be capable of sustaining on a clear span of 4′ 6″ a central load of 500 pounds when tested in the rough bar.

### WROUGHT IRON.

43. All wrought iron must be tough, fibrous, uniform in quality throughout, free from flaws, blisters, and injurious cracks, and must stand the following tests:

| | TENSILE TESTS. | | | | COLD BENDING. | |
|---|---|---|---|---|---|---|
| | Elastic Limit. | Ultimate Strength. | Per cent. Elong. | Per cent. Reduct. Area. | | Diameter; Bent Around |
| Kind of Material | | | | | | Twice Thickness of Plate. |
| Bar iron up to 4½″ square | 26,000 | 50,000 | 15 | 20 | 180 | " |
| Bar iron over 4½″ square | " | 48,000 | " | " | " | " |
| Channel Iron | " | " | " | " | 160 | " |
| "I" Beams | " | " | " | " | " | " |
| Angles | " | " | " | " | 140 | " |
| Other shapes | " | " | " | " | 120 | " |
| Plates of 18″ and under | " | " | " | " | 160 | " |
| Plates from 18″ to 36″ | " | " | 12 | 16 | 100 | " |
| Plates from 36″ to 54″ | 25,000 | 46,000 | 10 | 10 | 90 | " |
| Plates over 54″ | " | " | 8 | 8 | " | " |

### RIVET IRON.

44. Rivet iron shall be subject to the same requirements as tension iron of the same dimensions, and shall be further capable, without cracking or serious abrasion, of being heated to a good forging heat, made up into rivets, allowed to cool, reheated and driven as in riveting; again cooled, nicked, and cut out, when it must show a good, tough, fibrous structure, without any crystalline appearance.

### RIVET STEEL.

45. Rivet steel shall have an
Elastic limit of not less than 30,000 pounds per square inch.
Ultimate strength of not less than 52,000 pounds per square inch.
Ultimate strength of not more than 60,000 pounds per square inch.
And a minimum stretch of twenty-five per cent. in eight inches.

It shall bend double on itself without showing fracture, and after being subjected to the same practical test as iron rivets shall show a good silky fracture, with no crystalline appearance.

### STEEL.

46. Steel when tested in the specimen shall have an elastic limit of not less than 35,000 pounds per square inch.

An ultimate strength of not less than 56,000 pounds per square inch.
An ultimate strength of not more than 68,000 pounds per square inch.
A minimum stretch of twenty-two per cent. } after breaking in a length
and a reduction of area of forty per cent. } of eight inches.

It shall bend double without fracture.

### ROUGH EDGES.

47. All rolled material, iron or steel, with rough edges will be rejected.

### TEST SPECIMENS.

48. Test specimens of either iron or steel shall not be annealed, heated, hammered, forged, or otherwise treated.

### SELECTION OF TEST PIECE.

49. The inspectors shall in all cases stamp the piece of iron or steel which is to be cut off for a test piece.

### INSPECTION.

50. All facilities for inspection, testing, and weighing shall be furnished by the contractor, free of charge; and each finished member shall be weighed separately.

ACCEPTANCE BY INSPECTOR.

51. The acceptance of any material or finished member by the inspectors shall not prevent subsequent rejection of the same if found defective after delivery or erection; and the contractor shall replace the rejected material or member without extra compensation.

FULL-SIZED TEST STEEL.

52. Full-sized members tested to breaking must break in the body, and have an

Elastic limit of at least 33,000 pounds per square inch.

Ultimate strength of at least 56,000 pounds per square inch.

And a minimum stretch of ten per cent.

If these conditions are fulfilled, the contractor shall be remunerated for the broken members at the contract price per pound, less their scrap value.

ANNEALING.

53. All steel which has been worked hot shall be properly annealed.

PHOSPHORUS.

54. No steel will be accepted which has more than $\frac{8}{100}$ of one per cent. of phosphorus.

VARIATION IN WEIGHT OR AREA.

55. No material will be accepted which varies more than 2½ per cent. in weight, or cross section from that specified.

BLOW NUMBER.

56. Each ingot shall be plainly marked with the blow or charge number, and shall afterwards have this number stamped near the middle of each piece of finished material rolled from it.

DRIFTING TESTS IN STEEL.

57. Drifting tests shall be made in each varying size of steel plates and angles by punching a ¾" hole 1½" from the edge, and shall be proven capable of having these holes expanded by means of a sledge on a drift-pin until the holes become 1½" in diameter, without fracturing the steel.

## WORKMANSHIP.

58. All workmanship must be first-class, and satisfactory to the engineer in every respect.

### ABUTTING SURFACES.

59. All abutting surfaces must be planed or turned to insure even bearings, taking light cuts so as not to injure the end fibres, and must not be protected by white lead and tallow.

### RIVET HOLES.

60. Rivet holes must be carefully spaced and punched, and must be, in all cases, reamed to fit where they do not come truly and accurately opposite without the aid of drift-pins.

### FLOOR BEAMS CONNECTIONS.

61. All holes for floor beams, and stringer and floor beam and post connections, must be accurately drilled to an iron templet.

### RIVET HOLES IN STEEL.

62. Rivet holes in steel over $\frac{5}{8}''$ thick shall be drilled or punched $\frac{3}{16}''$ smaller and reamed.

### PAINTING.

63. All iron or steel must receive one coat of good linseed oil as soon as rolled; one coat of approved paint (red lead and linseed oil) before leaving the shops; and two coats of the same after erection.

All inaccessible surfaces are to be painted before assembling. All iron or steel to be scraped clean from dirt or scale before painting.

No painting shall be done in wet or freezing weather.

### ERECTION.

64. The contractor shall furnish all the falsework and arrange the same so as not to obstruct any thoroughfare by land or water; shall furnish and erect the entire superstructure ready for the rails; shall remove, without injuring it, and carefully load on cars, the old structure, if any; and shall assume all risk of accidents to men or material, until the acceptance of the completed structure by the engineer.

### FINAL TEST.

65. If required by the engineer, the bridge shall be tested before the acceptance by loading it up to the requirements of the specifications for any length of time (up to 24 hours) he may desire; the bridge must then return to its original shape, without permanent set.

# HIGHWAY BRIDGES.

### DEAD LOAD.

66. The dead load will be the weight of the structure; the timber being assumed to weigh four pounds per foot board measure.

### LIVE LOAD.

67. The contract will state which class is to be used.

Class A will have a live load of one hundred pounds per square foot of floor.

Class B will have a live load of eighty pounds per square foot of floor.

Class C will have a live load of sixty pounds per square foot of floor

### WIND STRESSES.

68. Same as for railroad bridges.

## UNIT STRAINS.

### THICKNESS.

69. The minimum thickness will be $\frac{5}{16}$ of an inch.

### LATERAL RODS.

70. The minimum section for lateral rods will be ¾ square inches.

### FIBRE STRESS ON TIMBER.

71. The maximum fibre stress on timber will be 1,000 pounds per square inch.

## QUALITY OF MATERIAL, ETC.

72. The quality of material, inspection, painting, workmanship, erection, etc., will be generally the same as for railroad bridges.

---

### Comments.

---

The following comments are numbered the same as the articles to which they refer.

7. It will be noticed that lattice girders are required for spans between 80 and 120 feet, as this is considered good practice. The writer, however, would prefer to do away with lattice girders altogether. He would use plate girders up to 90 or 100 feet, and then, if a span between a 100 and 120 feet was required, he would use a 120 feet pin connected truss. A well-designed lattice girder between these limits would probably cost more than

a good 120 feet pin, so why not use the longer and cheaper span? The New York Central R. R., under its very able bridge engineer, uses very heavy plate and lattice girders, the latter up to 200 or 300 feet span. The Coteau Bridge over the St. Lawrence has 240 feet lattice spans.

But the more the writer has to do with this kind of bridge, both in the field and shop, the more he dislikes lattice girders.

8. Double tracks on a bridge should be not less than thirteen feet apart, centre to centre; but it is not always possible to get this width without spreading the tracks, which would be objected to.

9. Most specifications call for a width in the clear of fourteen feet between trusses, but it would be much better to increase this to sixteen feet, as shown, as it would make a more rigid bridge and be safer in case of derailment, etc.; though, of course, slightly more expensive. The writer sent the Society last winter a copy of his N. & W. R. R. tables, showing the clearance required on curves.

10. The elevation suggested for the outer rail on curves is considerable, but is less than the Pennsylvania R. R. or N. & W. R. R. standards. These roads elevate the outer rail seven inches for curves of eight degrees and over.

13. It is accurate enough to consider two-thirds of the dead load as carried by the chord supporting the floor system, and, of course, saves labor, which should always be considered.

14. When engineers first began to calculate bridge stresses, a uniform load of, say, 2,000 or 3,000 pounds per lineal foot was adopted throughout the bridge. Now, while this was all right for the chords of long spans, it obviously gave results much too small for the web system, floor beams, stringers, and short spans in general, and has necessitated the renewal of many old bridges.

Theodore Cooper was the first to introduce the engine diagram, which has caused a vast improvement in the design of our bridges, inasmuch as it enables us to get the exact stress on every member of the bridge, instead of making some parts three or four times as strong as others.

But, unfortunately, this diagram business has been run into the ground, for every railroad wants its special diagram, or two or three special ones which, although giving results practically the same as the others, still, as far as the labor of calculation is concerned, are entirely different; and to aggravate the evil many roads space their wheels as so many feet, inches, and sixteenth of an inch apart. If this were necessary to ascertain the strains correctly, we would submit in silence; but it is not. In the first place, these highly complicated typical diagrams represent engines which are often never built, and, even if they are, are only some of the many kinds of engines that will pass over the bridge. This always reminds the writer of the military gentleman who paced the circumference of a circle, and then calculated the radius to six places of decimals.

Many advocate doing away with the engine diagram and using a table of uniform loads, varying for different spans, etc. The opposition to this is so great by those who assume a starting point, say, within ten per cent., and then make the rest of their calculations to one-fourth of one per cent., that it seems almost impossible to get this change adopted.

The writer believes that if the American Society of Civil Engineers were to suggest the adoption of two or three, or at the outside six, typical engine diagrams, the chief engineer of every railroad could select one to suit his railroad. Tables of shears and moments for these would then be published, and much of the drudgery of bridge calculation avoided. Calculating the stresses in a bridge is a very simple matter, though often tedious, which any machine can learn to do in a short time; but to properly design a bridge requires years of experience in the field, shop, and office.

The simple concentration diagram given for plate girders is the same as adopted by the Norfolk & Western Railroad for all their bridges. The writer sent the Society a table giving moments and shears for spans up to eighty feet with this loading.

For truss spans the writer prefers using a uniform load, and two concentrated loads placed fifty feet apart for the sake of simplicity.

15. Some specifications adopt these wind loads without, however, allowing anything extra for spans over 200 feet; allowing ten pounds per lineal foot for each additional twenty-five feet of span agrees very closely with C. Shaler Smith's rule of allowing thirty pounds per square foot on the train, and on twice the exposed surface of one truss, which is about right.

16. This is a simple way of allowing for curvatures, and gives safe results.

18. Mills are not required to roll iron or steel closer than two and a half per cent. in weight or shape; why, then, use hair-splitting formulas for the rest of the work?

19. Many specifications use tedious formulas for finding the unit stresses; some allowing for impact as such; others by considering the proportion of dead to live load. These are empirical, being founded on insufficient experiments. The writer sees no use of inserting such formulas in specifications. The table given has, it is true, been slightly modified from these formulas; but it does not require every one who uses it to go through the work over again, and to carry the results out to the last pound instead of stopping at an even hundred.

Many claim that they use impact formulas for safety. Now, as a matter of fact, most of these formulas give about the same results as of old for short span, and allow much higher unit stresses for long spans, which, of course, weakens them. Now, it is quite true that in long spans the greater proportion of dead load to live load reduces greatly the shock from the train; but, on the other hand, the great length and weight of each individual member render it more liable to injury in shipping, etc. There is more play in pin holes; long members have additional stresses, due to their own weight, etc. So even in long spans we should not use unlimited unit stresses.

20. Since steel has become so popular, it is hard to get such good iron eyebars as before. The writer considers mild steel the future bridge material.

21. The straight line formulas give results which are practically as accurate as the more tedious formulas involving $\frac{l^2}{r^2}$

28. His experience, both in the shop and field, leads the writer to strenuously oppose using iron or steel less than three-eighths of an inch thick. With less thickness the rivets are liable to crack the plates or shapes, and it is almost impossible to drive good field rivets or to cut out bad ones without injuring the work. All adjustable rods and struts affected by them should be allowed an initial stress of 10,000 pounds per square inch to allow for undue stresses in adjusting. It makes a better job to use riveted laterals instead of rods, etc.

The New York Central use a wrought iron corrugated floor on their bridges, and set the ties in ballast, which is excellent.

35. A common way of allowing for camber is to raise the centre of the span 1/1,200 of its length; but it is easier to increase the length of the top chord over the bottom chord, one-eighth of an inch for every ten feet of span.

This reminds the writer of a few more short cuts.

He had occasion to calculate the deflection of a drawbridge, when open, to find out how much the bridge should be raised at the ends to allow it to shut, and had used the following formula:

Deflection at end $= 1/E \ \Sigma (u \ l \ s)$

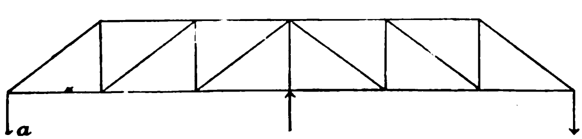



Fig. 4.

Where:

$u$ = Stress produced by 1 pound hung at "a."

$s$ = Stress per square inch in each member from dead load, span open.

$l$ = Length of member in inches.

E = Modulus of elasticity.

Now, to solve $u \times s \times l$ for each and every member in the bridge, add the results, and then divide by the modulus of elasticity, is certainly a tedious operation. It is, then, necessary to allow for pin play, etc.

He subsequently showed this formula to Mr. E. A. Schneider, of Pencoyd, who remarked he had a better formula than that. Mr. Schneider allows $\frac{1}{16}$ of an inch deflection for every ten feet of span, and said that this gave better results in practice than any other formula. In the case the writer had worked out, he had the same result as afterwards obtained by allowing $\frac{1}{16}$ of an inch for every ten feet.

Another practical short cut is for finding the radius of gyration for compression members made up of channels and cover plates, or web and cover plates.

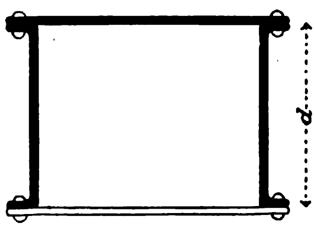


Fig. 5.

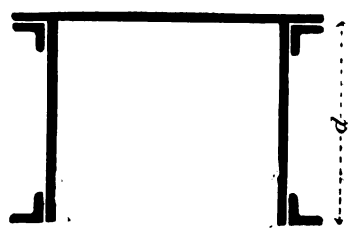


Fig. 6.

Now, we all know that it is rather a tedious job to calculate the exact radius of gyration for these sections; but if for ordinary sections, as now used, the radius of gyration is considered as ⅜ of "d" (Figs. 5, 6), the result will be practically correct unless the work is for some hair-splitting crank.

37. Plate or lattice girders of over 100 feet should be set on shoes or rockers like a pin bridge; otherwise they have a tendency to rest on the first roller or edge of bed plate when the girder deflects.

A common method of calculating the expansion for an ordinary bridge is to divide the length of the span in inches by 700.

40. Rivets in stringers carrying the ties should be not more than five, or preferably four, inches apart in the web leg of the top flange angles, and should be ⅞ inch in diameter. Of course, at the ends of the bridge they will be three inches apart. The writer had once to stop a prominent bridge company from using ¾ inch rivets throughout 300 and 500 feet spans, and often spacing the rivets seven or eight inches apart.

44. These results the writer obtained from examining the record of an immense number of tests; his object being to secure the highest results without making them so high that the manufacturers would have undue difficulty in living up to the specification, and therefore charging higher prices.

50. As a general rule, the inspector is handed his test piece in the testing room, and has no means of telling whether it is cut from his material or not. He might as well accept the manufacturers' word at once as go through such a farce.

53. Annealing steel, of course, reduces the hardness or brittleness, and also the tensile strength. The writer has had steel which broke at 71,000 pounds per square inch in the specimen break at 56,000 pounds per square inch in the finished eyebar after annealing, and yet he was asked why he tested the full-sized bar; had he not already accepted the material on the specimen test? The most treacherous substance in steel is phosphorus, which should never be allowed to exist in more than $\frac{8}{100}$ of one per cent.

If the pig iron contains more than the allowable amount of phosphorus, it is treated in one of two ways: either it is mixed with iron containing less phosphorus, thus reducing the proportion; or else it is treated by the acid process, which carries the phosphorus off with the slag.

63. Punching injures both iron and steel, and the conclusion drawn from many experiments is that up to ⅝ of an inch thickness the damage is not sufficient to make drilling or reaming pay. Reaming does not help as much as thought; that is, as far as remedying the injury caused by punching. The best work can be done by drilling, if the expense does not prohibit it.

64. All iron should receive a coat of linseed oil, or, better, be dipped in a hot bath of the same or some similar substance, as soon as rolled. Unfortunately, owing to the present equipment of the shops, this is a very difficult thing to get enforced, and the material is often allowed to rust in the yards before being used. It has been claimed, the writer does not know whether justly or not, that if iron once starts to rust it will go on doing so even after being painted. He has, however, taken scales ⅛ of an inch thick off iron which had been exposed to sea spray for twenty years, but apparently kept well painted. As the original thickness was only ¼ inch, the loss was very serious. The most common paint now used in the States is metallic oxides. Why? Because it is cheap in the first cost. But red lead and linseed oil is better, and certainly cheaper in the end. Metallic paints tend to scale off.

Anchor bolts should be set in Portland cement; say, four of cement to one of sand. The old practice of using sulphur is bad. The writer has taken out old anchor bolts where the sulphur had eaten away the iron and loosened the bolts.

Bolts with wedges are not desirable; for if the wedge is driven home, it is liable to crack the stone; and if it is not so driven, it is no good. The old method of suspending floor beams by means of loop rods has been relegated to the past. It may be better to suspend them by means of an independent post firmly riveted to the ends of the floor beams. This enables strains to be concentrated better, and prevents undue bending in the main posts every time the floor beam deflects, and has none of the disadvantages of the old suspender rods.

Our bridge specifications, like our bridges, are the results of the labor of many men, so that it is almost impossible for any one man to claim the credit for our best designs of specifications. Each one selects what suits him best from his predecessors, and perhaps adds a little more; this partly accounts for the length of most specifications.

# A TRIANGULATION SURVEY

**For a Tunnel at Niagara.**

By C. H. Mitchell, Grad. S.P.S.

Mr. President and Gentlemen :

Young engineers are generally led to look upon a triangulation survey as something belonging to the highest sphere of mathematical surveying and practice. A so-called "triangulation survey" is generally shadowed by spherical and spheroidal trigonometry, calculus, and least squares in abundance, with the accompanying shades of "single second" and micrometer transits, heliographs, long-distance signals, "sixty-mile sights," and operations in high places. We are too often liable to look upon such as the business of a few government officials, who are the soul of mystery itself, and who take no thought for the common order of things. In all this we forget that similar operations, involving similar practices on a reduced scale, are quite frequently carried on by private and public corporations for widely different objects from those which we usually attribute to such surveys.

Very few graduates (and the writer speaks from personal knowledge), when they leave college, have any idea of being for some years to come engaged in field operations on such a large scale as is required in a triangulation of even an ordinary kind. It was with such beliefs, at any rate, that three graduates of '92 (of which the writer was one) left their alma mater. It was with such beliefs still lingering that they were suddenly called on to execute a triangulation survey, on a small scale, for a tunnel at Niagara Falls.

To make a short explanation, this tunnel, as designed, was to be used as a trunk sewer to dispose of the sewage of a district of the city of Niagara Falls, N.Y., situated near the river, about a mile above the Falls. Fig. 7. The original intention was to sewer this district into the "Niagara Falls Water Power Company's" tunnel (at present under construction) by means of a vertical or inclined shaft from the surface. This scheme being abandoned for certain reasons, the city decided to have a trunk sewer built from a point near Port Day, and continuing through the city to empty into the gorge below the Falls, near the new Suspension Bridge.

It was finally decided to build a tunnel through the rock of a size of 8′ x 8′, and at a mean depth below the surface of about sixty feet. As this tunnel would be a mile long and pass under the heart of the city, a triangulation survey for it must needs be made, of a sufficiently accurate character as to enable the centre lines to be located and produced from each of the three shafts.

In a paper of this kind, it is not intended to describe in detail this proposed tunnel; the preliminary survey being the object. A few points, however, must be introduced, so as to convey a general idea of the nature of the work.

The tunnel, as proposed, was to pass under Erie Street, and parallel thereto, and continue in a straight line till it emerged at the cliff in the gorge. There are three shafts, and it is from these, together with the opening at the "portal" in the gorge, that the centre line is to be run. The running of these lines is, of course, the most delicate operation in all the surveys, and must be exceedingly accurate. There are two ways for dangerous errors to creep in: first, in the original survey, *i.e.*, in laying down the centre line of the tunnel *on the surface*, by getting the points in the several shafts in line; and, second, having the shafts sunk, and the tunnel under construction, the running of the centre line by means of plumb bobs in the shafts, etc.

Now, to particularize. This paper is to deal with the survey above ground, or the triangulation necessary to place the lines on the surface.

The first thing to be done was, naturally, a general reconnaissance of the "ground." This meant about three days "knocking about" the city and suburbs, and thinking out the ways and means, the location of survey stations, and of an economical base line. This proceeding is somewhat harder than would be supposed, as so many contingencies and obstacles are met with. I will not enter into an account of the trials and tribulations we encountered and overcame at this juncture of the work; suffice it to say that we had read a number of angles, and discarded them before we finally decided upon the arrangement of the present survey.

As for the base line, it must receive considerable attention. In this survey we had two base lines—No. 1 being situated on high level ground on the Canadian side of the river, and No. 2 on a very convenient stretch of level meadow land, in the present eastern suburbs (cut up into city lots, and selling at $30 per front foot). We made No. 2 our primary base, and used No. 1 to check on. Each line was about 1,475 feet long. No. 1 ran over very gentle undulations of grass land, having a total fall of about six

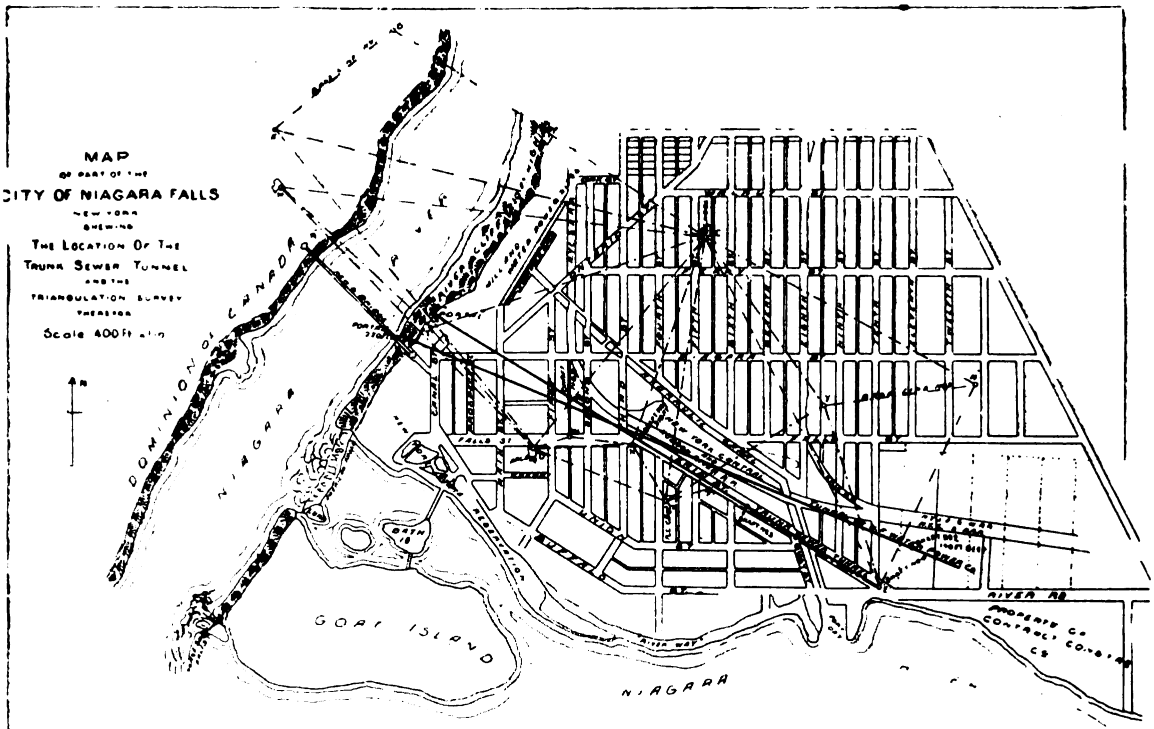

MAP
OF PART OF THE
CITY OF NIAGARA FALLS
NEW YORK
SHEWING
THE LOCATION OF THE
TRUNK SEWER TUNNEL
AND THE
TRIANGULATION SURVEY
THEREFOR
Scale 400 Ft. = 1 in
DOMINION OF CANADA
NIAGARA
GOAT ISLAND
NIAGARA
FALLS ST.
CANAL ST.
NEW YORK CENTRAL
RESERVATION
RIVER WAY
RIVER RD
BATH IS


Fig. 7.

feet. The line was run out with a transit and stakes 2″x 2″x 18″ (oak) were driven in convenient places, in depressions or summits on the line; the distances between these stakes ranging from 30 to 99 feet, so that they could be measured with a hundred-foot tape. Each stake was driven very solidly to within an inch of the surface, and had a copper tack with a well-defined head driven in it on top. The end stakes consisted of large oak stakes driven well down, and firmly supported by smaller ones; the copper tack in these having a cross cut in the head. All the stakes being driven (21 in case of base No. 1), levels were taken on each. Then commenced the actual chainage. The tape used was a hundred foot aluminium, tested and compared before using; it was graduated only in feet. In conjunction with this was used a small steel tape reading to tenths, hundreths, and thousandths. At each measurement of the line the temperature was read. A scale was attached to the tape and every reading was taken with a pull of sixteen pounds, for which we had the catenary correction to apply. In taking the first reading, *i.e.*, from stake 0 to stake 1, the distance was measured between the centre or cross in the tack in stake 0 and the south *edge* of the tack in No. 1; and the next was between the south edge of tack in No. 1 and that of No. 2, and so on, ending at the centre of the tack in the end station. In this way, ten measurements of the whole line were taken. Two men held the tape; one having the scale; while a third did the reading and took the notes.

In the office the ten readings for each short distance were first averaged; next, each average distance was corrected and reduced for temperature correction to the standard of 20° Centigrade, the correction being ·0013 feet per 1° C. per 100 feet, which is for steel—aluminium being considered the same. Then, again, each distance, where it was necessary according to the field notes, was treated to the catenary correction for a pull of sixteen pounds. All the corrections being applied, the result was (in the case of base No. 1) a set of twenty distances, comprising the whole line. These distances were in themselves the hypothenuses of the respective vertical right-angled triangles, of which the differences in elevation between the stations formed the perpendiculars. By solving these triangles, the *horizontal* distances between each two tacks were obtained, and hence the whole base line. The measurement of No. 2 base line was essentially the same as that for No. 1, except that we made an improvement by driving the stakes at distances apart of between 99 and 100 feet, so that every distance read 99 feet and a fraction, thus shortening the work.

Now, to turn our attention to the reading of the angles at the respective stations. We had, of course, four base-line stations. Two stations, very centrally situated and on elevated points, formed our principal places of operation. One of these, station C, was in the belfry of a large city school—a stone building with a heavy tower—and the other, station D, was on the top of a large brick chimney of a prominent business block. Stations H and F were so located as to be on a line parallel to the proposed tunnel. Station E was located at a convenient point near the intersection of Erie and Buffalo Streets, and as nearly in the line of H F as could be judged roughly—being unable to sight between them. These last three stations consisted of 18″ oak stakes, driven to about 6″ below the surface of the ground, and well supported by other stakes. These were then covered by a flat stone, macadam, and earth, so as not to be disturbed, but as to be easily accessible to "set up" over. Station G was the extreme top of the cross on the R. C. Church spire, and was used as a reference point only. This point was sufficiently stable to be relied on at any time, except in high wind. Station T was located on the verge of the cliff at the river, and consisted of a cross cut in the stone masonry of the foundation of a gas tank at the gas works. Station M was a point in the gable of a stone residence on the Canadian bank, and was used only as a reference point.

| | | | | |
|---|---|---|---|---|
| From Station | A | could | be seen | C and D. |
| " | B | " | " | C and A. |
| " | C | " | " | A, B, D, T, G, F, E, Y, Z, M. |
| " | D | " | " | A, M, C, G, H. |
| " | H | " | " | F, D, and G. |
| " | F | " | " | C, G, and H. |
| " | T | " | " | M and C. |
| " | E | " | " | C, G, Y, Z. |
| " | Y | " | " | C, E, G, Z. |
| " | Z | " | " | Y, C, E. |

The above table, with the accompanying "angle sheet," will serve to show what angles were read. (See table, Angle and Distance Sheet, pages 27 and 28.)

The details of the survey will now be described. The precise station consisted (as before stated) of either a copper tack (about ⅛″ head), or a chiselled cross in stone. The sight boards we used were rather an experiment, and a new idea in this kind of work. They consisted of ½″ pine boards, 6′ long and 8″ wide. They were painted red and white, in blocks of 21″ x 4″ alternately, with a dividing line down the centre. At the top was a hook from which hung a plumb line and bob, intended when plumbed to cover the centre line. The boards were placed and plumbed directly over the tacks, and guyed firmly in place by a set of three stout wires. Con-

ANGLE AND DISTANCE SHEET OF TRIANGULATION FOR TRUNK SEWER TUNNEL.

Completed September 29th, 1892.

| TRIAN. | ANGLES | OBSERVED ANGLES. | INDIRECTLY OBSERVED ANGLES. | COMPUTED ANGLES. | SUM OF ANGLES. | VARIA'N FROM 180° | CORRECT'N FOR EACH ANGLE. | CORRECTED ANGLES. | SIDES. | LENGTH OF SIDES. | LATITUDES (EAST + WEST −). | DEPARTURE. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Z E Y | 43°04'00" | | | | | —00".6 | 43°03'59".4 | Z E | 2099.314 | | |
| E Y Z | E Y Z | 79°06'58".3 | | | 180°00'01".8 | 01".8 | —00".6 | 79°06'57".7 | E Y | 1809.313 | | |
| | Y Z E | 57°49'03".5 | | | | | —00".6 | 57°49'02".9 | Y Z | Base No. 2. 1459.768 | | |
| | Y C Z | 27°32'16" | | | | | +00".2 | 27°32'16".2 | Y C | 1999.537 | | |
| C Z Y | C Z Y | 39°17'33" | | | 179°59'55".7 | 04".3 | +02".3 | 39°17'35".3 | C Z | 2902.739 | | |
| | Z Y C | 113°10'06".7 | | | | | +01".8 | 113°10'08".5 | | | | |
| | E C Z | 33°22'20" | | | | | +01".6 | 33°22'21".6 | E C | 3787.090 | | |
| C Z E | C Z E | 97°06'36".5 | | | 179°59'55" | 05".0 | +01".7 | 97°06'38".2 | | | | |
| | Z E C | 49°30'58".5 | | | | | +01".7 | 49°31,00".2 | | | | |
| | E C Y | | 5°50'05".4 | | | | 00" | 5°50'05".4 | | | | |
| C Y E | C Y E | | 167°42'50" | | 179°59'56".2 | 03".8 | +03".8 | 167°42'53".8 | | | | |
| | Y E C | | 6°27'00".8 | | | | 00" | 6°27'00".8 | | | | |
| | G C E | 36°24'22".5 | | | | | —01".0 | 362°4'21".5 | G C | 2522.152 | | |
| C E G | C E G | 40°25'37" | | | 180°00'01".0 | 01".0 | 00".0 | 402°5'37" | | | +2766.276 | 00.0 |
| | E G C | | 103°10'01".5 | | | | 00".0 | 1031°0'01".5 | E G | 2308.334 | | |
| | G C Y | 42°14'27".9 | | | | | —01".0 | 42°14'26".9 | | | | |
| C Y G | C Y E | 85°37'06".0 | | | 179°59'59".1 | 00".9 | +01".9 | 85°32'07".9 | | | | |
| | Y G C | | 52°13'25".2 | | | | 00".0 | 52°13'25".2 | Y G | 1700.672 | | |
| | Y E G | 46°52'37".8 | | | | | 00".0 | 46°52'37".8 | | | | |
| E G Y | E G Y | | 50°56'36".3 | | 179°59'58".1 | 01".9 | 00".0 | 50°56'36".3 | | | + 480. 90 | + 324.837 |
| | G Y G | 82°10'44" | | | | | +01".9 | 82°10'45".9 | | | | |
| | G C F | 11°46'35".5 | | | | | 00".0 | 11°46'35".5 | | | | |
| C F G | C F G | 92°57'44" | | | 180°00'00" | 00".0 | 00".0 | 92°57'44" | C F | 2442.426 | + 897.940 | + 21.8968 |
| | F G C | | 75°15'40".5 | | | | 00".0 | 75°15'40".5 | F G | 5154.472 | | |

| TRIAN. | ANGLES | OBSERVED ANGLES. | INDIRECTLY OBSERVED ANGLES. | COMPUTED ANGLES. | SUM OF ANGLES. | VARIA'N FROM 180° | CORRECT'N FOR EACH ANGLE. | CORRECTED ANGLES. | SIDES. | LENGTH OF SIDES. | LATITUDES (EAST + WEST –). | DEPARTURE. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | H F G | 35°59'40" | | | | | 00".0 | 35°59'40" | H F | 897.940 | | |
| F G H | F G H | | 111°47'51" | | 180°00'00" | 00".0 | 00".0 | 111°47'51" | | | | |
| | G H F | 32°12'29" | | | | | 00".0 | 32°12'29" | G H | 568.373 | | |
| | G C D | 30°01'48" | | | | | 00".0 | 30°01'48" | C D | 2640.131 | | |
| C G D | C G D | | 79°51'25" | | 180°00'00" | 00".0 | 00".0 | 79°51'25" | | | | |
| | G D C | 70 06'57" | | | | | 00".0 | 70°06'57" | G D | 1342.241 | | |
| | G D H | 22°46'30" | | | | | 00".0 | 22°46'30" | | | | |
| D H G | D H G | 113°54'24" | | | 180°00'00" | 00".0 | 00".0 | 113°54'24" | D H | 1007.260 | 0.00 | + 21.8968 |
| | H G D | | 43°19'06" | | | | 00".0 | 43°19'06" | | | | |
| | D A C | 37°08'43" | | | | | +01".4 | 37°08'44".4 | D A | 3993.855 | | |
| A C D | A C D | 65°59'17" | | | 179°59'56" | 04".0 | +01".3 | 65°59'18".3 | A C | 4257.838 | – 433.494 | – 2025.72 |
| | C D A | 76°51'56" | | | | | +01".3 | 76°51'57".3 | | | | |
| | T C D | 31°34'01" | | | | | 00".0 | 31°34'01" | T C | 2759.027 | | |
| C D T | C D T | | | 78°40'16".6 | 180°00'00" | 00".0 | 00".0 | 78°40'16".6 | | | – 836. 2 | + 383.487 |
| | D T C | | | 69°45'42" 4 | | | 00".0 | 69°45'42".4 | D T | 1473.035 | | |
| | M C T | 26°09'25" | | | | | 00".0 | 29°09'25" | M C | 3918.485 | | |
| C T M | C T M | 109°08'59" | | | 180°00'00" | 00".0 | 00".0 | 109°08'59" | | | –2219. 47 | + 77. 25 |
| | T M C | | 41°41'36" | | | | 00".0 | 41°41'36" | T M | 2020.930 | | |
| | M C D | 604°3'26" | | | | | 00".0 | 60°43'26" | | | | |
| C D M | C D M | 780°2'30" | | | 180°00'00" | 00".0 | 00".0 | 78°02'30" | | | | |
| | D M C | | 41°14'04" | | | | 00".0 | 41°14'04" | D M | 3493.810 | | |
| | C A B | | 54°11'33" | | | | 00".0 | 54°11'33" | | | | |
| A B C | A B C | 106°22'32" | | | 180°00'00" | 00".0 | 00".0 | 106°22'32" | A B | Base No. 1. | | |
| | B C A | 19°25'55" | | | | | 00".0 | 19°25'55" | B C | 1476.427 | | |
| | F C E | 24°37'46" | | | | | 00".0 | 24°37'46" | | | | |
| C E F | C E F | | | 33°00'31".3 | 180°00'00" | 00".0 | 00".0 | 33°00'31".3 | | | | |
| | E F C | | | 122°21'42".7 | | | 00".0 | 122°21'42".7 | E F | 1868.464 | | |

derable pains were taken to get this board perfectly plumb, and keep it so. It being known to the signal man just what angles were to be read by the instrument during the day's work, he attended to the signal boards under his charge by keeping them plumb and squarely facing the line of sight. Only where a number of angles were to be read from one station were more than two signal men needed. The instrument party consisted of two men; these, together with the accompanying signal men, constituted the survey party. Each man on the party was provided with a strong field glass, and a code of telegraphic signals (with white flags) was arranged for long-distance signalling.

The instrument used was a 7″ transit by a well-known American firm. The instrument had a power of twenty-four diameters, and was provided with all the latest improvements, including shifting centre. The graduations were on silver, and read to twenty seconds. It was supplied with a very steady extension tripod. The instrument was examined for adjustment very frequently, principally for the horizontal axis and levels.

Now, as to reading angles. Several methods were used and experimented on. (1) A repetition of ten readings—that is, (for the benefit of the junior years) reading the same angle continuously, accumulating the number of degrees. Thus an angle of, say, 60° read ten times would read 600°, or the Vernier reading would be 240°(600° − 360° = 240°). In this way, by taking the average from the final reading, the angle is determined (all things being equal) to two seconds. (2) By "four sets of five readings" —that is, four sets of five repetition readings—each set commencing at different points in the circle; thus: (*a*) at 0°; (*b*) at 180°; (*c*) at 90°; (*d*) at 270°. (3) A repetition of *twenty* to *thirty* readings. This was the method finally adopted. It proved to be of the greatest accuracy, and involved fewer instrumental errors. By this method each angle could be read to one second, or even half a second. In reading the angles, of course the *first* reading would not be expected to give the angle any closer than ten seconds (though the Vernier really read to twenty seconds). The fifth reading should give it to two or three seconds; while the tenth should determine it definitely to two seconds; and, lastly, the twentieth to one second. The usual criterion for the successful reading of an angle was the relation between the results of the tenth and twentieth readings. If the angles as determined by each differed by more than 1.5 seconds, the previous results were thrown out, and the angle read again by twenty more readings.

If, during a set of observations, the instrument was known to have received a shock or jar from any cause, the whole was unclamped and the readings commenced again. If, also, it was found that the wind affected the instrument to any great extent, the operations were suspended.

## Readings Taken at Fifth Street (F),

September, 1893.

Mr............... } Inst.
Mr............... }

................. } Signals.
................. }
................. }

| Sta. Observed. | Vernier A. | Vernier B. | Remarks. | Calculation. | Mean Angle. |
|---|---|---|---|---|---|
| G | 0°-00'00" | 0'-20" | — v v v v v | 104-47-55<br>360<br>464-47-55<br>10 | |
| C | 104-47 45 | 48'-05" | | 5 \| 464-47-55<br>92-57-33 | 92° 57' 33" |
| C | 180-00-00 | 0'-30" | + v v v v v | 180-00-15<br>360<br>500-00-15<br>75-12-00 | |
| G | 75-11-50 | 12'-10" | — | 5 \| 464-48-15<br>92-57-39 | 92° 57' 39" |
| G | 90-00-00 | 0'-20" | — v v v v v | 194-48-35<br>360<br>554-48-35<br>90-00-10 | |
| C | 194-48-20 | 48'-50" | + | 5 \| 404-48-25<br>92-57-41 | 92° 57' 41" |
| C | 270-00-00 | 0'-20" | + | 270-00-10<br>360<br>630-00-10<br>165-11-30 | |
| G | 165-11-20 | 11'-40" | | 5 \| 464-48-40<br>92-57-44 | 92° 57' 44"<br>Final Mean = 92°57'39" |

## Readings Taken at Fifth Street, Station F, Angle *G F C*

September, 1892.

| | | | | |
|---|---|---|---|---|
| 92° 57'40" | | 1st Reading | | 92° 57' 40" |
| 104 47'40" | v v v v v | 5th Reading | 104-47-40<br>360<br>5 \| 464-47-40 | 92° 57' 32" |
| 209 37'00" | v v v v v | 10th Read. | 209-37-00 (360x2)<br>720<br>10 \| 929-37-00<br>92-57-42 | 92° 57' 42" |
| 59 13' 40" | v v v v v<br>v v v v v | 20th Read. | 59-13-40<br>1800<br>20 \| 1859-13-40<br>92-57-41 | 92° 57' 41" |
| | | | Final Reading. | 92° 57' 41" |

The *modus operandi* of reading an angle is as follows:

(1) Set up.

(2) Set plates as accurately as possible at 0°, clamping upper plate. This is checked and corroborated by the assistant instrument man.

(3) Receive "all right" signals from stations between which angle is being read.

(4) Set telescope on the signal of that station which is to the left of the angle read, "split" it with the cross wires, and clamp the lower plate. In "setting" on the signal, the tangent screw is used in such a way that the cross wires will advance from left to right on the signal; that is, the motion of the plate is always positive in the direction of the hands of a clock. This was the case in our instrument, as in this way the tangent screw is turned against the spring. If the tangent screw were placed the opposite way, the motion would be from right to left. This is the direction in which the plates are usually graduated. If, in "setting," the wires pass beyond the signal, bring them back past the centre, and then move them up in the proper way.

(5) Unclamp the upper plate, and, moving it from left to right, set the telescope on the second signal, advancing in the proper way. Then clamp the upper plate and read the angle.

(6) Unclamp the lower plate, and move the *whole* around (left to right) until again at the first signal, on which set the wires as before, and again clamp lower plate.

(7) Unclamp upper plate and sight again on the second signal; and so on, in this way—always making every movement from left to right.

In this way the first, fifth, tenth, and twentieth readings are read and recorded in degrees, minutes, and seconds; whilst the intermediate so-called "readings" are not recorded.

Most of our readings were taken with only one Vernier, as any index error does not enter. One man always conducted the observations on one angle, and in this way obviated the correction for personal error. The other man kept notes and checked all the Vernier readings. In this way errors in reading or sighting were quickly detected.

After considerable practice, it was found that, all being favorable, an angle of twenty repetitions could be read in from twenty to thirty minutes of time.

In the triangulation in hand, there were only five triangles in which it was possible to read with the instrument the three angles. Of the rest, with the exception of two, only two angles were read. This fact made the success of the survey much less possible, as in such cases there was no way to check on the readings. Where three angles were read, the error of closure to 180° was limited to five seconds, and was apportioned to each angle, as will be seen on the accompanying angle sheet. In a large triangulation this apportioning would have been arrived at by least squares, but in this case the errors were apportioned directly. It very often happened that such angles as were already corrected in this way would be included in *some other triangle*, and would also require a correction as regards the second triangle, in which case it was quite difficult to arrive at a result.

The calculation of the sides of the triangle of the triangulation was no small task. We found in this that system was everything, and also "the more hurry, the less speed." Having determined the exact length of the base lines on the horizontal, and having the final and accepted reading of every angle, we set to work. Four men were employed—two on each side of the table. One set started and solved a triangle on the base line; one man doing the work, and the other giving logarithms. This triangle being solved, the data used was handed across the table; and the other set of computers traced the data back to its source, and thus checked it. They then solved the given triangle any way they pleased, and compared their result with that of the first set. If the results differed by more than two or three thousandths of a foot, it generally showed that "some one had blundered," and there was forthwith a general overhauling of figures. In this overhauling one man from each set interchanged places, and the two sets then went over the work afresh. The method of giving logarithms was as follows: The computer wanting the logarithmic sine of an angle wrote the angle down on a blank slip of paper provided for the purpose, and at the upper left-hand corner wrote his initials, while in the upper right-hand corner he designated the name of the angle. This slip was handed to his assistant, who wrestled with a ponderous book of tables, found the necessary logarithm, and placed the result beneath the angle designated, together with the accompanying work. He then signed his initials in the lower left-hand corner, and passed back the slip to the computer. In this way there was no confusion by talking; the result was on paper, and an absolute check was obtained on the computers. All the logarithm slips were preserved and filed away for future reference.

By the above means, all the triangles were computed and checked, with the result as shown on the angle sheet. Wherever it was possible, the triangles were solved by the ordinary formula: $\frac{\text{Sine } A}{a} = \frac{\text{Sine } B}{b}$

I describe this method of computation so minutely because it may be valuable to some of our members as a simple and correct way, and one which we found to give entire satisfaction.

In computing we commenced at base No. 2, and proceeded toward No. 1, intending, of course, to get a result for the length of the latter which we could compare with our measured length. It may be interesting to know that the discrepancy or the error of closure in this way was .59 of an *inch*, which was considered a very satisfactory result.

This result of the calculations warranted our accepting the computed triangulation as sufficiently correct to proceed with the secondary surveys.

The latitudes and departures of all the stations were then computed, assuming a line through $E$ parallel to $FH$ as the meridian and centre line of the proposed tunnel.

Each of the shaft centres was then located by means of a secondary survey, simple in itself, but necessarily as accurate as the triangulation itself.

The surveys and works were under the direction of the city engineer, E. Z. Burns, E.M. ('87 Columbia, New York).

NIAGARA FALLS, N.Y., January 20th, 1892.

# TUNNEL AT NIAGARA

**For Development of Power.**

By J. B. Goodwin, Grad. S.P.S.

Mr. President and Gentlemen,—In the proceedings of one or two of the meetings of the Engineering Society last year, several suggestions were made relative to the preparation of papers which would be of greater interest to those in the first-year courses. It was often stated, and stated undoubtedly with justice, that the wants of the first-year students were, to a great extent, overlooked; and that if more papers were read and discussions started bearing more directly on subjects which were not so full of abstruse mathematics and complicated engineering problems, the attendance and interest of this very important part of our members would be greatly enhanced.

The want of such was greatly felt by the writer in his first year, and it may also be said, in part, of his second year; and with this principally in view, the present paper is constructed.

In order to at once comprehend the situation, it would be well to first give a general geographical location of the work under consideration. This tunnel is driven in from the cliff which forms the east bank of the Niagara River below the "Falls," and below the new International Suspension Bridge which spans the river between the part of the present city of Niagara Falls, formerly known as the village of Niagara Falls, and Niagara Falls South, on the Canadian side. The course of the river a mile above the Falls is about at right angles to its course after its plunge into the narrow gorge below.

The main line of the tunnel is about at right angles to this latter course, which evidently will make it about parallel to the first course. The supplying of water for power in use in the mills along this bank was brought about in this way. A canal was excavated about 75 or 80 feet wide, leading from a point about three-quarters of a mile above the Falls to a basin about 350 feet from the cliff at the tunnel (Fig. 8). This basin, though excavated some years ago, was deepened in order to make of service every available inch of water entering the canal. The sill on which rests the rack at the intake was also lowered for a similar purpose. This reservoir, as it may be called, is walled up with masonry. In the "river-side" walls are placed racks and gates, admitting water to the several flumes of manufacturers which get their supply through the canal. In this particular case the water passes through the rack and gate, down a vertical shaft into the tunnel, and then into the wheel-pit, passing out from below into the river. Hence the tunnel acts as a sort of conduit, conveying water to the wheel.

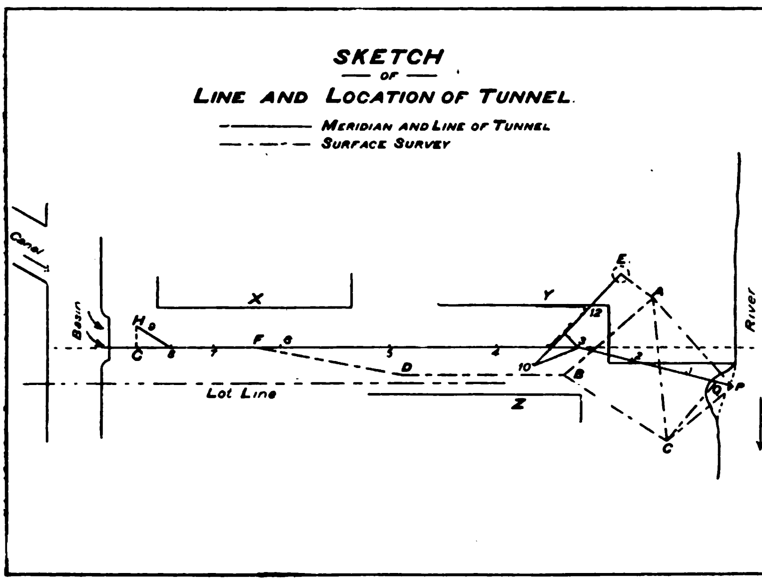



Fig. 8.

The rack at the intake is made of flat bars of iron $5/8'' \times 3\frac{1}{2}''$, placed $1\frac{1}{2}''$ apart, being kept apart by sleeves over long bolts or rods, which pass through at about four or five feet apart. These are all fastened to "I" beams, the ends of which are set in masonry on each side of the intake.

The whole has an inclination of three feet in twelve. This serves the purpose of collecting all sorts of grass, weeds, and sticks, of which there seems to be quite a quantity.

Before the tunnel was constructed, the water was conveyed to the wheel-pit by the ordinary flume, in which were placed two gates—one being near the intake, a short distance behind the rack, and the other in front of the rack, which is placed near the wheel-pit. Thus, with this double set of rack and gate, very little floating débris was allowed to enter the pit, endangering the wheel.

In order to increase the power and to make way for foundations for an extension of the mill, it was proposed to abandon the old flume and drive a tunnel through to a point under the intake, a few feet behind the rack at the basin. This was to connect with the intake by a vertical shaft, which is covered by a horizontal gate hinged on to a heavy oak frame around the edges of the shaft.

Now, since the wheel-pit to which access was to be made is situated under the mill, at the edge of the cliff, a small or rather short cross-tunnel was made, leading from the main artery to the wheel-pit. Near the portal and in the main tunnel is placed a gate regulating the supply to the pit. A gate is also placed at the entrance of the cross-tunnel to the wheel-pit. This will be under immediate control of workmen in the mill. The vertical gates in the old flume were raised by a simple gearing with a crank, and are let into the walls of masonry at the sides.

In the case of the horizontal gate, the means of raising and lowering are altogether different. Its construction is simple, consisting of a heavy oak frame built of required size, and laid resting on the sides of the vertical shaft alluded to, the centre of the frame in the same centre as the shaft. To this frame is hinged a strong trap-gate, which is kept shut by the head of water above it. It is opened by a chain which passes around a drum of a simple hoisting apparatus, the other end of the chain being attached to the free end of the trap.

This constitutes the description of the general features and use of the work. The method of laying out the lines and the construction proper will next deserve consideration.

As the cliff near the point at which it was desired to start the opening was about perpendicular, a ledge was made by removing a V-shaped mass out of the face of the rock, from the surface of the ground to the desired level of the floor at the portal of the tunnel.

After this was done, it was necessary to construct a sort of staging or floor over it, on which to place a windlass to handle the materials and implements used below. This consisted simply of beams let into the rock at both sides. This staging was about ten or twelve feet below the surface of the ground, but was readily accessible from it. These beams were made use of from which to suspend two wires, the line of these wires being the direction of the first part of the tunnel. Attached to the wires were weights, which swung in vessels of water, in order to prevent undue swaying. The centres of the nail-heads over which these weights were swung are the points marked P′ and Q.′ A station "C" was established near the cliff, and at a point from which P′ and Q′ could be seen. As previously mentioned, these stations were ten or twelve feet below the level of the ground on which "C" was located. It, therefore, became necessary to use a more convenient and accurate method than ordinary of arriving at the horizontal distances between " C " and P′ and " C " and Q.′ This was done by setting the transit at station " C," and sighting to the centres of the nails at P′ and Q′ in turn; then reading the angles made with the horizontal, and stretching the tape from the centre of the telescope to the points in question. Thus the measured distances form the hypothenuses of right-angled triangles, and the angles read the remaining necessary data to solve the triangles, one side of each being the horizontal distance between points.

It will be seen from the foregoing description that the points P′ and Q′ form connecting links between the surface and underground stations.

Naturally following upon this is the description of the *surface* survey. In order to aid in understanding this, it will be well to give the limits and position of the property lines. Since these lines only extended about fifteen feet from the building marked "X" in the drawing, it necessarily limited the line of tunnel to within this strip. The dotted line represents the property limit over which no part of tunnel was to extend. As the foundations had, as far as possible, to be avoided, this again limited the bounds to a strip about eleven feet wide along the building " Y." It was, however, impossible to avoid the foundations of the wing of this building, but the depth of excavation here precluded all probability of danger.

It was from the position of these buildings and lot lines that the line of tunnel was derived. Since the object was to connect with the intake at the basin, the direction was easily obtained.

Stations " F " and " G " were established on a line approximately midway between the line of building " X " and the lot line. Stations " D " and " B " were taken on a line about parallel to building " Z."

Station " A " was a point in the mill floor in the building " Y," which could be observed from " B " and " C " through doorways. The horizontal distances to this point were similarly measured as from " C " to P′ and Q′, as this floor was ten or twelve feet higher than " B " and " C." Station " E " is a point in the same floor, directly over the centre of the wheel-pit, *i.e.*, as far as the centre could be gotten at—the sides of the pit being very irregular.

These points established, the horizontal angles between them were then read, and the horizontal distances either calculated as described, or directly measured.

These points being thus fixed with reference to each other, the next thing to be considered is to connect the surface and underground points. First of all, the line of tunnel proper bisects the strip of property referred to between building "Y" and the lot line. The position of station "B" with reference to these buildings and lines being known, it is evident that it can readily be found how far station " B " is from this line of tunnel. Using a point directly opposite " B " on the line of tunnel, or *meridian* line, as it shall be called, for a reference point, or the point from which to measure *latitudes* and *departures*, a method is thus obtained to answer the requirements. Calling towards the basin positive, and the opposite way negative; and to the right positive, and to the left negative; station " B " has about 8 feet departure, and o feet latitude. The angle that " B D" makes with this meridian line is easily found by knowing the positions of these various lines at the ends of the buildings (these buildings and lines being divergent).

Knowing this angle and the angle that the line " B C " makes with " B D," it is easily seen that the angle that " B C" makes with the meridian can be found. Thus, knowing the distance " B C," and the inclination to the meridian, this distance, multiplied by the sine of the angle of inclination, gives the *departure; i.e.*, the number of feet to the right or left of the meridian. This same distance into the cosine of the angle gives the *latitude; i.e.*, the number of feet forward or back from the reference point. This, of course, gives the position of " C " with reference to " B." From the sketch it will be seen that the departure of " B," together with the departure of " C " from " B," gives the total departure of " C " from the meridian. The latitude of " B " (which here is o), together with the latitude of " C " with reference to " B," will give the total latitude of " C " from the starting point of o latitude and o departure. (See table.) Thus, in brief, is the method of " Latitudes and Departures," as applied to the location of points. This description will probably be, to a great extent, superfluous; but it is repeated that it may freshen the memories of those to whom it once was familiar, and to aid those to whom it is not quite so clear.

If, now, the position of " B " is clearly understood, it can be readily seen how successive points can thus be fixed, and, after tabulating them in the order obtained, the exact location of any one point with reference to any other point can be at once determined. In this way the method of *surface* survey was carried out.

To locate and connect with these points, those in the tunnel constitutes the *underground* survey.

Slight reference was made to the hanging of plumb-lines from the stations P′ and Q′. Fine wire was used in the hanging, care being taken to suspend directly over the points to which connection was made with " C " and " B." Since the stations P′ and Q′ were only about four and a half feet apart, a slight deviation here would throw the whole line of tunnel out; hence, at these points, it required more than ordinary care.

Now, from the line given by these two plumb-lines the first thirty or forty feet of the excavation was made; but here the question might be raised as to where the point of turn-off to the main line was to be, and also how the exact distance was obtained.

However, by reference to our tabulated "Latitudes and Departures," we obtain the position of P′ and Q′, or "P" and "Q" (as they are termed on the ledge of rock about thirty-three feet directly beneath). From this, the angle that "P Q" makes with the meridian can at once be calculated; for the difference between their departures, divided by the difference between their latitudes, will give the natural tangent of the angle made with meridian. Having thus obtained the angle, it is next necessary to know how far to proceed before the turn is made. Looking into the table of "Latitudes and Departures" for the total departure of "Q," and multiplying this by the cosecant of the angle just obtained, we get the required distance from "Q" to the point of deflection. This point was called station 3, the stations underground being numbered instead of lettered, to distinguish from points in the surface survey.

After this distance was driven, a station was established exactly at the point 3. The transit was set here and sighted back to "P" and "Q," which of course should be in line; then reversed, and the calculated angle turned off. This gives the main line of tunnel, and the instrument is now in the meridian.

The method of establishing these underground stations is somewhat different from that in the ordinary surface survey. In this the stations are located in the roof, instead of floor. To establish a station, suppose, for instance, the instrument is still set at station 3, and we wish to locate station 4, farther along the tunnel; the distance is first measured off, and an approximate point located at which to drill a hole three or four inches in depth. In this hole is inserted a plug of wood, which is driven up flush with the roof. On this is established the exact point; the line being given by the instrument, and the distance by the measurement. At this point a nail with an eye on the head is driven so that the centre of the eyehole is on line, and also at the required distance.

In order to "set up" under a station, the plumb bob of the instrument is suspended from this nail, and the instrument is shifted till the point of the plumb bob is directly over the intersection of the axes of the instrument, which point is exactly under a small drilled hole on the top of telescope, when the telescope is truly horizontal.

## LATITUDES AND DEPARTURES—UNDERGROUND.

| Course. | | Angle with Meridian. | | | Distance. | Latitude. | | Departure. | | Total Latitude. | | Total Departure. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | F + | B — | R + | L — | F + | B — | R + | L — |
| Q | 3 | 13° | 25′ | 34″ | Calculated | 33.85 | | 8.08 | | | 7.96 | 0 | 0 (Refer to Q′) |
| 3 | 4 | 0 | 0 | 0 | 35.41 | 35.41 | | 0 | 0 | 27.45 | | 0 | 0 |
| 4 | 5 | 0 | 0 | 0 | 67.83 | 67.83 | | 0 | 0 | 95.28 | | 0 | 0 |
| 5 | 6 | 0 | 0 | 0 | 59.93 | 59.93 | | 0 | 0 | 155.21 | | 0 | 0 |
| 6 | 7 | 0 | 0 | 0 | 77.50 | 77.50 | | 0 | 0 | 232.71 | | 0 | 0 |
| 7 | 8 | 0 | 0 | 0 | 25.00 | 25.00 | | 0 | 0 | 257.71 | | 0 | 0 |
| 8 | 9 | 22° | 46′ | 25″ | (Cal.) 15.76 | 14.53 | | 6.10 | | 272.24 | | 6.10 | |
| 3 | 11 | 30° | 58′ | 00″ | 5.83 | 5.00 | | 3.00 | | | 2.96 | 3.00 | (See surface points.) |
| 11 | E | 44° | 09′ | 21″ | 24.09 | | 17.22 | 16.72 | | | 20.18 | 19.72 | |
| 11 | 10 | 44° | 09′ | 21″ | 6.00 | 4.30 | | | 4.18 | 1.345 | 1.18 | | |

NOTE.—Stations 10, 11, and also 12, are on line of cross-tunnel.

## LATITUDES AND DEPARTURES—SURFACE.

| | | Latitude. | | Departure. | | Total Latitude. | | Total Departure. | |
|---|---|---|---|---|---|---|---|---|---|
| COURSE. | ANGLE WITH MERIDIAN. | DISTANCE. | Forw'd + | Back — | Right + | Left — | F + | B — | R + | L — |
| o B | 90° 00′ 00″ | 8.62 | o | o | | 8.62 | o | o | | 8.62 |
| B C | 23° 55′ 00″ | 33.71 | | 30.82 | | 13.67 | | 30.82 | | 22.29 |
| C Q′ | 52° 16′ 40″ | 17.965 | | 10.99 | 14.21 | | | 41.81 | | 8.08 |
| Q′ P′ | 13° 25′ 34″ | 4.60 | | 4.47 | | 1.07 | | 46.28 | | 9.15 |
| P′ A | 49° 04′ 02″ | 27.89 | 18.27 | | 21.07 | | | 28.01 | 11.92 | |
| A E | 44° 54′ 12″ | 11.05 | 7.83 | | 7.80 | | | 20.18 | 19.72 | |
| C A | 85° 16′ 40″ | 34.37 | 2.82 | | 34.27 | | | 28.00 | 11.96 | |
| B D | 0° 28′ 00″ | 96.83 | 96.82 | | | 0.788 | 96.82 | | | 9.41 |
| D F | 5° 02′ 40″ | 110.8 | 110.37 | | 9.74 | | 207.19 | | 0.33 | |
| F G | 0° 15′ 20″ | 66.65 | 66.65 | | | .297 | 273.84 | | 0.033 | |
| G H | 75° 51′ 24″ | 6.25 | | 1.5 | 6.06 | | 272.34 | | 6.10 | |

Columns of "Total Latitude and Departure" give the location of the points to which reference is made.

NOTE.—Station "H" was not established except by calculation.

A line is produced similarly to the surface survey methods, excepting, of course, that the instrument is sighted on suspended cords or wires, which are illuminated by lights held behind them.

In giving the point of "turn-off," supposing one is required, the angle is calculated and turned off; but as this point must of necessity be near the "heading," no station can be given ahead of the instrument. The telescope is therefore reversed and a back station put in. In using these, the workmen hang lights to the nails, and work to the line thus given.

The distance along the main line was about 270 feet, and then was turned off another angle, as above described, to a point directly under the centre of the shaft, which was about 16 feet back from the basin. This shaft was driven upward, as it was impracticable to sink it, as the water could not be well kept out with the pumps employed; the floor of the intake being ten or twelve feet below water level in the basin. When they reached the point where at the drill holes water came through in small quantities, the blasts were inserted and fired; and this, with a little help from above, soon made a sufficiently large opening to drain off the water.

The work of laying the frame over the shafts could now be proceeded with. As previously mentioned, this timbering was made of oak, which was well jointed and bolted together, and set on a good rock-bed and well grouted around. The trap-gate was then hinged and the chain connected, and water allowed to enter the intake. Work could now be carried on in the tunnel in driving the cross-tunnel to the wheel-pit. The old flume could also be used while this was being done

The direction and distance of the centre of the wheel-pit "E" was arrived at as before, and lines given to work from. As this distance was short, a few blasts soon brought the "heading" within a few feet of the side of the pit. Holes were put in to within one or two feet of the pit, and left to blast till the other necessary work of placing a gate in the tunnel below this cross-tunnel was done, to regulate the supply and head, as referred to previously. A staging had also to be erected in the pit to keep rocks from falling to the wheel when the blast was fired.

The ordinary rock-drill was used. It can be used with either steam or compressed air. In this case compressed air was the working fluid, and was conducted from the air compressors through pipes. The use of air is more economical, being less liable to serious effects due to change of temperature and distance conducted. It also serves as a good ventilator, as the exhausted air is forced through the tunnel by that following. The drills were "jacked" into position, and held there with the ends of the column against the floor and roof.

Holes were sunk about six feet deep, which when blasted constituted a "heading taken out" of a depth of about five feet.

It required about twenty-four hours per heading, which in this case was about twelve cubic yards, as the tunnel was 7′ x 9′ in cross section.

The charges were fired by electricity from a battery on the surface.

The blasted material was removed by wheelbarrows and dumped over the cliff into the river.

The work was started the second week in May, and drilling was finished about the middle of October.

The kind of rock met with was limestone; in thickness varying from six inches to two feet.

Buildings "X" and "Y" are under one management, Pettibone Cataract Paper Co., for whom the tunnel was constructed.

NIAGARA FALLS, N.Y., November 30th, 1892.

# SEWAGE FILTRATION.

By E. F. Ball, Grad. S.P.S., A.M. Can. Soc. C.E.

Mr. President and Gentlemen,—Before investigating any method of sewage purification, let us consider briefly the constituents of raw sewage and the chemical changes that are necessary to deprive it of offensive or injurious properties.

Sewage contains about 998 parts per 1,000 of water, one part of mineral matter, and one part of organic matter; and from 200,000 to 2,000,000 bacteria per cubic centimetre.

If all the mineral and organic matter and bacteria could be removed, the effluent would be pure water; but, of course, such a result would be impracticable on a large scale, and, indeed, it is uncalled for.

The mineral matter in sewage is generally unobjectionable, so there remains only the one part per 1,000 of organic matter, together with the disease-producing or "pathogenic" bacteria which require to be removed or rendered harmless.

If the bacteria alone be removed, leaving the organic matter unchanged, other micro-organisms will, before long, accumulate, and, feeding on the organic matter, set up a process of putrefaction. If the organic matter alone be removed, leaving the bacteria, they having no food will not multiply; but their spores may lie dormant, and if introduced into the human system may cause disease.

It thus becomes apparent that both the bacteria and organic matter must be removed, or so changed as to be harmless, before sewage can be considered purified.

The process of intermittent filtration does not *remove* all of the organic matter from sewage, but converts it into inorganic compounds, and it is to this important action that your attention is especially directed. It has long been known that if a limited quantity of organic matter be placed in water certain chemical changes occur, and the complex organic structure is broken down into simpler inorganic forms. This change is frequently spoken of as *oxidation*, and attributed solely to the free oxygen dissolved in the water. That this is not correct will be shown later on.

The chemical changes which occur in the breaking down of organic matter are, roughly, as follows:

(1) The oxidation of ammonia to nitrous acid.

(2) The combination of the nitrous acid thus formed with bases forming nitrites.

(3) The further oxidation of nitrites to nitrates.

Thus, *when all the bacteria have been removed or killed, and all the organic nitrogen converted into nitrates, the sewage may be considered entirely purified.*

The process of nitrification is due to micro-organisms or bacteria, and, of course, requires the presence of oxygen.

From numerous experiments, it appears that the nitrifying organism is present in all natural waters containing the ordinary amount of free or albuminoid ammonia, and in soils. It has further been observed that when the nitrifying process is in progress, the numbers of bacteria are enormously decreased.

Having thus discovered :

(1) That organic matter may be broken down into inorganic compounds by the action of micro-organisms in the presence of oxygen ;

(2) That bacterial life is almost entirely destroyed during this process ;

(3) That the organisms giving rise to nitrification are present in ordinary soils and waters ;

Let us endeavor to ascertain how these phenomena may be utilized in the purification of sewage.

If a liquid containing both dissolved and suspended matter be passed through an ordinary filter, only the suspended matter will be retained by the filter, and this is all that would be accomplished by passing sewage continuously through soil or sand. If, however, we apply a small quantity of sewage to the soil, allow it to settle, and on each succeeding day apply a similar quantity, we shall find that after a time the effluent has changed considerably in chemical composition ; the ammonias will decrease and the nitrites and nitrates increase, showing that nitrification is taking place ; while the bacteria will be almost entirely removed or destroyed.

Neither the chemical changes described, nor the removal of bacteria by filtration through sand, can be attributed to the mechanical properties of the filter, *i.e.*, by simple straining, for good results have been obtained by filtration through gravel stones as coarse as robins' eggs.

When sewage is passed intermittently through a sand filter for the first time, there is little or no chemical change, because the organisms necessary to nitrification are not present in the sand ; but, as the sewage itself contains them, they eventually find a home in the top layers of the sand, and then the process of purification commences. The filter then becomes a delicate mechanism, and the applications of sewage must be made with regularity and uniformity, and an even distribution effected over the whole surface. Should any portion of the filter be unused, the first applications of sewage to this portion will result in a poor effluent.

One of the first questions which presents itself is, what becomes of the suspended matter in the sewage? Does it clog the filter and necessitate its cleaning?

Astonishing as the statement may appear, it is found that when sewage is not applied in excess of the capacity of the filter all suspended organic matter disappears, and no crust is formed on the surface. When, however, the capacity of the filter is unduly taxed, a crust is formed which must be raked over and incorporated with the top layer of the filter.

The next question that presents itself is one of capacity. Filters five feet in depth, and composed of the following materials, may be expected to purify the quantities indicated:

(1) Coarse gravel between ¾ inch and 1¼ inch in diameter, 20,000 gallons per acre per day.

(2) Gravel between ⅛ inch and ⅜ inch diameter, under 70,000 gallons if applied hourly.

(3) Very coarse sand, from 60,000 to 100,000 gallons, with a capacity for a limited period of 175,000 gallons.

(4) Very fine sand, 25,000 to 30,000 gallons.

Fine soils six inches in depth and resting upon sandy material, although giving excellent results as to quality of effluent, have a very limited capacity.

Fine soils five feet in depth remain nearly saturated, and nitrification does not take place. The bacteria, however, are removed.

Peat, even one foot in thickness, is impervious to water, and useless.

## REMOVAL OF BACTERIA.

Although the removal of bacteria is very effective, in some cases reaching 999 per mille, it has been demonstrated that a few bacteria may occasionally pass through the filter. Whether pathogenic forms can survive the passage has not been determined.

## PURITY OF EFFLUENT.

This is to be judged by the *absence* of bacteria, the *low* percentage of free and albuminoid ammonia and nitrites, and by the *high* percentage of nitrates.

The greatest degree of purity that may be expected is the destruction of from 99 to 99.7 per cent. of the nitrogenous impurities, and the removal of from 97 to 99.5 per cent. of the bacteria.

Such effluents have been frequently used for drinking by a number of people without any noticeable effect.

### NITRIFICATION IN WINTER.

Experiments indicate that nitrification does not take place at a temperature under 39° Fah. In severe climates this might necessitate the protection of the filters from snow, and the delivery of the sewage on the filters at a temperature of 46° Fah. or over.

# THE NICKEL MINING AND SMELTING INDUSTRY OF SUDBURY.

---

By T. J. McFARLEN, Grad. S.P.S.

---

The mining industry of Sudbury consists largely, as in most new mining districts, of prospecting and developing, as well as the regular work of mining and smelting.

The prudent prospector secures the latest and best map of the district he proposes to search, a geological map being a very great assistance. If he is not already familiar with the indications of the presence of deposits of nickel, he visits some of the mines already in operation; and by a close study of the spots in the adjacent country rock, and the brown gossan that often occurs where there are surface outcrops of the ore, his eye will soon be able to recognize a good indication when he meets with one. He can also learn a good deal by familiar chats with miners and trappers. The latter class are, as a rule, very observant, and will furnish a great deal of valuable information about the district they have worked. Of course, the best training in this line is to go out with an old prospector; but you cannot always pick up a good experienced prospector who is ready to run round and teach you to discover the minerals which he wants to secure for himself.

In this district the nickel ore (pyrrhotite) occurs in ridges of trappean rock, consisting largely of diorite and diabase; the ridges have a north-easterly strike.

Having selected what he considers the most promising field—which, by the way, is likely to be covered with trees—the prospector secures an outfit consisting of the map already mentioned, a pocket compass, three or four one-inch steel hand drills, a light strike hammer, a few pounds of dynamite, some fuse and detonating caps, a hatchet, a prospector's pick, a shovel, and provisions. Arrived at the field, he deposits all but his pick and shovel in a safe place, and proceeds to the search systematically by going over the field in parallel lines, a few rods apart, stopping every few rods to clear away the leaves and shallow soil, and to examine the rock if it be not sufficiently exposed. When indications of ore are found, he selects the spot where they are most promising, drills a hole, puts in a charge, and breaks as much rock with as little dynamite as possible. The first shot may satisfy him that he has a good deposit, but it may take days and even weeks of work to determine whether he is warranted in taking up a claim.

Having discovered a deposit of more or less value and taken up the claim, the next thing is to develop the deposit. This may be done by the diamond drill (the Blezard mine was tested by five or six borings with a diamond drill, to the depth of about two hundred feet), or it may be done in the usual way by sinking shafts.

After the developing has been carried on sufficiently to prove the size, character, and quality of the lode or lodes, the manager is in a position to determine the situation, character, and amount of the dead work necessary to work the mine to the required depth. I quote a few lines from the Report of the Royal Commission :

" These questions, *re* the dead work, should be settled by careful surveys made in the light of all the local facts and surrounding circumstances, such as the geological structure of the country rock, the probable amount of water to be raised, the lowest point of adit, and the most convenient point of delivery of ores to the surface.

" The preliminary exploration must have enough ore cut and under run, or otherwise exposed or determined, to give at least two years' work for reduction works of an extent sufficient for the average annual output of ore. Before erecting reduction works, the ore exposed in the mine should be so thoroughly tested as to guarantee a net profit sufficient to pay the whole cost of such work."

The further exploration of the mine is carried on side by side with the regular mining operations, the aim being to develop as much new ore as is being taken out, so as to avoid any loss from delays caused by the lode pinching out, and no new lode developed far enough to keep up the supply of ore to the works.

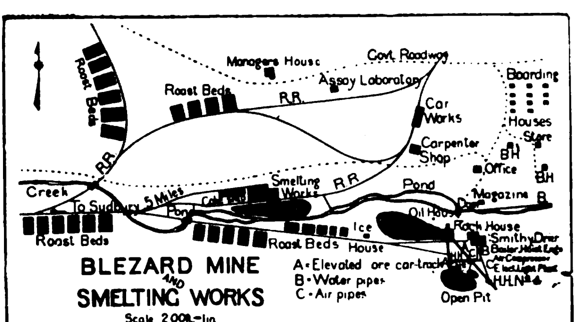



Fig. 9.

At the Blezard mine (Fig. 9) all the shafts are vertical. Four shafts have been sunk, and another one was started last summer. No. I is about

180 feet deep. Nos. II. and III. were about 50 feet, at which depth they touched the bottom of the lode, and were not continued. No. IV. is 90 feet deep. Nos. I. and IV. are 7 feet by 10 feet.

Seven power drills, driven by compressed air, are constantly at work: four drills are run in the third level of shaft No. I.; two in the first level of No. IV.; and one at the surface. The blasting material chiefly employed is black powder containing about 30 per cent. of dynamite, and called dualin. The gas from this powder is very apt to give a severe headache, as the writer found to his sorrow. The principal point in blasting, with the aim of getting the most work from the least powder, is to place the shot so that it will overcome the resistance of the rock in its weakest point; that is, its tensile resistance.

In stoping, a compromise between underhand and overhead stoping is followed. The ore in the Blezard mine occurs in large pockets, varying in depth from 30 to more than a 100 feet. The shaft is sunk to the bottom of the lode, and an inclined drift run through the lode to within reach of the highest part of the lode. Where the lode is very deep and limited in horizontal proportions, this inclined drift is forced in the form of a winding gallery. After the top of the lode has been reached, the stoping is carried on by enlarging the drift, keeping the working face as steep as possible, so that the ore cars can be brought close to the bulk of the broken ore. Large pillars are left to support the roof; these pillars are generally about 20 feet in diameter, and the distance between them varies from 20 to 50 feet, according to the soundness of the roof rock. In stoping, the drill holes are placed about 15 inches from the face of the rock, as nearly parallel to it as possible, and made of any convenient depth from 2 feet to 12 feet. The holes are placed about 14 inches apart, and loaded to within 6 or 12 inches of the top by ramming the powder down with a wooden tamping rod.

In drilling upwards the dust falls out as it is made; and in drilling downwards the hole is kept full of water, which, being constantly agitated by the drill, washes out the drill dust. The holes are called dry holes and wet holes. Before loading the latter are blown out by compressed air forced to the bottom of the hole through an inch pipe. The charges are loaded down by packing fine ore into the hole above the charge. The firing is done either by fuse and detonating caps, or by electricity. If it is an advantage to have all the shots fired simultaneously, they are connected by wire and fired by electricity. When thus fired, most of the pieces are small enough to lift into the ore car. The larger pieces are reduced by the hand sledge or mud shots. A mud shot is made by placing a quantity of powder on a flat or hollow part of the block, as near the middle of the stone as possible, attaching a fuse with cap and loading the charge down with one or two shovelfuls of fine ore, and firing it.

The ore is hoisted by a cage in the vertical shaft, the ore car is run on to the floor of the cage, and the cage is operated by a wire cable from a friction drum hoist in the engine house ; the cable passes over a pulley in the top of the head house, the head house being built directly over the shaft. A new safety cage was put into shaft No. IV. last summer. It is so constructed that, if any accident should happen to the hoist engine or the cable, as soon as the weight of the cage is taken off the cable the cage grips the guide post and comes to a stop.

The hoisting shaft is divided into two compartments, one in which the cage works is firmly timbered ; the other is furnished with a series of ladders reaching to the bottom of the shaft, and contains the air and water pipes and electric wires. A strong plank partition separates the two compartments.

A miner, with power-drill and helper, in this mine stopes, on an average, ten tons of ore in a ten-hour shift.

The average amount of ore stoped and hoisted in a double shift of ten hours each is 160 tons.

Situated, as all the nickel miners of this region are, in the most ancient formation, there is no danger or annoyance from the presence of explosive gases ; and as the country rock is very strong, and at a moderate depth quite free from weathering and frost cracks, little or no timbering is required in the drifts and stopes. The chief source of danger occurs in connection with overhead loose ground. As the blasting proceeds, there is a good deal of ground fractured which is not displaced. This fractured ground, either in the roof or walls of the stope, is constantly jarred by the drilling and blasting in the immediate vicinity ; some of it becomes gradually loosened, until it is ready to fall at the slightest jar. The presence of water veins in the ground greatly facilitates this loosening effect, as it percolates along the new fractures and acts as a lubricant between the two surfaces.

A systematic and thorough inspection should be constantly kept over all the underground workings, and all ground deemed dangerous removed. This branch of the work is called scaling, and is very important to the safety of the workmen, and often a very delicate and sometimes dangerous piece of work to perform. One or more experienced and skilled men are detailed to attend to this task.

From the cage in the head house at the top of the shaft, the ore cars are run along an elevated track to the top story of the rockhouse, and the ore is dumped close to the crusher. The crushers in general use in this section are the Blake jaw crushers. The one at the Blezard mine is the largest working in the district; it will readily crush a block of ore 10 x 14 x 18 inches. The ore crushes much more easily than the rock, but certain mixtures of ore and rock are tougher than the rock alone. The smaller sized crushers employed by the Canada Copper Cliff Co. are built to break any rock or ore you can get into them; while the large one already mentioned sometimes gives way under the strain.

The crusher is adjusted to break the ore so that the largest pieces will pass through a ring three inches in diameter. An inclined cylindrical revolving screen receives the crushed ore from the crusher; the fine ore passes through the meshes of the screen and falls into hand-cars below; while the coarser parts pass out of the lower end of the screen and fall on an inclined slide lined with sheet iron, down which they are moved by three men to the ore cars, and drawn by a locomotive to the roast beds.

The sorting of the ore at the Blezard mine is done in three places:

(1) In the mine, if a convenient place occurs, such as an old stope at a lower level, the bulk of the rock is thrown into it; failing this, the rock is filled into separate cars, hoisted, and run on an elevated track to the rock dump, or dumped into cars and drawn off to any convenient place of deposit.

(2) In the rockhouse the men feeding the crusher continue the sorting by sledging off rocky portions.

(3) At the roast beds the ore is dumped from the cars upon a wooden platform; then shovelled into wheelbarrows and run upon the roastbeds. As it is being filled into the barrows, four or five boys pick out the most rocky pieces and carry them out of the way in pails.

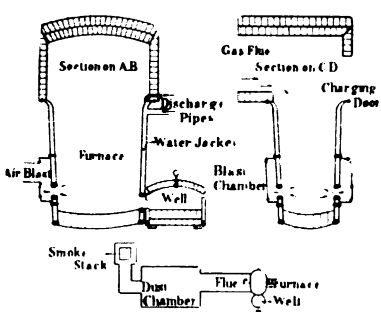
At the Murray mine the last sorting is done on a circular revolving table below the crusher by three men standing around the table; and at the Copper Cliff and Evans mines upon an inclined oscillating table by two or three men on each side of the table. At the two latter places the ore rich in chalcopyrite is separated from the ore rich in pyrrhotite, each being treated separately afterwards, and giving matters rich in copper and nickel respectively.

The ore is roasted in large heaps in the open air. The ground is levelled off and a foundation of rough wood laid down, from 20 to 24 inches deep. Temporary drafts or chimneys are provided by binding three or more sticks of wood together, and placing two to five of such bundles vertically on top of the wood foundation. The ore is now dumped on the wood foundation; first, the coarse ore, to a depth of five to seven feet, and within a foot from the edge of the foundation. The top of the bed is made flat, and the sides are left at the angle of repose, and the whole covered over with six to ten inches of fine ore. The heap is now ready for firing, which is done by pouring coal oil on the projecting wood foundation, and lighting. Before the wood is all consumed the sulphur in the ore begins to burn, and dense fumes of sulphur dioxide rise from the heap. If left to itself, the escaping gases make vents through the covering of fine ore. At these points a strong draft sets in, rapidly roasting the ore in the wake of the drafts, and then cooling down before the ore out of the influence of the drafts has been properly roasted. It is necessary, for the best results, that the whole body of ore should be simultaneously heated. For this purpose two or more men are kept watching the newly fired roast beds, and as soon as a gas vent is formed it is choked up by throwing over it a few shovelfuls of fine ore.

After the beds have been burning from six to ten days the heat subsides considerably, and the beds are left to take care of themselves. They continue to smolder for two or three months.

The object of the roasting is to drive off a large part of the sulphur and oxidize the iron, so that it will form a silicate, and slag off in the smelter.

After the roasting process has been completed, the burnt ore is loaded into cars, either by hand-barrows or by a crane, and run to the smelting house, where it is dumped into ore bins. The smelting is done in a Herreshoff water-jacketed furnace. This furnace (Fig. 10) consists of two concentric envelopes of steel boiler plate, with an empty space between the plates of one inch. The bottom of the furnace is a cast-iron plate, 1¼ inches thick, fastened on with bolts, and covered with a layer of fire-bricks set in fire-clay cement.




HERRESHOFF FURNACE

Fig. 10.

The furnace is provided with a well or receiver, into which the ore runs as it melts in the furnace. This receiver is a cast-iron water-jacketed chamber, lined throughout with fire brick set in fire-clay cement. It has three openings: one connecting it with the furnace, through which it receives the molten ore; a second one at the top of the well, through which the slag flows into metal pots mounted on wheels, in which it is run to the slag dump; and a third one close to the hearth of the well, through which the matte is drawn off. The last-named opening, called the tap-hole, is kept stopped up with a plug of finely-worked clay. About once in thirty minutes the matte is tapped off by punching a ¾ inch hole through the clay plug with a sharp iron bar and sledge, allowing the heavy sulphides of iron, copper, and nickel to flow out into a pot. When it is required to stop the discharge through the tap hole, a bud of finely-worked clay is swiftly and dexterously thrust into the hole. This bud of clay is stuck on a small circular plate attached at right angles to the end of an iron rod about twelve feet long. The bud is held firmly in the hole for about ten seconds, till it firmly adheres to its place. The well is mounted on wheels; and in case it gets clogged up or otherwise deranged, it is wheeled to one side for repairs, and replaced by another one kept in readiness.

The blast enters the furnace about a foot from the bottom, through eleven tuyeres leading from an air chamber which passes almost entirely around the furnace. The blast pressure is about five ounces.

The water for the furnace jackets, which comes from a tank elevated above the level of the furnace, enters the water-jacket near the top of the furnace, in the rear, and passes downwards around the furnace and discharges through two pipes in the front of the furnace; one of these pipes is situated near the top of the furnace; and the other, a ¾-inch pipe, passes from the highest part of the water-jacket to permit the escape of any steam that may be formed.

The discharge of the pipe is in full view of the furnace men, and, as long as water is discharging from the small one, the jacket is full of water; but if it discharge steam, the volume of water passing through the jacket must be increased until the heat from the furnace does not raise it above the boiling point.

This adjustment is made by a cock in the pipe leading from the tank to the jacket.

There are three separate water-jackets, each supplied by an independent pipe; one jacket about the furnace, a second about the well, and a third about the tap-ring.

The molten matte is very erosive, and soon eats away the iron surrounding the tap-hole. To prevent the ruin of the whole well from this cause, a large opening is left and fitted with a water-jacketed cast-iron ring. When this ring becomes eaten away too much, it is replaced by a new one of which a stock is kept on hand.

To start the furnace, a little wood is thrown in the bottom, the balance is filled with coke, and a light applied. As the coke settles down, a little ore is spread over the surface, more coke added, and the blast turned on; ore and coke are now alternately thrown in, care being taken to distribute the alternate layers evenly over the entire furnace chamber, so that each part of ore will lie over its proper proportion of coke. If this is not done, the ore in some parts will not be properly fused, and, settling down over the tuyeres, will choke the blast and cause trouble. At least one experienced charger is kept at the work, and the charge varied from time to time to suit the condition of the furnace.

So far, no mechanical contrivance has been found to work so satisfactorily as the hand charging.

When the furnace is in full blast, about 300 pounds of coke is used to the ton of ore; each charge consisting of half a ton of ore, and 150 pounds of coke, laid on in four to six layers of ore and coke alternately.

The bottom of the furnace is concave upwards, the brick hearth following the same contour; a shallow trench leads from the centre of the hearth to the furnace outlet. This form of hearth prevents the molten matte from collecting about the sides of the furnace.

To close down the furnace, the feeding of ore is stopped, and enough coke added to thoroughly fuse all ore in the furnace, and when all is in a good state of fusion a hole in the side of the furnace is opened and the contents rapidly drained off into a set of cast-iron troughs, resting on a frame at the side of the furnace. These troughs and the matte pots are covered internally with a thick wash of clay to prevent the matte adhering to them.

Sometimes the opening from the furnace to the well becomes clogged; this may be relieved by thrusting a long wrought-iron rod through the slag hole and working it to and fro in the opening referred to.

Again, if the temperature of the furnace is a little low, a crust may form on the surface of the slag in the well. This is relieved by thrusting a stick of wood into the well through the slag opening; it floats on the top, burns fiercely, and fuses the crust.

Sometimes the ore in the furnace becomes matted together in places, stopping the draft. To relieve this, a heavy iron bar is thrust into it through the charging door, and the matted part broken and pried up.

If the tuyeres become choked up, they may be relieved by opening the tuyere window and thrusting in an iron rod; but in general, when the furnace begins to block up, more coke is fed and less ore, thus raising the temperature; sometimes green ore is fed to raise the temperature, but this is sure to decrease the richness of the matte.

As the coke costs about $7.00 per ton, it is a matter of economy to run the furnace with as little coke as possible.

The furnace gases are carried along a horizontal flue from the top of the furnace to a large dust chamber. Here the gases which have a high velocity in the flue lose the greater part of their velocity, and a lot of fine ore carried from the furnace through the horizontal flue is deposited on the floor of the dust chamber. From the bottom of this chamber the gases pass through another horizontal flue, and escape through a smoke-stack, fifty feet high.

The matte from the furnace is broken up by sledges, and packed in barrels, about 1,200 pounds in each barrel; in these barrels it is shipped to market.

The daily product of the smelter at the Blezard mine is about 26,000 pounds of matte; containing about twenty-five per cent. of nickel, and twenty per cent. of copper; or, thirteen tons of matte, containing about three and a half tons of nickel, worth about $4,000, and two and a half tons of copper, worth about $400.

The amount of nickel and copper ore smelted in the Sudbury district during the year ending October 31st, 1892, was 61,924 short tons; giving 6,278 tons of common matte. The amount of Bessemerized matte, for the same year, was 1,880 tons; the amount of nickel contained in the matte was 2,082 tons; of copper, 1,936 tons; and of cobalt, 8½ tons.

The product of nickel for 1890 was about 668 tons. Thus, we see that, in two years, the product has trebled.

I do not need to speak here of the great increase in the demand for nickel in the markets of the world. Its value as an alloy with steel in the manufacture of armor plates for warships has been so well established as to call for thousands of tons yearly for this branch alone.

Of the present known nickel deposits of the world, Ontario has almost a monopoly; and we confidently expect, in the near future, a very great extension of the mining, smelting, and refining industry in this part of Ontario.

# ELECTRIC TRACTION,

## As Applied to the Street Railway.

---

By E. B. Merrill, B.A.

---

Foremost amongst the useful applications of electricity, to which a great deal of attention is being directed to-day, on account of its service to the general public, and of the great financial interests which it already represents, is that relating to traction, which, though it at present is limited to street railway service, or to use on short suburban roads, promises to extend and include the fast express and passenger traffic, if not all the railway service of the world.

In considering the subject of electric traction, we find that, though its history is short, its development has been very rapid ; so much so that, if we were to give the merest outline of its ramifications, it would require far more space than the nature of this paper would allow. We must forbear a consideration of our subject, either from an historical or a prophetic point of view ; though a glance back to the beginnings and development of the electric railway, or a dip into the probabilities or possibilities of its future, could not fail to be both interesting and instructive.

It will be our aim to consider briefly the main electrical with some of the mechanical principles of the electric street railway. The subject, then, falls naturally under three heads :

(1) The car, with special reference to the motor.

(2) The line and track, or conducting system.

(3) The station, or source of supply.

But before proceeding with these, perhaps it would be well to review the more important electrical principles upon which a great deal of what follows must depend.

First, then, as to electrical quantities.

There are three fundamental terms : Potential* (*V*) or Electromotive force (*E*), Current (*C*), and Resistance (*R*), which can be most readily understood by reference to hydraulic analogies. Potential *V*, corresponding to pressure or head, provides the force that produces the current or rate of flow against the given resistance ; which in the case of water pipes depends on their smallness of bore, or their length ; and in the case

---

*Commonly spoken of also as electrical pressure, or voltage.

of electrical conductors increases with the decrease of cross-section, or increase of length of wire. The greater the cross-section of conductor, the greater the conductivity, or the less the resistance; the longer the conductor, the less the conductivity, or the greater the resistance.

Since the current is a rate and the same at all cross-sections of a conductor, we may regard it as analogous to so many gallons of water per second crossing a given section of pipe.

In applying these analogies, one must guard himself against the idea that electricity is really a fluid, or that it moves along a wire when a current is said to flow. The best authorities believe that electricity is a *form of the ether*, or a part of it; that electrical phenomena are due to strains or disturbances in electricity; that when a current flows, a state of motion of the molecules of the conductor, and of a strain in the medium surrounding it, passes along from one end to the other; and that if electricity itself moves at all, it must be exceedingly slowly. Lodge accepts, provisionally, "the idea of the ether consisting of electricity in a state of entanglement similar to that of water in a jelly."

The corner stone of the science of electricity is Ohm's law,—the statement of the relation between the above three quantities: $C=\frac{V}{R}$ or $\frac{E}{R}$, or, as it is frequently used, $C=V\left(\frac{1}{R}\right)$ where $\frac{1}{R}$ is the conductivity; or, the current is equal to the quotient of difference of potential or electromotive force by resistance, or the product of difference of potential or electromotive force and conductivity. The former is used principally in dealing with resistances in series; the latter with conductors in parallel.

The electromotive force is that which produces the difference of potential, causing the flow of current between any two points under consideration. The letter $E$ is used for electromotive force, and is also commonly used for potential difference. We will use $V$, however, for this quantity, as it will assist in distinguishing the two. According to this, then, $C=\frac{E}{R}$ applies only to a closed circuit; while $C=\frac{V}{R}$ applies to any part of a circuit outside the source of the current.

A clear understanding of the following units and relations is necessary from the very outset in electrical work.

| | | |
|---|---|---|
| Electromotive force, | E | unit called a volt. |
| Potential difference, | V | |
| Resistance, | R | " " ohm. |
| Conductivity, | $\frac{1}{R}$ | " " mho. |
| Current, | C | " " ampère. |
| Quantity, | $Q = CT$ | " " coulomb |
| Work or energy, | $EQ = ECT$ | " " joule. |
| Power* | $\left\{ = \frac{ECT}{T} \right\}$ | " " watt. |
| | $EC = C^2R$ | 1,000 watts = 1 kilowatt. |
| | | 746 watts = 1 horse power. |
| | | = 33,000 ft. pounds per min. |

Roughly, we may take ¾ kilowatt = 1 horse power.

Now, we have to deal mostly with the pressure of 500 volts, or thereabouts, in the street railway system, as that is the pressure used in American practice, though they are trying a lower one in England of 350 volts. For every ampère, then, we have ½ kilowatt = $\frac{1}{2} \times \frac{4}{3}$ horse power, or $\frac{2}{3}$ horse power. That is, every ampère of current being used at this pressure represents, roughly, ⅔ horse power.

It is important to note that the product $VC$ or $EC$ always represents the *power* being supplied in the parts of the circuit to which these quantities refer. If a generator supply a current $C$, and generate an *EMF* $E$, then the power expended is $EC$ watts, or $\frac{EC}{746}$ horse power. If a current $C$ passes through a resistance $R$, it does work in heating the conductor to the extent $VC$ in a second, where $V$ is the drop in potential due to the resistance. This is equal to $C_2R$, and is usually written in this way.

THE CAR AND MOTOR.

We proceed then with the first main division of our subject—the consideration of the electric car, of which, for our purposes, the motor is the chief part, as it is the machine by which the conversion of electrical into mechanical energy is effected.

A few words, then, as to the theory and construction of the motor; and as in most cases they are reversible, we may include most of the principles of the generator. Let us take the simplest case of a bi-polar dynamo. In

*The rate of doing work, or the rate at which energy is being transformed, or the work done, or energy transformed per unit time.

this the magnetic circuit consists of various modifications of the horseshoe magnet, usually of several parts—the yoke. A Fig. 11 connecting the two cylindrical cores *B*, upon which the wire *C* is wound, and at the end of these the two pole pieces *D*, between which revolve a cylindrical or ring-shaped mass of iron *E*, variously built up, also with wire wound upon it, called the armature. The armature is centred upon the shaft *F*.

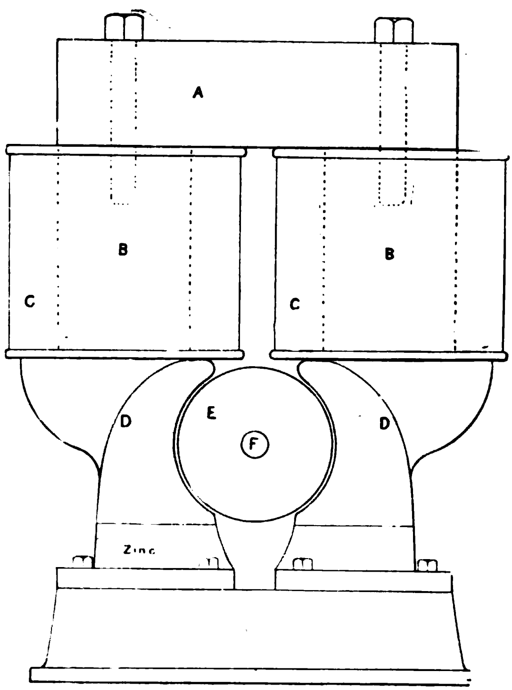



Fig. 11.

If the fields--as the horseshoe magnet or parts corresponding to it in other forms are known—are magnetized, it is now usually said that so many lines of magnetic induction, or simply so many magnetic lines, flow in the magnetic circuit; the amount of magnetism being measured by the number of lines. When the strength of the field changes, more or less lines flow in it.

With a given magnetizing force—produced by the current flowing about the field coils—certain things affect the flow of magnetic lines. Some qualities of iron allow a much greater flow than others; a large cross-section of the iron circuit allows more than a small one. Air gaps offer a great resistance to the flow of lines; it is important, therefore, to reduce them to a minimum by making the contact between the different parts of the fields as good as possible, and by making the space between the poles and armature as small as mechanical considerations will permit.

We have a similar relation between the quantities in the magnetic circuit to that which we have in the electric, viz.:

$$\text{The flow of magnetic lines} = \frac{\text{magnetizing or magneto-motive force}}{\text{magnetic resistance or reluctance.}}$$

The magneto-motive force is furnished by the electric current circulating around the fields. It is proportional to the amount of current flowing and to the number of times it encircles the fields, or, combining the two, it is proportional to the ampère-turns; the greater the current, or the greater the number of turns, the greater will be the magnetizing force, and the greater the magnetic flux.

Now, on the armature core are wound loops of wire, and for the following purpose: Consider, first, the motor. If wire is wound around a mass of iron and an electric current is sent through this wire so that it circulates in one direction about the iron, then it makes an electro-magnet of it with north and south poles. Now, like poles repel, and unlike poles attract; so that if this magnet is suspended between two fixed poles it will move until its south pole is near the fixed north pole, and its north pole near the fixed south pole; but if it be so arranged that another coil of wire then comes into play and magnetizes this movable magnet, say, in the same direction as before it was moved, the attraction of the fixed poles draws it again from this position; and if these coils are so arranged that they continually repeat this change of magnetism, then the moving magnet will continue to move. In the motor the armature is this moving mass of iron which is magnetized by the current passing around the loops of wire wound upon it, and the commutator is the mechanical means by which the current is changed from loop to loop as the armature revolves, so that its poles are continually shifted away from the fixed poles of the field, and are continually being drawn up toward them. With the armature its shaft rotates, and from a pulley and belt, or gear, etc., other machines are driven or work done.

Consider, second, the generator. If a coil of wire revolve between the poles of the fields so as to include a varying number of magnetic lines within its circuit, then as the number of lines cut increases or decreases an electromotive force is generated in the wire in one direction or the other. This causes a current to flow in the one direction, or in the other about the coil. Add to this that the completed armature is simply the mechanical arrangement of a number of coils so placed and connected as to combine the currents which flow in one direction, and those which flow in the other and send them all out in one direction by means of the commutator and brushes, and we have the outline of the theory of the generator. The current that passes around the armature magnetizes it as in the case of the motor, but the direction of motion is now reversed, and a mechanical torque is applied to draw the poles apart in generating the current. In this respect it is the reverse of the motor, for the torque applied is greater than that due to the magnetism produced by the current generated; and, again, the one is the reverse of the other, inasmuch as in the generator the cutting of magnetic lines induces an *EMF* in the armature coils which sends out the current, and in the motor the revolution of the armature induces also an *EMF* which acts against that of the current driving it, and thereby reduces the effective *EMF* in as far as the flow of current is concerned. This opposing *EMF* is called the counter *EMF* of the motor. We shall see later how this may be determined.

The following diagrams illustrate the directions of the magnetic lines in the two cases for a gramme-ring armature.

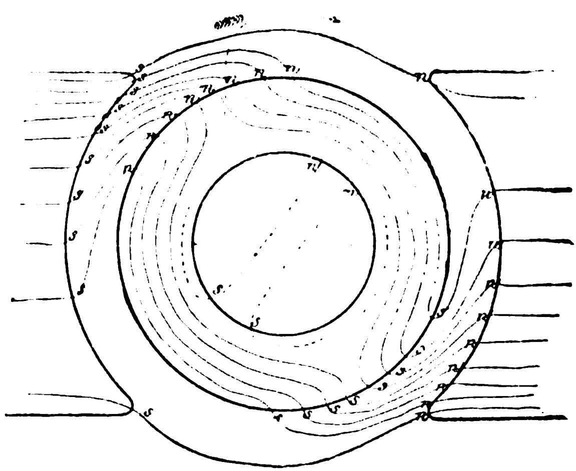


Fig. 12.—GENERATOR.

There are four principal types of motor, depending on the way the fields are magnetized, and the current supplied the armature:

1. Fields, permanent magnet or separately excited.

2. Series wound motor, when the field windings and armature are in series, and therefore the same current passes hrough both.

3. The shunt motor with fields and external circuit in parallel.

4. The compound wound motor, being a combination of the series and shunt.

Now, it is as transformers of energy that we have to deal with motors and generators; and providing that they are otherwise suited for their work, it is to the efficiency of transformation that we look in forming a judgment of a machine for practical purposes; for it is energy or work that is paid for, whether obtained from coal or water, or any other source.

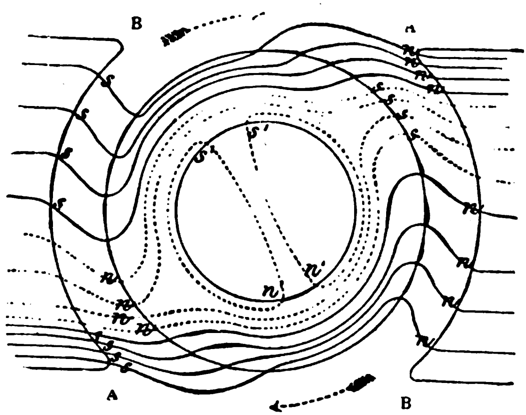



Fig. 13.—MOTOR.

The energy transformed by the dynamo is, then, the product of the *EMF* which it generates, the current which this *EMF* causes to flow, and the time $=ECT$, or the rate of transference of energy would be the power generated by the machine, and this would be the product $EC$, giving the number of watts, which may at once be reduced to horse power by dividing by 746.

The energy transformed by the motor from electrical back to mechanical again is equal to the product of the current flowing through the armature, the counter *EMF* and the time $=eCT$. The counter *EMF* $e$ is, as is the direct *EMF* in the generator, proportional to the number of magnetic lines cut per second—that is, to the strength of the field, the rate of revolution of the armature, and the number and arrangement of loops on the amature; but this last is fixed in a given machine, the others may vary. Whenever current $C$ flows through a resistance $R$, energy is expended to the extent $C^2R$; so that for a system which works at a given range of potential difference, the lost energy is kept down by reducing the resistances of generators, circuit, and motors as much as possible. The energy transformed by the generator $EC$ is equal to that re-transformed by the motor $eC$, plus that lost in heating the resistance, $C^2R$, where $R$ is the total resistance through which $C$ flows. $EC=eC+C^2R$. A small proportion of the energy is lost in the motor on account of eddy currents and hysteresis, etc., and mechanically in overcoming friction on the bearings, of the air between armature and poles, etc.

It is often convenient to represent electrical quantities and conditions graphically; and, as we shall have some recourse to this method, let us consider the following diagrams:

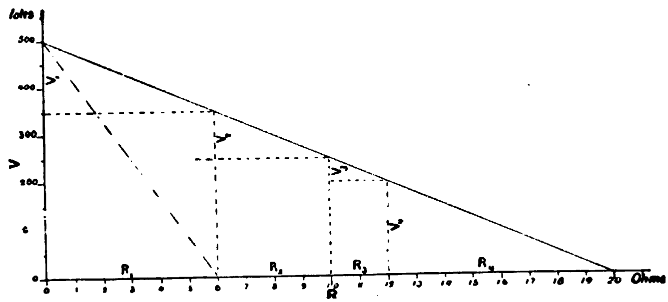


Fig. 14.

Let vertical lines represent differences of potential or electromotive forces, and horizontal lines resistances. Let $V$ be the difference of potential between the two ends of a line whose resistance is $R$ (see Fig. 14); then, since the drop in potential is always proportional to the resistance (when there is no addition of $EMF$), the points representing the potential at different parts of the conductor must fall in a straight line, the slant line in the diagram; and the potential, at any point in the conductor, is measured by the ordinate to that line from the point representing the number of ohms from either end. The current flowing is $\frac{V}{R}$. If the resistance is lessened to $R_1$, and the potential difference kept the same, the line representing the potential at corresponding points in the conductor is again a straight line, but has a greater slant than in the former case. The current $\frac{V}{R_1}$ is also greater; so that the slope of this line so drawn is a measure of the current flowing. The current or $\frac{V}{R}$ is really measured by the tangent of the angle which this line makes with the horizontal.

For a circuit of varied resistances in series, since the same current passes through all, the slant line must have the same inclination throughout. $C = \frac{V_1}{R_1} = \frac{V_2}{R_2} = \frac{V_3}{R_3} = \frac{V_4}{R_4} = \frac{V}{R}$

Where an *EMF* is being added, as in the case of a battery dynamo, or the line representing the change of potential is altered, and is no longer an indication of the current (Fig. 15), the ordinates are increased proportionately to the *EMF* added, and this increase may vary according to any curve, depending on the form of generator used, as, generally, it is not proportional to the internal resistance.

In Fig. 15, *P* represents the positive and *N* the negative pole of the battery or dynamo. *V* is the difference of potential between the poles or brushes, as measured by a volt meter.

In the street railway service, the generators at the station are so designed that they may maintain a practically constant difference of potential between their brushes. The generated *EMF*, of course, must vary with different conductivities of the external circuit in order to maintain this difference of potential at the brushes. This is also illustrated in Fig. 15.

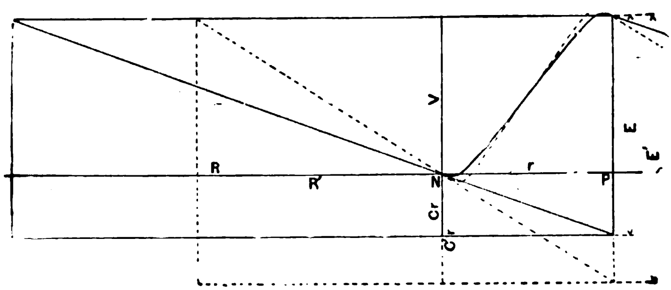



Fig 15.

$$C = \frac{E}{R+r} = \frac{V}{R} = \frac{E-V}{r}$$

$$C' = \frac{E'}{R'+r} = \frac{V}{R'} = \frac{E'-V}{r}$$

$$E = V + Cr.$$

$$E' = V + C r.$$

The electromotive force *E*, generated by the dynamo, is seen by referring to the graphical representation to be the sum of the difference of potential between the brushes *V* and the product of the current flowing and the internal resistance of the armature *Cr*. $E = V + Cr$. The greater the current, the greater must *E* be to maintain *V* constant.

Again, $C = \frac{V}{R}$; that is, the less the resistance in the external circuit, the greater will the current be. With the street railway, every time a car makes connection with the line, it makes a new path for the current; that is, supplies an increase of conductivity, or lowers the resistance of the circuit so that more current will flow. This is what is required to drive the cars.

As the motors are designed to give efficiency at the difference of potential, $V$, on the line, the resistance of the line must not be so high as to make a very great drop along it before reaching the farthest car, Best practice requires that this drop be not greater than fifty volts as an average, or a maximum of 100.

The following diagram, Fig. 16, illustrates the relations between $C$, $E$ and $R$ on a circuit with generator and motor.

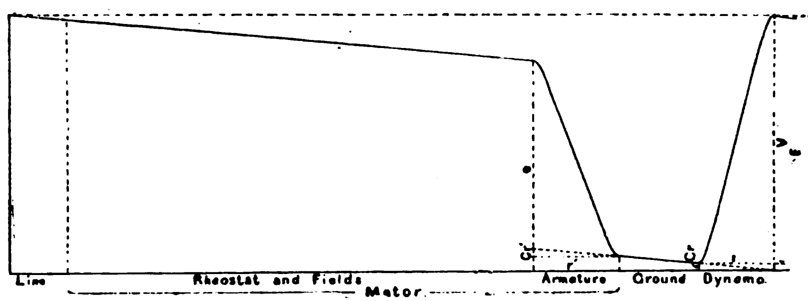



Fig. 16.

$E$ = generated $EMF$ $e$ = counter $EMF$. $E-e$ = effective $EMF$.

$C = \frac{E-e}{R}$, where $R$ is the total resistance of the circuit.

To find the counter $EMF$ which is being generated by a motor at any time, we take the difference of potential between the brushes, and subtract from this the product of the current flowing and the internal resistance of the armature. If the internal resistance is not known, or cannot be determined practically by bridge measurement, then it may be calculated by holding armature fixed and passing a known current $C_1$ through $V_1$, measuring the difference of potential between the brushes, and then $r = \frac{V_1}{C_1}$, which may be used above. $e = V' - Cr' = V' - C\frac{V_1}{C_1}$; and if the current is the same in both cases, we have $e = V - V_1$.

The resistance of fields in series with armature of motor will have the same effect on the power of the motor as an extra resistance in line.

The efficiency of a motor is measured by the ratio of the energy which is transformed by it per second, which is used in driving the armature shaft and car wheels or other work, as the case may be, to the energy per second which is supplied by the generator. Another efficiency is the ratio of the work done by the motor to the work done in the dynamo by engine, etc., which drives it; another is the ratio of the work done by the motor to the electrical energy supplied by the dynamo; but in both these cases, if we are simply considering whether the motor does its work well as compared with other motors, it is evidently unfair to it to charge it with either the mechanical losses in the driving of the dynamo or of the electrical losses in dynamo and line. So that, if we want to know how to rate a motor for its work, we must consider the energy supplied to it between its two terminals, or in the street-car motor between the trolley and the ground, and consider how it makes use of it. We charge it with the energy which is wasted in heating the field and armature windings, as well as that used in driving the armatures.

Let us take $V_m$ as the difference of potential used by the motor between line and ground at the car. This will be less than the generated *EMF* by the amount lost in generator, feeding system, and connection with ground. We have then the electrical power passing through the motor as $V_m C$; the amount transformed is $eC$; the efficiency of the transformation will then be the ratio of the latter to the former, or $\frac{eC}{V\ C}$ or $\frac{e}{V_m}$; so that the greater $e$ is, the greater will be the efficiency. But, at the same time, the greater $e$ is, the less will be the current $C = \frac{V_m - e}{R}$; so that the rate of work done by the motor $eC$ decreases when $e$ becomes too large. This work is a maximum when $e = \frac{V_m}{2}$, but then the efficiency is only one-half.

These are two important points: As $e$ approaches the value $V_m$ the efficiency increases; as it drops towards $\frac{V_m}{2}$ the power of the motor increases.

The following diagram illustrates this:

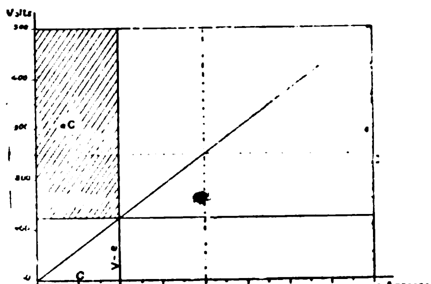



Fig. 17.

Horizontal distances represent currents, and vertical ones differences of pressure. The hatched area represents the work done by the motor, and this is a maximum when $e = \frac{V}{2}$, as is readily understood. The efficiency is $\frac{e}{V}$.

Take as possible values in the equation: power of motor $= eC = e\frac{V-e}{R}$

| | | WATTS. | H.P. | EFFICIENCY. |
|---|---|---|---|---|
| $(A)$ | $eC = 240.\frac{500-240}{10} = \frac{240 \times 260}{10}$ | $= 6240$ | $= 8\ 32$ | 48% |
| $(B)$ | $= 250.\frac{500-250}{10} = \frac{250 \times 250}{10}$ | $= 6250$ | $= 8.33$ | 50 |
| $(C)$ | $= 260.\frac{500-260}{10} = \frac{260 \times 240}{10}$ | $= 6240$ | $= 8.32$ | 52 |
| $(D)$ | $= 300.\frac{500-300}{10} = \frac{300 \times 200}{10}$ | $= 6000$ | $= 8.00$ | 60 |
| $(E)$ | $= 400.\frac{500-400}{10} = \frac{400 \times 100}{10}$ | $= 4000$ | $= 5.33$ | 80 |
| $(F)$ | $= 450.\frac{500-450}{10} = \frac{450 \times 50}{10}$ | $= 2250$ | $= 3.00$ | 90 |

A motor should be designed for a high efficiency for average running conditions; say, 90 per cent. A much greater power may be obtained fromit then, when specially needed, when the efficiency is not of importance. The efficiency affects most the cost of running the motor; so that the average running conditions affect the cost, and not, particularly, special demands on it.

Let us consider how $e$ may be increased. As we have seen, it depends on the rate at which the conductors on the armature cut magnetic lines. This depends on:

(1) *Number of loops on the armature, and its diameter.* This is limited by considerations of mechanical design for strength, size, etc., as well as the space required for magnetic core, for good insulation, and for low resistance conductors to save energy in heating, and prevent burning out. The most danger arises to a motor from this cause when the car is just starting. The armature is not revolving, and therefore $e$ is zero; there will then be a rush of current, due to $V$, through the windings of the motor $C = \frac{V}{R}$ which may be great enough to produce serious effects.

(2) *The rate of revolution of the armature.* This, again, depends on the rate of travel of the car (or the average rate), or to the amount of reduction between the speed of the armature shaft and that of the axle. The question of double or single reduction or of gearless motors comes under this head.

(3) *The strength of field.* This depends on the number of ampère turns about the fields up to the point of saturation, and to the amount of cross-section of the magnetic circuit, as well as on the permeability of the iron or steel used. The latter is fixed in the design. As it is important always to have a strong field, it is usual to design the motor so that the lowest current keeps the fields nearly up to saturation.

The ampère turns may be altered by what is known as field commutation, which affects the number of turns, as well as the current, by altering the resistance of the fields. An added external resistance is also used for decreasing the current. Some systems use it entirely instead of the field commutation, but the best combine the two, using the external resistance, especially for starting, to prevent a heavy rush of current through the motor. Of course, energy is lost in these added resistances; so that they should not be used for average running conditions.

A great deal of trouble, however, has been experienced with motors with commutated fields on account of the difficulty of providing good insulation in the limited space allowed them.

Field commutation is resorted to more on account of the changes of resistance, and therefore of current flowing through the motor which it affects, than for changes in field strength. There are, as a rule, three sections in the fields, which are designed to produce progressive effects by the following combinations; these being affected by the cylindrical switches which are placed on the end platforms of the car, to be used one at a time as required. In nearly all cases in the present practice, the fields and armature are in series:

(*A*) The three coils in series.

(*B*) One cut-out, or short-circuited; the other two in series.

(*C*) Two in multiple, with other in series.

(*D*) Two in multiple, the other cut-out or short-circuited.

(*E*) All three in multiple.

The Edison controlling switch has seven positions: The first, *A*, with an external resistance in series; $2 = A$; $3 = B$; $4 = C$; 5 has two in multiple, with the third short-circuited; 6 two in multiple, with the third cut-out; and $7 = E$. There is practically no difference between 5 and 6.

Supposing, as an example, a motor designed for efficiency at a rate of ten miles per hour, and that the fields are nearly saturated with the smallest number of ampère turns employed, and that it is running with combination (4) or (*C*) at this efficiency. Then by changing through (3) (2) to (1) we decrease the current, and therefore the product *eC*, and therefore the work done, or the speed, since the field remains nearly the same. This lessening of speed reacts in lowering *e*, which allows an increase of current, tending to increase the speed until a balance is reached. The motor is then running at a lower speed with a lowered efficiency.

Or let us pass to combination (7) or *E*. *R* is diminished, and therefore *C* increased, and the product *eC* increased, and the speed; since *e* is not altered much from the change of current. But the increase of speed increases *e*, which reacts on *C* to decrease it, tending ~~again to decrease~~ the speed until a balance is obtained. The speed is increased and the efficiency at the same time.

The series motor appears to have a number of advantages over the shunt:

(1) The slowness of magnetization of the fields in the shunt motor, due to self-induction, and a consequent abnormal rush of current through the armature in starting.

(2) Regulation of current and field strength effected by field commutation in the series motor.

(3) The fields used as a resistance in the series motor.

(4) Insulation of series motor more easily made on account of lower difference of potential at the brushes.

(5) Automatic field regulation up to the point of saturation in series motor.

The mechanical considerations relating to motor and car pertain to the position of the motor and the nature of its connection with the axle. On its position depend the readiness with which it can be got at for inspection or repairs; its protection from dust; whether it occupies space or not, which would interfere with the carrying capacity of the car; and its dimensions when attached to the axle, with a view to leaving a sufficient space between it and the ground.

Special precautions must be taken to keep dust out of the motor and gears by coverings of various kinds. The spur wheels are sometimes allowed to dip or run in oil in a tight case that surrounds them, which reduces the wear and noise.

The car now used commonly has two motors, which are placed beneath the flooring, one connected with each axle.

Different methods have been used for connecting the armature shaft to the axle; such as (1) spur gears; (2) sprocket chains; (3) bevelled gears; (4) connecting rod, as in locomotives; (5) worm gears; (6) ordinary belting; (7) ropes and pulleys; (8) friction plates; (9) gearless, or centering of armature on axle.

Most roads now use spur gearing with single reduction; a small cogged wheel on the armature shaft being geared into a larger one on the axle, or sometimes two sets of such wheels are used side by side; the one set staggered with respect to the other; that is, set one-half pitch farther ahead.

In most types of motor part of the weight rests directly on the axle, the rest being supported by spring connections to the truck. Where too much weight is supported directly on the axle, it causes great wear on the tracks from pounding. Spring connections obviate this difficulty to a great extent.

The other modes of connection have been tried, but must have been discarded on account of their greater complication and losses of efficiency due thereto. One especially is likely to survive, and may yet displace the single reduction spur gear which is now the favorite, and that is the gearless motor, in which the armature is centered directly on the axle. This is the ideal as regards simplicity, and has been making considerable headway. Objections to it that have stood in its way have been that the speed of revolution of the armature is reduced, and therefore that the strength of the fields must be greatly increased; or that the diameter of the armature must be considerably greater that the speed of the rim may be greater; or that the number of turns on the armature must be increased; that the electromotive force may be kept up for good efficiency. The torque on the armature is also increased by increasing its diameter. But all these changes conflict with the necessity of keeping dimensions down on account of the very limited space allowed the street car motor between floor of car and ground.

The current enters the car by way of the trolley, whence it does its work, and passes to ground through the bearings and wheels.

First, there is a wire from the trolley leading to each end of the car to the controlling switches, which are placed on the platforms. Through these switches, as they are thrown into the different positions, the current is sent through different wires to a central point in the car, where it divides and goes through the same parts of the two motors and then to the ground.

Another circuit passes from the trolley to supply lamps in the car, of which there are enough in series to make up the required potential thus:

five 100 volt lamps are usually used in the 500 volt circuit. There is another circuit when heaters are used, and an open one for lightning arrester.

The lightning arrester is an instrument which provides a gap in its circuit across which the current at 500 volts will not jump, but the high potential lightning leaps across and thence to ground in preference to the longer paths through the motors. The regular current usually follows the lightning across this gap, so that some contrivance is usually provided to break this arc automatically. Lightning arresters are indispensable for the preservation of motors during thunderstorms.

There are switches and cut-outs in each circuit. The cut-outs are provided with properly graded fuse wire, which burns out when the current increases to an extent dangerous to the circuit on which it is placed. The failure of fuse wire to go at the right time is the cause of many burn-outs in fields and armatures of motors.

The number and style of cars to be used will depend on the service required, and on the length of line or lines.

Suppose that we require a five-minute service between two points, five miles apart, at an average speed of ten miles per hour—each car will make a round trip in one hour; so that there must be a car for each five minutes between the time it starts one trip and the next one hour after, or twelve cars in all. If it were essential that this service should be maintained constant, then there would need to be several cars extra to rely upon in case of breakdown or stoppage for repairs. The demands of the case will determine whether single motor cars are to be used, or with trailers; it being less expensive, if the service will allow, to run motor cars with trailers, if motors are constructed for that purpose, than to run two motor cars carrying the same number of passengers.

## THE LINE.

Under the head of *Line* is usually comprised the whole conducting system, from the dynamo out through the feeders and trolley wires, and from the cars through the track and ground back to the dynamo again.

The principal problems connected with the line are:

(1) The determination of the arrangement and dimensions of the trolley lines and their points of connection with one another and with feeders.

(2) The arrangement and dimensions of feeders.

(3) The subdivision of the line into separately fed sections.

(4) The suspension and insulation of the trolley line, trolley wire crossings, frogs, switches, insulation crossings, guard wires, and, generally, overhead construction.

(5) The bonding, that is, the cross or end connecting of the rails, or connecting them to ground.

There are a number of different ways in practice of connecting feeders and trolley lines. The more important are:

(1) The single trolley line with feeder to nearest point.

(2) A feeder running the full length of the trolley line, and connected to it at intervals of 500 to 1,000 feet,

(3) Same as (2), but trolley line divided into sections midway between points of connection with feeder.

(4) Continuous line fed at intervals with independent feeders.

(5) Same as (4), but trolley line divided as in (3).

(6) The ends of the sections in (3) and (5) are often connected to the feeders instead of the centres. This virtually doubles the capacity of the trolley line by allowing the current to flow from both ends of a section at once to cars in between.

The settling of the general arrangement as regards subdivision of line and relation of feeders and trolley wires depends on the following data:

(1) The length of line or lines, and their position with regard to the station.

(2) The service required of the line, and therefore the average and maximum current to be supplied.

(3) The initial pressure at the station.

(4) The minimum pressure allowable in trolley wire at average or maximum load.

(5) The line should be divided into shorter sections in parts of a city where there is danger of fires occurring, so that only a small part of the line need be out of service at a time from this cause.

The position of the line, the service required, and the general nature of the road as to grades, etc., are the primary conditions to be considered in the projecting of a street railway from an engineering aspect.

From these we may obtain an idea of:

(*a*) The maximum number of cars likely to be simultaneously in use on the line.

(*b*) The number on the level and ascending and descending grades, their speed, and power used.

(*c*) The weights to be carried and horizontal effort per ton weight required; that is, the co-efficient of traction.

Having settled these questions, we readily deduce the effective power required for the whole system for the use of the cars and the distribution of the power along such lines. Then, knowing the efficiency of transformation of the motors used under the given conditions, and also the loss of energy in heating the resistances of the line, we may determine the electrical energy required to be supplied by the station to meet these demands.

The power required per car consists of three parts:

(1) That lost in the transformation, electrical and mechanical.

(2) That used in lifting the car against gravity on grades.

(3) That used to move the car along the rails in overcoming friction; the weight of the car multiplied by the co-efficient of traction multiplied by the velocity of the car.

In determining the power required, it is usual to allow from ten to fifteen horse power per car as a maximum for small roads; and where there are many cars supplied by the same station as low as seven or eight. It will be less than double per car for trailers.

Knowing the power required along the line, and its general distribution, we can then estimate the most advisable cross-sections of trolley lines and feeders, and their dispositions, as we shall presently consider.

The copper required for feeders and trolley line is a matter of considerable expense. Nevertheless, as they are practically uninjured by time, and the life of the latter is very long, estimated on good authority to exceed twenty years, the running expenses for this portion of the equipment are very light, the charge going against interest on capital account.

Let us consider the electrical conditions of the line which determine the dimensions of feeders and trolley line.

First, then, what does the service demand of the line? Two things: that the pressure shall not vary much on it, being kept up to the standard for the system; and that it shall carry sufficient current for all the cars in use without excessive waste in heating.

The generators at the power station are supposed to keep the initial pressure in the lines practically constant. We will calculate, then, the necessary conductivity of the line to meet the above conditions.

Required to find the resistance of a line supplying current for a nnmber of cars along it, given the total allowable drop and the initial pressure. See Fig. 18.

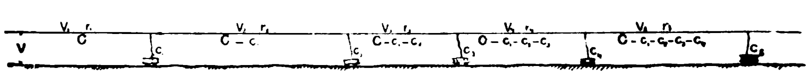


Fig. 18.

Let $C$ = total current supplied.

$c_1$ = current passing through 1st car.

$c_2$ = " " " 2nd car, etc.

$V'$ = total drop allowed on line.

$V_1$ = drop between beginning of line and 1st car.

$V_2$ = " " 1st and 2nd car, etc.

$r_1$ = resistance between beginning of line and 1st car.

$r_2$ = " " 1st and 2nd car, etc.

Then: $V' = V_1 + V_2 + V_3 + \ldots$

$= Cr_1 + (C - c_1)\ r_2 + (C - c_1 - c_2)\ r_3 + \ldots$

$= (c_1 + c_2 + c_3 + \ldots)r_1 + (c_2 + c_3 + c_4 + \ldots)r_2 + (c_3 + c_4 + \ldots)$
$r_3 + \ldots$

$= c_1\ r_1 + c_2\ (r_1 + r_2) + c_3\ (r_1 + r_2 + r_3) + \ldots$

Where each one of the co-efficients of the currents $c_1$, $c_2$, $c_3$, etc., $r_1$, $r_1 + r_2$, $r_1 + r_2 + r_3$, etc., is the resistance from the beginning of the line up to the point where the respective currents leave it; or

$V' = C\bar{r}$, where $\bar{r}$ is the resistance up to the electrical centre of gravity. The current leaving the line corresponding to the elementary masses, and the resistances between the points where they leave, and the beginning of the line being the ordinates.

That is, the resistance of the line to the electrical centre of gravity is equal to the allowable drop in potential along the line divided by the total current supplied.

If we suppose that the cars are at an average distance (resistance $r'$), nd are using an average current $c'$, we will have

$$V' = c'\ (r' + 2r' + 3r' + \ldots + nr').$$

$$= c' \frac{n\ (n+1)}{2} r'.$$

$$= nc' \frac{n+1}{2} r'.$$

$= C\bar{r}$, where $\bar{r} = \dfrac{n+1}{2} r'$; that is half the line, plus half the resistance between two cars. Or we may put it in this form: The total resistance of the line $R = nr' = \dfrac{2}{n+1} \dfrac{V'}{c'}$, which depends on the allowable drop of potential, the number of cars, and the current used per car.

As an example, suppose that we wish to ascertain the size of a trolley wire necessary for a section of road, two miles in length, upon which there will be not more than five cars at a time, this will give a six-minute service, at an average speed of eight miles per hour. Suppose that the average horse power per car is ten, which is equivalent to fifteen ampères approximately at 500 volts. Then we have:

$$R = \frac{2}{5+1} : \frac{50}{15}. \text{ if we allow a total drop of fifty volts along the line.}$$

= 1.111 ohms for two miles, or 10,560 feet.

= .152 per 1,000 feet.

An allowance of conductivity of fully twenty per cent. should be made in this in practice to meet extra requirements of the line.

$R$ = .152 − 20% per 1,000 feet.

= .122 per 1,000 feet.

Now, we find from tables that No. 1 B. & S. copper wire has .127 ohms per 1,000 feet, and No. 0 copper wire has .101 ohms per 1,000 feet. Either of which might be chosen, depending on the cost of power, on the one hand, or the value of money invested in line, on the other.

If t' e road were double-tracked, and therefore there were two trolley wires cross-connected, two wires of half the conductivity each could be used. No. 3 B. & S. has .202 per 1,000 ft., and No. 4 B. & S. has .254 per 1,000 ft. Either of which might be again chosen, depending on the above considerations.

Let us consider the result, $E = C_r$, as relates to the distribution of cars along the line.

If most of the cars are bunched at the beginning of a line, or if there is a heavy demand for current, due to heavy grades, heavy traffic, etc., then the centre of gravity will also be near the beginning of the line, and therefore $V'$ will be proportionately small. If they are collected at the centre, the centre of gravity will be the same as if they were evenly distributed along it. $V'$ would therefore be the same; but if most current is demanded at the far end of the line, the centre of gravity is shifted towards that end, and the total drop in potential $V'$ will therefore be increased. This distribution of cars must therefore be considered in laying out the line.

Following are a few notes taken from the report of Charles H. Smith, of the committee of the American Street Railway Association, referring to overhead construction. *Electrical World*, October 29th, 1892:

"All well-built lines should be sectioned, and the trolley wire should not be of too great a size, as it would then call for clumsy supports; and as it is not the main current wire, it can be of a smaller size. I would therefore recommend No. 4 B.W.G. silican bronze wire, which affords sufficient carrying capacity, and has great strength and durability.

"Sections should not be of greater length than two miles, and should be separated by trolley breakers, of which there are now a number of good ones in the market. In cities and villages where there is great liability of fires, it would be advisable to put trolley breakers at short intervals. Trolley wire hangers and pull-off brackets should be of the lightest make possible, and still have the required strength and the very best insulation."

"Feed-in taps must not be more than five poles apart, and should take the place of the trolley span wire at that point. They should be of at least No. 0 insulated wire.

"The trolley wire being sectional, it is necessary to run a feeder wire to each section; I would, therefore, recommend that the feeder wire be at least thirty per cent. larger than the occasion demands. It will be found that this is money well invested. The insulation in the feeder wire should be the best that can be procured."

"A cut-out box should be located on the pole at each trolley breaker, and should not carry a fuse. It should have the same wire running through it as there is on the outside. The fuses should be at the station, with ampère meter and cut-out switch for each section. Then, in case of trouble in any section, the location can be easily seen, and that section cut out if necessary until repaired.

"Lightning arresters are of great importance on the line, and I would strongly recommend using them at least every 1,000 feet."

The track as an engineering construction we have not time to deal with here, further than to say that for electrical traction it requires to be much more substantial than for horse or cable systems, and that modern steam railroad practice has many valuable lessons for the electrical street railway engineer.

The bonding of the tracks is that part of the construction which aims at insuring small obstruction to the current in reaching the ground, through which it returns to the power house.

Practice varies as to the means of attaining this end. Some roads bury a wire parallel to and between the tracks with frequent copper connection to the rails. The best construction seems to be the connecting by copper wire successive rails with frequent cross-connections to opposite rails, and also connections at intervals with plates of metal, buried near hydrants or other places where the ground is likely to remain moist. An addition of about twenty per cent. to the conductivity of the overhead system should be made to allow for possible resistance in the ground circuit.

### THE STATION.

This is perhaps the most important part of the whole system, as it is the centre of supply, where mechanical energy is transformed and sent out as electric energy. Everything must go well here, or the effects are at once felt in all parts of the system.

The location of the station is the first important question to settle. This depends on :

(1) It should be as near the centre of the system as possible, so that the copper necessary for feeders may be a minimum.

(2) It should occupy such a position that the cost of carrying fuel to it is as small as possible.

(3) Water should be available for boilers and for condensing purposes.

The cost of handling fuel is considerable. If coal is brought from a distance by train, the best position is where a siding can be had, so that the coal may be dumped or stored within reach of the boilers.

A great deal of water is required for boilers and condensers. City water is far too expensive as a rule. The station should be near a stream, or other unfailing ource of supply.

These conditions often conflict with one another. A central position would often involve an outlay in real estate which would be prohibitive, as well as being out of reach of coal or water. Usually, the most important condition is the supply of fuel, and after that the central position and supply of water are to be considered. A final balance will be obtained, which must depend on the consideration of prime cost and possible saving of running expenses.

The station must be able to supply power for the maximum service. It is advisable also, where possible, that it be provided with an extra amount of equipment to provide for breakdown of individual machines, or their stopping for repairs, for cooling or adjusting bearings, etc.

The requirements of a power station for street railway work differ from those of a plant for any other service, and that on account of the irregularity of the load, its sudden and extreme variations, and the great range of average load to be met, which are severe tests of the working of any machinery. For these reasons strong, substantial machinery must be used, and for steam plant quick regulating engines with efficiency at a wide range of power.

As we have seen before, the power sent out on the line is equal to the product $VC$, where $V$ is the difference of potential between the brushes which is kept practically constant. The work done, then, will vary with $C$. When small current is flowing, little work is being done along the line; and when a heavy current flows a greater amount of work is being done, so that the amount of work being done is proportional to the readings in the ampère meter. Suppose that the meter stands at 60, that would mean about 40 h.p. being sent out on the line, and rather more that the dynamo was transforming, and that the engine was conveying to it. Now, suppose that this current suddenly increases to 120—as would happen often enough—that would mean that more than 40 h.p. extra was suddenly required of the engine in addition to the 40 it was supplying, which would throw a severe strain on the whole plant concerned.

The boiler capacity should be ample for maximum running requirements, with one or more extra to be used alternately to provide for cleaning and repairing any of them.

High-speed engines, condensing if possible, excepting for large plants, have perhaps given the most satisfaction. The horse power required of them varies greatly at different times, and with wide range of cut-off they can best meet the varying loads; they have less to get out of order than the slow speed, and the initial cost is less. The high-speed engine, too, allows of less reduction between driving and driven pulleys, which is also desirable.

Condensing engines save about forty per cent. of fuel.

For large plants the generators may be connected in parallel, so that a heavy demand for current in any line may be equalized amongst the generators, and therefore amongst the engines driving them. If the total load rises or falls considerably at any period of the day, then one or more extra engines may be started or stopped, as the case may be, keeping the load on all thus within reasonable limits of their rated capacities; that is, at those for which they work most efficiently.

In this case slow-speed engines would come into play. Compound engines, too, work efficiently, and even triple expansion ones may be advisable where the total load is large and fairly steady.

Small units in proportion to the total power required are considered best; this on account of the wide variation of the load at different periods of the day, machines being thrown in or out as required, and also on account of the liability of accidents to the parts. The greater the part of the plant injured, the greater will be the impediment to traffic, and the more difficult will it be to repair.

Large fly wheels—which may be driving wheels at the same time—are an important requirement, as they assist in keeping up the speed when a heavy load is suddenly thrown on until the engine governor has had time to act.

A plan which is often followed is to connect each engine directly by belting to two dynamos with combined capacity equal to that of the engine. This is because an engine is less liable to injury than a dynamo; and if anything happens one of the dynamos, the engine may run on with the other until the first is repaired.

Counter shafts have been used a great deal, but are being discarded as objectionable. Their advantage was that with a number of engines and generators any engine could be thrown in to work with any of the dynamos. Considerable power, however, is lost in driving the shaft. It occupies considerable floor space, largely increases the quantity of belting used, and the losses connected therewith.

The following is quoted from C. J. Field: "What we want in the generating station for electricity is the smallest division of units, consistent with the safe and economical operation of the station. Each unit should be entirely independent and separate from all other units, thereby increasing the reliability. This cannot be obtained in a safe and economical way by the use of the counter shaft. In railway work with large generators we can see no excuse at the present time for its use. Generators should be belted directly to the engines, whether Corliss or high-speed, or else coupled directly to the engine shaft.

"A type of engine which we believe is going to be largely used on this class of work, as well as lighting work, is one that will come in between the high-speed engine and the Corliss, and which will combine many of the advantages of both. . . . This engine in units of 500 h.p. would run at a rotation speed of 140 or 150 revolutions, and with a piston speed of about 650 to 700.

" . . . . Beyond any question, when it comes to this size we have got to come to the Corliss practice of double valve, thereby reducing the clearances and bringing it down to the extent of the Corliss practice. The trouble in this line has been to get electric manufacturing companies to take up the building of large multipolar generators adapted for direct coupling at a speed of from 100 to 200 revolutions. We find that in Europe, where their work has been more special, they have successfully developed this type of engine and generator, and beyond any question it is going to be, both for lighting work and for railway work, the type of unit for central station practice in the future. It means, when the vertical engine is used, the installation of the steam and electric plant in the space formerly used for engines alone. This means reduction in the cost of building, operation, and maintenance."

It may be well to add—from the same source—a table giving the average fuel consumption per horse power, and the cost of the different styles of engine:

| Type. | | Lbs. Coal per H.P. Hour. | Cost per H.P. Sizes over 100 H.P. |
|---|---|---|---|
| High speed, | single | 4 to 5 | \$11 to \$13 |
| " " | compound | 3 " 3½ | 14 " 16 |
| " " | comp. cond. | 2¼ " 2½ | (14 " 16) |
| " " | comp. triple | 1¾ " 2 | 18 " 22 |
| Corliss engine, | single | 3½ " 4 | 16 " 18 |
| " " | comp. cond. | 1⅔ " 2 | 22 " 25 |
| " " | triple | 1½ " 1⅔ | 27 " 30 |

"The cost of steam plant complete is about $50 to $60 per horse power for high-speed, and $65 to $75 per horse power for Corliss."

There are four principal types of direct current generators corresponding to the different combinations of field and armature. They are:

(1) Field excited from separate source.

(2) The series dynamo where fields and armature (and external circuit) are connected in series sc that the same current passes through all.

(3) The shunt dynamo; in which the fields form a shunt between the brushes of the armature, so that a small part of the total current generated in the armature goes through the fields, and the rest through the external circuit.

(4) The compound dynamo has two sets of windings in the fields, being a combination of (2) and (3).

The dynamo for railway service must be a constant potential machine—that is, with the potential between the brushes constant—and this can only be accomplished for varying loads by having it compounded.

We have $E = V + Cr$, where $E$ is the generated $EMF$, $V$ the potential between the brushes, $C$ the current and the resistance of the dynamo between the brushes, so that when there is an increase of current $E$ must be increased to keep $V$ constant. Now, in the compound machine the shunt winding supplies the part $V$ and the series coils, by carrying the total current, increase the field strength, and the generated $EMF$ proportionally to that current, and equal to the product $Cr$, or within a reasonable difference from it if correctly designed.

A rheostat is usually placed in series with the shunt field in order to regulate $V$ as desired. Throwing in or taking out extra resistance decreases or increases the current flowing through the shunt field, decreasing or increasing the generated $EMF$.

Injury may happen to a generator from the following electrical causes:

Too large a current flowing—due to (1) too many cars being supplied; or (2) a short circuit to ground, either through car or any point on the line—may cause the overheating or burning out of the armature, or injury to the commutator.

Too high a potential difference—due to (*a*) too great a rate of revolution of the armature (due, perhaps, to the engine failing to govern quickly enough after a heavy load is thrown off); or (*b*) too great field strength (due, perhaps, to there being not enough resistance in the rheostat of the shunt field)—may cause the puncturing—that is, the current jumping across from one wire to another at a point of weak insulation, or from a wire to the metal of the machine—of the armature, or of the shunt field, or may cause the overheating or partial burning out of the shunt field.

The machine should be well insulated from ground to prevent this puncturing between the conductors and the metal of the machine. It should also be done for the safety of the attendant, who is liable to touch the metal of the machine and the positive brush at the same time.

The interior arrangement of the station should be made with an eye to simplicity, and ready accessibility to all parts; the engines, generators, switch board, etc., being all in sight, so that if any part is not working properly it may be detected at once and remedied, if possible.

The switch board should provide:

(1) That any dynamo can be thrown in or out of use at pleasure by means of a single cut-out.

(2) That the total load required from the station may be equalized amongst any number of the dynamos. This is done by connecting the positive wires to a bus bar.

(3) That in case a dangerous current is flowing through any dynamo it may cut itself out automatically. There are various forms of automatic circuit breakers for this purpose. A spring released by an electro-magnet when the current reaches a certain limit throws the circuit open.

(4) That any feeder may be thrown in or cut out at pleasure by means of a single switch.

(5) That any feeder may be cut out automatically when too great a current is passing out to it. As the line cannot be injured by this excessive current, the circuit breaker should be so regulated as not to throw for any possible current on the line which is used by the cars, but only in the case of short circuits to prevent waste or too great a strain thrown on the generating plant.

(6) That each dynamo circuit should have a current meter to show how much each is supplying, and whether they are properly equalized or not.

(7) That each line should also have a current meter.

(8) That the potential of any machine or that between a bus bar and ground may be determined at any time. One or more volt meters are used for this purpose. They are needed for the individual machines, to make sure that they are running at the right pressure before they are thrown into parallel with the others on the bus bar.

It is advisable also to have an auxiliary bus bar with which lines may be connected at pleasure, upon which it is desirable to have a higher pressure than for the rest of the system; this is sometimes necessary for lines reaching distant parts. It should be possible to connect any dynamos to this auxiliary bus. It may be advisable to increase their potential to from 550 to 600 volts. This may be done by rheostat regulation or increase of speed of armature.

Lightning arresters should be placed on all feeders entering the station.

# SOME EXPERIENCES WITH A CANADIAN TURBINE IN AUSTRIA.

By H. E. T. HAULTAIN, Grad. S. P. S.

MR. PRESIDENT AND GENTLEMEN,—It was in the beginning of January, 1890, that I took the position of resident engineer in charge of the ——— mines in Austria, previously having been assistant in the same mines. At that time a small 6-inch "Little Giant Turbine," manufactured, as I saw by the name on it, by some firm in Picton, Canada, had just been put in position. It was placed in the adit level at the foot of the day shaft, and was connected by vertical pipes in the shaft, with a reservoir on the surface; the perpendicular distance between the reservoir and the turbine was 265 feet. The lower 140 feet was of riveted wrought-iron pipes, 9 inches in diameter; the upper 125 feet, and a horizontal distance of 35 feet from the shaft to the reservoir was of plain 5-inch wrought-iron pipes. The connection between the 9-inch and the 5-inch was a cone 5 feet long. The 5-inch pipes happened to be on the mine, consequently they were used as far as they would go, the idea being to increase the whole length to 9-inch, if future developments required it.

The amount of water available was from 30 to 80 cubic feet per minute, according to the season. The turbine was to drive a dynamo by Immisch & Co., of London, capable of converting about 20 horse power into electrical energy. The dynamo was connected by cable along 550 yards of adit level with an Immisch motor, capable of giving out about 16 horse power, which was to drive the pumps and hoisting machinery in the pump shaft. The mine was flooded to adit level, and had to be pumped out to a depth of 120 feet; to this depth the mine contained about 1,000,000 cubic feet of water.

The turbine had been supplied by a London firm of agents to the order of the London office of the mining company, and in supplying the turbine they expressed their inability to give any guarantee as to its working under such a high fall, as they had never had the opportunity of seeing it at work under such circumstances. They calculated that it ought to make about 2,700 revolutions per minute, and for this speed it was geared down by means of a pair of bevel wheels to a counter-shaft which was connected with the dynamo by a leather link belt, the speed of the dynamo being 700 revolutions per minute.

If any one will take the trouble to look in the advertisements of almost any engineering magazine, he will see an engraving of this kind of turbine. It generally works with a vertical axle, and consists of a wheel (in this case 6 inches in diameter) which is as if it were in two stories, the one discharging to the top, the other to the bottom. The wheel is placed in a cast-iron case, which is in the form of a true spiral round the wheel. The water enters the wheel all round its sides, and leaves it at the top and bottom. The case is supplied with a gate which admits the water to both stories of the wheel, or only to the lower half. The whole is self-contained, and is most conveniently connected direct with an iron pipe conveying the water. A box built round it prevents the escape of spray; and this being connected with the tail race, it requires nothing more. It is most suited to falls of from 3 feet up to 50 or 60 feet. It is a remarkably convenient form of turbine, and can be put in position by anybody. But it certainly did seem ridiculous in its position at the bottom of the shaft; the belt connecting it with the dynamo weighed as much as the whole turbine—case and all; and beside the dynamo, which weighed a ton, it looked so small that it went by the name of "The Coffee Mill" among the Austrian workmen. Nevertheless, if we had had sufficient water to supply it fully, it would have driven several such dynamos; the trouble was that we had so little water that we could only open the gate about ¼ to ½ inch, instead of the 2½ inches it required for the lower half alone.

On inquiring into the matter, I saw that it was quite unsuited for our requirements, and could never be expected to give satisfactory results under such circumstances. When the dynamo and motor were in place, I saw by the reading of the electrical instruments that we could get only some 4 to 8 per cent. of the energy of the water passing through the turbine. Of course something different had to be put in its place, but until that arrived we had to do the best we could. So we placed a block of wood in the lower compartment of the turbine, blocking most of the spiral space round the wheel, and admitting the water to somewhat less than one-quarter of its circumference. A convenient thaw gave us plenty of working water, and as in the beginning the pumps had light work we succeeded in getting along all right.

The choice of the new wheel was left to me, and an advertisement was placed in an English engineering magazine. I wrote for catalogues and estimates to many places in England, Germany, Austria, and Switzerland, and went here and there examining turbines at work under various circumstances, but none that I saw had such a high fall as ours. I received quite a liberal education in the utilization of water power and choice of water motors, and, truly, I saw that it is by mistakes we learn.

The choice lay between a "Partial Girard" by Toelle & Co., of Niederschlema, and a Pelton wheel, offered by Hett, of Brigg, England, in answer to our advertisement. That the Pelton was a satisfactory wheel under high falls I knew from the description of the work done by these wheels in the Comstock mines, where they were working under a fall of 1650 feet. The Partial Girard I had seen at work most satisfactorily under falls of about 100 feet, in the valleys of the Erz-Gebirge, driving pulp and paper mills. The Pelton wheel could be delivered at the mine in about five weeks, the Partial Girard not under two months, so we chose the Pelton wheel.

I used to live alone in a disused stamps' house situated in the valley below the mine, and one night about three o'clock I heard steps coming stealthily along the stamps' house to my room I jumped out of bed, grabbed a big heavy oak stick I had brought from England with me, and waited to see what was going to happen. I was much relieved to hear the voice of the night-shift machineman asking me to come underground, as the turbine was acting very strangely.

I blessed that turbine in two languages, dressed myself, and went underground in a very bad temper. The turbine had already cost me hours and hours of worry and trouble and patient toil, because it was always getting out of order on account of the vibration of the cogwheel going its 2,700 revolutions per minute (and sometimes as high as 3,300).

I had always to attend to this kind of work myself, and it was no joke, I assure you. When I got underground the turbine was making about as unearthly a noise as I ever heard.

The assistant machineman, a stolid German, had given the thing up as a bad job, and was quietly smoking "Die verdammde Kaffee Mühle" was all he remarked. I shut off the water, determined that the turbine should not work any more in that place, and left the men to take it to pieces. They found that the block of wood inside had become loose and was jammed hard against the wheel—hard enough to reduce its speed to about 1,000 revolutions per minute and to absorb most of the power. Fortunately, the Pelton wheel arrived in a few days, and it was immediately put in place.

The way we all blessed that Pelton wheel, stood round it, and watched it by the hour, would have made a stranger think we had gone mad, or had found a new god. For nearly two months we had been continually worried and bothered to our wits' end over this "Coffee Mill"; it very seldom went for twenty-four hours without the bearings giving way and having to be readjusted. There were four bearings in four feet of shafting, and they, of course, had to be in perfect line; the upper two had been badly made by a local manufacturer, and were extremely difficult to adjust. The turbine was in a low corner of the shaft, where one had to crouch down and crawl about on hands and knees in a place always sopping wet and dripping with oil; the turbine had consumed two kegs of oil in two months. Then, the terriffic noise of the badly-fitting bevel wheels in the confined space made the life of the attendant miserable; but now we had a machine that went at a respectable speed of 600 revolutions per minute, it did not spill a drop of water or oil, and, beyond a slight hissing, it did not make a sound. There was no possibility of its getting out of order, and it gave a proper efficiency.

I made some tests with a Prony brake; and using only about eight to twelve cubic feet of water per minute, it gave an efficiency of about 60 per cent. There is no doubt that when more water was used and the nozzle wider open a considerably higher efficiency would be obtained.

The Little Giant Turbine had had its day underground; it was put in a place it was never designed for, and as a natural result it was a failure that cost considerable time and money.

From this out everything went smoothly underground, and the mine was soon drained.

About 200 yards from the shaft house was the smelting house, and for this we required about two horse power for driving the blast fan and other things. The London office had advised using a thirty-foot water wheel in the shaft house driven by the water before it went down the shaft to the turbine, and then by means of wire rope transmitting the power to the smelting house. When I arrived at the mine the trestles for the wire rope pulleys were already in place, and the water wheel was being constructed. I found it would be cheaper and decidedly more satisfactory to put an electric cable up the shaft, and an electric motor in the smelting house driving it from the Pelton wheel underground. This would have been a permanently satisfactory method, though still not the cheapest.

At this time I received instructions to arrange for the smelting house in the cheapest and most expeditious way possible, without paying much attention to its lasting qualities.

Above the smelting house was a reservoir about fifty feet by thirty feet, and six to ten feet deep; and into this flowed the water that did not go down the shaft to the Pelton wheel. The reservoir was about sixty feet higher then the smelting house, and now that the mine was drained and the pumps going only occasionally we could depend upon about fifty or sixty cubic feet of water per minute for three or four days at a time, and this was as long as the smelting generally lasted, so I decided to put the

"Little Giant Turbine" in the smelting house. The problem now was, what connection should I use between the turbine and the reservoir, which was 100 yards away?

The foreman assured me that there would be no difficulty in getting a man to bore logs of wood four yards long with a six-inch bore. We were surrounded by woods, and wood was cheap, so this seemed the most advisable way. We ordered our logs ten to thirteen inches in diameter, to be free from knots, and gave special instructions for them to be delivered with the bark on.

The foreman said he would get the man to do the boring; there were lots of men who did nothing else but bore logs for irrigating the fields. The logs arrived, but *without* the bark, and the man who had engaged to bore them suddenly found out he could not bore a six-inch hole; no, nor five inches either; nothing bigger than three inches. We hunted through village after village—the villages are all just about two miles apart from each other up there—but could not find a man who could tackle a five-inch bore. Here was I in a nice fix—the logs bought and *paid* for, and all drying and splitting without their bark on; the ore waiting to be smelted; pay day coming round and no money for wages; everything at a standstill for want of a borer. At last we found a man who possessed a 3½-inch borer, and another man who could use it, and professed to be able to use a five-inch borer made by a blacksmith in the neighborhood. If you take an incomplete hollow cone five inches in diameter at its base, and two inches at the top, and split it lengthways in half, one of these halves would be like this five-inch borer.

The new professed borer and an assistant, working at the extravagant pay of fifty cents a day (the average miner only getting thirty cents a day), with a promise of a bonus if he finished within a given time, started in fairly with his 3½-inch borer at the rate of about five logs a day, and my spirits rose again. After he had finished four or five, I thought I should like to see him try his hand on the five-inch borer. He sharpened it up well and began, and he and his assistant struggled away at it till the perspiration poured down their faces. At the end of about half an hour, they had only succeded in enlarging the 3½-inch hole to five inches for a distance of about six inches. The blacksmith who had made the borer was called in and sworn at; he guaranteed to make the borer all right, and next day they tried again, with no better luck, and the professed borer coolly informed me it could not be done, and that there was nobody in the Erz-Gebirge who could bore those logs with a five-inch bore.

The foreman came, and I blessed him for having assured me the thing could be done so easily; he lost his head, and intimated that I was a fool for not being satisfied with a 3½ bore ; as if water could not run *down hill* through a 3½-inch pipe !

I had several times been on the point of ordering wrought-iron pipes up from Prague ; but now, having got so far, I was bound I was going to put those logs in even if we had to cut them up in short pieces and dig them out with a gouge.

All of a sudden I received an inspiration, simple enough, but still an inspiration. I caught sight of a disused hand-hoisting gear which had two cogwheels, about three feet and six inches respectively in diameter. With the help of the blacksmith and carpenter we fixed the large wheel on the five-inch borer, and the small one on a crank handle, and arranged the whole on a sort of sliding table. Then we fastened a rope with a swivel to the end of the five-inch borer and drew the rope through a log that had already been bored by the 3½-inch borer, and fastened the end to a sort of capstan, and put a boy to keep it taut, and thus pull in the borer and keep it well up to its work. All one had to do now was to turn the crank handle, and the five-inch borer got through the wood in fine style. We put the four most active men on the job, and kept it going night and day. On the fourth day we had the satisfaction of seeing the last log finished. But still they were not fit for use, as the five-inch borer did its work very roughly, and the inside of the bore was left covered with big splinters. We had some iron rollers just about the size of the bore, and were able to quickly and thoroughly burn the splinters out with these. The logs were all bound with iron bands made from 1½-inch by ¼-inch iron ; those near the reservoir with three bands, and those near the turbine with four bands. The two end bands were plain hoops hammered over the ends, and the middle ones were made with a bolt and nut, and were screwed on hard while hot. The logs were laid in a trench from one to four feet deep, in as straight a line as possible.

In fastening them together, a hoop seven inches in diameter of 1½-inch by ⅛-inch iron was hammered alternately into the two corresponding ends of two logs. It was first fitted to the end of one log by hammering it into the wood to a depth of ¾ of an inch, and was then taken out and carefully fitted in the same way into the other log ; so that, when the two ends were placed together, ¾ of an inch of the iron hoop was thus in each log. This made a very simple and satisfactory joint. One of the logs, which had cracked rather badly before boring, split when the water was let in, but two extra bands put on immediately made it all right, for when it was thoroughly wet the cracks closed up.

The connection with the turbine was made with an odd bit of eight-inch cast-iron pipe that happened to be left over from the pumping gear. It fortunately had a flange that could be fitted to the turbine, and the end of the last log was pared down to fit into the end of it which had no flange. At the reservoir end a "gate" made out of the top of a stove was fitted to slide up and down on the end of the log, and an old beer tap was let into the log just below the reservoir to let the air out or in, according as the water was let in or out.

The turbine was geared to run at about 1,000 revolutions per minute, and everything worked perfectly smoothly. The smelting was begun immediately, and directly the metal began running properly samples were sent off to dealers in Vienna, Prague, and Berlin, asking for their bid. Answers were received by telegram, and the metal, which was of a remarkably good quality, was shipped off to the highest bidder in Vienna by express, and was paid for cash on delivery, just in time to meet the wages.

Of course there was considerable loss in the pipes, but still we had quite sufficient power for what we wanted.

Connected with the turbine, but never all going at the same time, were the blast fan, a pair of crushing rolls, a set of three small slag stamps, a heavy end-shove concentrating table, and a set of vibrating sieves. All the counter-shafting, belting, and gearing were made out of odds and ends lying about on the mine; several of the pulleys were made of wood by the carpenter, and some of the bearings were of beech. Not a thing but the logs and the iron for binding and connecting them was bought; the highest wages received by any of the men on the job was that of the head carpenter, who got forty guldens or sixteen dollars a month. So I think I fulfilled my instructions to do the job in the cheapest and most expeditious manner possible.

To those who have been accustomed to seeing turbines and other machinery easily and comfortably put in place by ordinary workmen, and to seeing logs bored out for pumps, etc., as an everyday occurence, it probably seems strange that an engineer should attempt to waste the time of a scientific society in describing these clumsy efforts about an apparently simple makeshift. But there is the point—it was a *simple makeshift.*

Plans had been drawn up by the resident engineer, under the instructions of the London office—which seemed very nice from simply the engineer's point of view—for a thirty-foot water wheel and transmission by wire ropes for a distance of 200 yards. Plans had been drawn up and approved of for meeting the same end very neatly and more cheaply by electricity, using the Pelton wheel in the shaft as the motive power. This was highly satisfactory, and would have been so permanently, whereas the turbine in the smelting house must be only temporary, because the water supplying it would later on be required for the Pelton wheel to furnish power for the hoisting machinery. With the electrical plan, all one had to do was to order the machinery, drop it into place when it arrived, and *pay*; but there was the trouble—the *paying*.

I give you this as a true bit of experience—as an experience that impressed itself very strongly on my mind, and which, I feel confident, has played an important part in my education; simply because it was rough, clumsy, simple, a makeshift, in a place where everything that I expected and desired was the opposite.

FREIBERG, SAXONY, December, 1892.

# NORTH BAY WATERWORKS.

By T. R. Deacon, P.L.S., Grad. S.P.S.

The town of North Bay, population 2,500, stands on a neck of land about two and three-quarter miles wide, which forms the height of land between the waters flowing into the Georgian Bay *via* Lake Nipissing and the French River, and those flowing into the Ottawa River *via* the Mattawa River. The geological formation is Laurentian, the rock being chiefly gneissoid granite and quartzite of an extremely hard nature. As the town is quite young, it being only nine years since the first house was built in that locality, though a very important point as a railroad town, and, at present supported by little agriculture or mining, the town fathers thought that it would be unwise to go to any very great expense in the construction of a waterworks system.

The services of John Galt, C. E., of Toronto, were obtained as consulting and chief engineer; and, under his direction, a careful examination was made of each of the different sources of supply.

The first scheme considered was to obtain water by gravitation from Chippewa Creek, above the falls on the same, at a point about two and a half miles north of the town, where an elevation of some 215 feet could be got. This would have been the most desirable system, as, though the first cost might have been greater, still, no machinery, fuel, or storage tank, would have been required. And I may say here that for these and many other reasons, wherever practicable, a gravity system is always the best. However, the Provincial Board of Health condemned the water absolutely, as unfit for domestic purposes, owing to certain organic impurities in it. The scheme was therefore abandoned, as the cost of constructing filters and purifiers, such as would have been required, rendered the scheme impracticable.

The next proposition examined was one to gravitate water from Trout Lake (a lake about nine miles long, and three-quarters of a mile wide; the head waters of the Mattawa River, two and three-quarter miles northeast of the town) into a storage basin, near the town, and then pump it into an elevated storage tank. The lake had an elevation of about twenty feet above Lake Nipissing; but, after an examination of the country between, it was found to be impracticable owing to the intervention of a wide ridge of almost solid rock, about 2,000 feet in width, and having a maximum elevation of nearly sixty feet above Trout Lake. The water in Trout Lake was of a better quality than that in Lake Nipissing, and would have been more desirable for domestic use. It might have been obtained by pumping, but only at a very heavy cost, as it would have required two and three-quarter miles of pipe to be laid through a piece of country covered with dense bush growing on a light layer of soil, underlaid for almost the whole distance by hard Laurentian rock, besides having either to cross or get around a deep muddy lake and a boggy marsh. This was beyond the financial resources of the town.

It was finally decided to use Lake Nipissing as the source of supply, as the water was of a fairly good quality. This being settled, Mr. Galt designed a very simple and efficient system, capable of being used either as a storage or a direct pumping system. A point was selected at the extreme western end of the town where the conditions were most favorable for obtaining an abundant supply of good water, unaffected by sewage from the town, and there the pumping station was erected. A twelve-inch cast iron conduit pipe, 585 feet long, with flexible joints where necessary, was laid out into the lake. The conduit was laid in one day and a half. The weather was fine and calm; and, as the shore end had been excavated for and laid, the remainder was put together, one length at a time, on a flat raft of timber; and, as each joint was made, the raft was pushed out from under it, the pipe sliding on wooden rollers. The pipe was suspended from tripods of 4 x 4 inch scantling, with feet of bits of plank to keep the legs from sinking in the clay bottom. The tripod was placed over the pipe, and the one and a quarter inch rope made fast and twisted up tight with a stick before the raft was shoved out from under the end of the pipe. When the special casting for the intake end had been put on, and everything made ready, the whole length was lowered gradually by untwisting all the ropes at the same time, till the conduit rested evenly and firmly along its whole length upon the bed of the lake.

A neat and commodious pumping station was built of brick and stone, consisting of the boiler room, pump room, dwelling, and, underneath the dwelling part, a large room, 32 x 25 feet, in which to place dynamos for electric lighting. The dwelling for the engineer consisted of seven large rooms, with hall and stairway; a balcony in the rear looking out over the lake. The pump, made by the Kerr Engine Co., of Walkerville, was of the Worthington pattern; compound, duplex, and direct acting, of one million gallons capacity per twenty-four hours. The boiler was a sixty horse power, double return, multi-tubular steel boiler, five and a half feet in diameter, ten feet long, and three-eighths of an inch thick, with a single thirty-six-inch flue, and fifty three-and-a-half-inch return tubes arranged around the sides; the products of combustion being discharged into the chimney through a tunnel under the boiler, thus sending them out at as low a temperature as is consistent with a good draught. When all connections were made and steam turned on, the pumping machinery worked beautifully and smoothly. The pump was provided with an automatic cut-off, to prevent overflowing the tank. When the pressure in the pump rose to the pressure due to the elevation of the tank, plus the head due to friction, by means of a piston loaded with a weight, a sliding rod was moved that shut off the steam and stopped the pump. The pump was also provided with revolution counter, time clock, water gauges, steam gauges, etc.; and was very complete. From the pump, which had a ten-inch discharge, the water flowed into a ten-inch main leading down to the more thickly populated parts of the town, where it was distributed through eight, six, and four inch mains, according to the requirements of the several localities ; while an eight-inch pipe led to the elevated storage tank, placed on a high elevation at the northern end of the town. This was one of Mr. Galt's patent storage tanks, and has several important improvements over the ones designed for the Essex and Amherstburg systems, drawings of which were shown in a paper read by Mr. A. T. Laing, and published in last year's pamphlet by the Society. The whole structure consisted of a masonry tower, sixty feet high above ground, with substantial stone foundation placed six feet underground, and laid in cement mortar. The masonry was twenty-one feet external diameter at the top, circular in form, and varying in thickness from five and a half feet at the surface of the ground to two and a half feet at the top, the internal face being perpendicular. Upon this is placed a steel tank, twenty feet in diameter, and twenty-eight feet high, with an inverted conical bottom. The base of the cone is sixteen feet in diameter ; two feet of the bottom of the tank, all round, being horizontal, and resting on the masonry, as shown in the accompanying sketch (Fig 19). The tank was provided with overflow pipe, and had a capacity of 60,000 gallons.

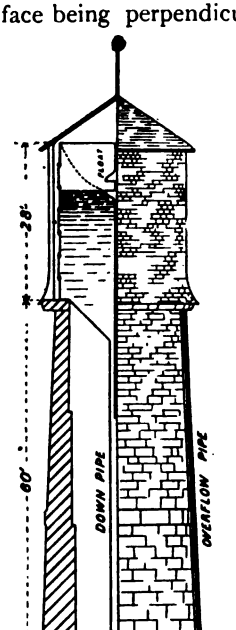


Fig. 19.

You will notice that this tank does not rest on brackets, and that the masonry tower is circular in form.

Owing to the difficulty in obtaining brick at North Bay, the contractors were allowed to build the whole structure of stone instead ; and, as good stone was difficult to get also, constant attention was required to prevent the use of bad stone in the work ; and, even then, as good results as wished for were not obtained in the appearance and finish of the tower.

The pipes used were from the Canada Pipe Foundry, of Hamilton, and proved to be of very good quality. I examined them nearly every time a pipe was cut, besides having them all sounded, and found them very free from blowholes or flaws. Of course, some of them were bad and had to be condemned; but, as a whole, they were a good lot of pipe.

In putting together cast-iron water pipe, the joints are made by first placing the spigot end of the pipe in the bell end of the last pipe laid, and shoving it home with a pinch bar until it is tight up to the shoulder inside. Then a gasket of oakum is wound round the spigot end, and with a thin, flat steel chisel or "yarning iron," as the tool is called, it is driven in tight against the shoulder inside to prevent the molten lead from running into the inside of the pipe. A piece of rope covered with clay is then wound round the pipe and pressed up against the end of the bell, leaving a small space on the top of the pipe for pouring the lead into the joint. When the lead has been poured, the clay is at once removed; and, with a steel caulking iron and hammer, the lead is driven firmly into the joint, making it perfectly water-tight. A joint in a ten-inch pipe ought to stand a tensile pull of, at least, six tons before pulling apart; in fact, if the pipes are good and the joint is well made, the more they are pulled the tighter they get. The amount of lead required in a joint may be roughly stated as one and a half pounds of lead per inch in diameter of the pipe, and costs about three or four cents per pound. No joint should ever be passed about which there is the least doubt. All interested should be sure, before it is covered up, that it is absolutely water-tight and will stand any pressure the pipes themselves will stand; say, 300 pounds per square inch of hydraulic pressure.

The hydrants used were similar in design to the Toronto hydrants, but scarcely so heavy. They were placed from about 300 to 500 feet apart, according to the locality, being closer together in the business portion of the town. There were thirty-six in the whole system. Valves, sixteen in all, were placed at different points along the mains, and upon all branches from all the larger mains, to allow for repairs or extensions being made to any part of the system without disturbing the rest. There is a good deal of rock in the streets of North Bay, and it is exceedingly hard, so that considerable blasting was required. The pipes were laid at a depth of 5½ feet below the street grade, and covered with soft earth to within two feet of the top; the remainder of the trench being filled up with finely broken rock and sand mixed together. Steam drills of the Rand pattern were used, the steam being supplied from a small upright boiler to the drill through a 1¾-inch hose. There were two drills used, and each would drive about seventy-four feet per day of ten hours, the hole driven being about two inches in diameter. The holes had to be drilled about every fifteen inches apart and seven feet deep. In blasting, it was found advantageous to use dynamite containing seventy-five per cent. of nitro-glycerine for the first two or three feet in the bottom of the hole, and then a few sticks of fifty per cent. on top, the rock being hard to shatter. Fifty per cent. dynamite was used altogether at first, but did not do good work. When the works were finished a trial test was made, under Mr. Galt's supervision, in the presence of the majority of the council and a large number of the citizens, with very gratifying results; water being easily thrown over the highest hotels, churches, and other buildings in the town, from the tank pressure alone. The valve on the main leading to the tank was then closed, and a direct pumping test made. When the pressure at the pump end was raised to 140 pounds per square inch, the water was thrown vertically from the hose nozzles until it separated into finely-divided spray at an elevation of about 100 feet, as nearly as could be judged. A few days afterwards, a fire occurred in a row of old wooden buildings which, it had been predicted, time and again, could never be saved should fire get into them. In six minutes the firemen had three streams playing on the fire, and completely extinguished it without any of the houses being rendered entirely uninhabitable, except for the water. The system was put in at the very small total cost of a little over $29,000, and has proved, so far, a gratifying success. The Canadian Pacific Railway Co. has large shops here, as North Bay is the headquarters for the "Soo" branch, and for a division of 125 miles each way, east and west. It is also the northern terminus of the Grand Trunk Railway from Toronto. Both these companies take water from the town for all purposes.

# AN EXPLORATORY TRIP THROUGH THE ROCKIES.

By L. B. Stewart, P.L.S., D.L.S.

According to previous agreement our party met together at Morley on July 3rd. Morley is situated within a few miles of the Rockies, close to the Stoney Indian reserve, and consists of an Indian mission and a trading post. It is thus a convenient starting point for an expedition into the mountains, as everything needful can be procured there—supplies, horses, and guides. The Indians here have possession of one of the most beautiful spots in the territories. Their reserve occupies the Bow River valley extending from Morley to the base of the mountains. The valley is three or four miles in width, and is flanked by hills several hundred feet in height, from which it appears to be a level plain, with the river meandering through it, but a closer inspection shows that it rises in a series of terraces from the river. This terrace formation is observable in the valleys of many of our western rivers, and seems to point to the fact that their channels at one time must have been much wider than at present, the water being dammed up by some obstruction below, and allowed to subside suddenly at long intervals by the breaking away of a portion of the obstruction. This theory is borne out by the fact that the Bow valley is dotted over with "islands"—as they are called—or high isolated hills covered with large Douglas fir; probably these were at one time actual islands, in a lake-like expansion of the river.

After spending a few days at Morley in purchasing supplies and horses and engaging guides, we finally started on the 8th of July Our party numbered seven, including our two guides, each man being provided with a saddle horse, and we had besides six pack horses, so that ours was quite an imposing "outfit"—to use a western term. Horses, or Indian ponies, in that part of the world cost from $20 to $30, and can generally be sold at the termination of a trip for about two-thirds of their original price, so that transport is by no means expensive.

We generally travelled for four or five hours without stopping, and would then pitch camp about the middle of the afternoon, thus allowing ourselves time to explore the surrounding country, which we usually did by climbing the nearest hill or mountain that commanded the most extensive view.

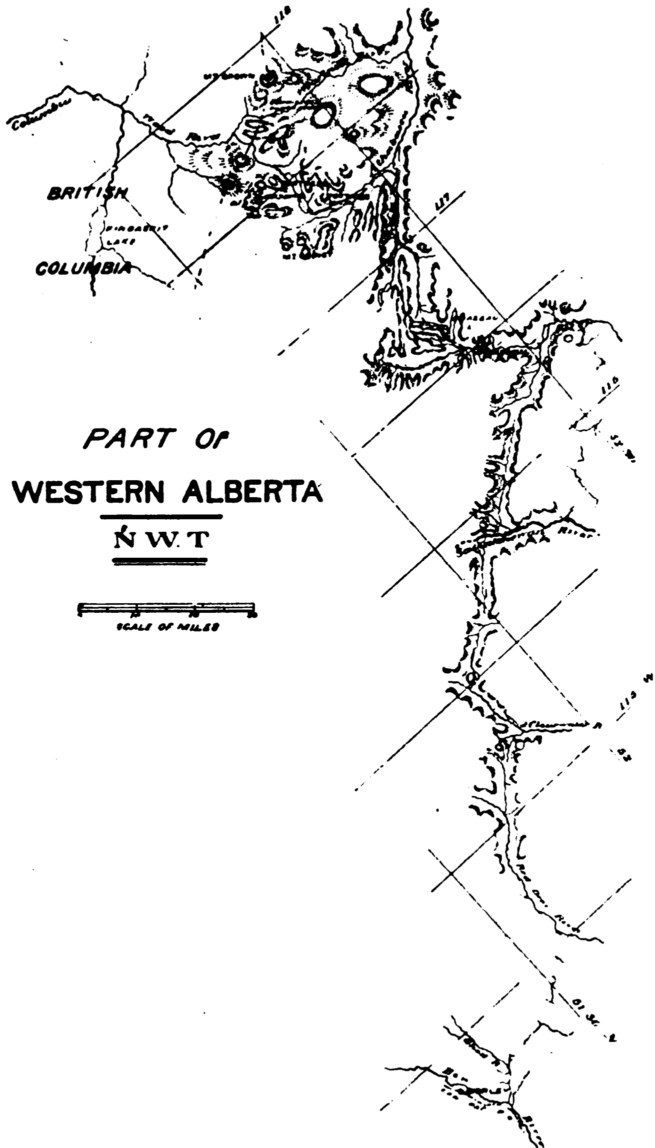



Fig. 20.

For the first three or four days our route lay among the foothills, where the scenery is of a much less rugged nature than that among the mountains proper. Hills they are called only by contrast with the mountains, but they would put to shame many of the so-called mountains in the lower provinces, many of them being 1,000 to 1,500 feet in height above the valleys, and between 5,000 and 6,000 feet above the sea.

On Saturday, July 9th, we reached the Red Deer River, where we prepared to spend Sunday. We were now fairly on our way, and "far from the madding crowd's ignoble strife," in the words of the poet, having left the last outpost of civilization far behind us, and with the prospect before us of meeting with no human beings, except, perhaps, a few roving Indians, and hearing no news of the outside world for at least two months.

We now followed the Red Deer for thirty or forty miles, and on July 12th reached a beautiful spot among the mountains known as the "Mountain Park," at a place where a small tributary enters the main stream. This "park" is a gently undulating plain several square miles in extent, and is rendered all the more beautiful by contrast with the rugged mountains by which it is surrounded; several streams fringed with timber cross it at intervals, and add greatly to the effect. It would be a good location for a small ranch, but would only suit a person who was tired of the world and desirous of retiring into seclusion, as there is no room for a neighbor in that part of the valley.

The following day we packed up and followed the tributary of the Red Deer mentioned above, crossed a height of land, and were soon following a small stream, which led us through a narrow valley, finally, to the Clearwater. Our trail now followed this river for about twenty miles, and then turned sharply to the right and ascended a height of land about 1,500 feet above the river, leading to another valley. That night we camped at about 7,000 feet above the sea; patches of last winter's snow were to be seen in several places, and the night was bitterly cold, but we enjoyed perfect freedom from mosquitoes. These pests are rather numerous in the lower valleys and among the foothills, but they have the good taste to avoid the heights, and they disappear altogether from the mountains early in the fall. Some of us before retiring took the precaution to sew our blankets together in the form of bags, after the manner of Arctic explorers, thus rendering them very much warmer. The next day we pushed on as rapidly as possible, hoping soon to reach a lower altitude, and therefore a higher temperature, and travelled a distance of about thirty miles. It was necessary to make a long move, as our trail led through a narrow thickly-wooded valley, which afforded no food for the horses. We now found ourselves in the valley of the Saskatchewan, though still some miles from the river. We arrived here on Friday, July 15th, and decided to remain till Monday to give our horses a rest, as they were rather used up after the long journeys of the last two days. This gave us an opportunity to explore a little in our neighborhood. The Saskatchewan here flows through a wide open valley, thinly wooded; one part of it might almost be called a prairie, being quite level, and destitute of trees. It bears evidence, however, of having been wooded at one time, the timber probably having been destroyed by fire. This prairie goes by the name of the Kootanie Plain, from the fact that in years gone by the Kootanie Indians were in the habit of coming here from British Columbia to hunt buffalo. To the north of our camp towered a high mountain, which we named Sentinel Mountain, from the fact that it commands an extensive view in every direction, up several valleys that radiate from that point. Below the Kootanie Plain a large river enters, which the Stoneys call the Hahaseji Wapta, or the Bad Rapids River, and on making its acquaintance in fording we heartily concurred with them in the appropriateness of the name.

This halt of a couple of days I found very acceptable, as I had been walking since I left the Little Red Deer River, about eighteen miles from our starting point. My object in so doing was to test the value of the pedometer in making a tract survey of a country. The plan adopted was to read the pedometer at every point on the trail where its general direction changed, and to take the bearings of the portions of the trail between those points with a prismatic compass. In this way a rough traverse of the route was made, the distances being greatly in excess of the straight-line distances, but latitude determinations, made as often as possible, served to connect the lengths of the courses. Latitude observations can be used as a check on the dead reckoning only when the general direction of the route travelled does not make too large an angle with the meridian. If the general direction is nearly east or west, the method fails altogether, although if portions of the route are nearly north or south the survey of those portions may be used to determine the ratio between the length of a course given by the pedometer and the length in a straight line, and the other courses connected accordingly.

On Monday, July 18th, we moved on, and after travelling about ten miles crossed the river and continued down the left bank until we were again among the foothills. One of the chief objects of our trip was to reach Mounts Brown and Hooker, at the source of the Athabasca River; but by observation I found that we were already in the latitude of those mountains, and about eighty or ninety miles to the east of them, and our guides were still taking us in a northerly direction. We accordingly held a consultation with them, and by means of a mixture of Cree, Stoney, English, and signs, we found that they had no very clear idea of where we wished to go; but by the aid of a map sketched on a piece of paper we made them understand the direction of our proposed destination.

For the next few days our trail lay among the foothills, keeping parallel to the main range of the mountains—through endless swamps and muskeg, and swarms of mosquitoes, which made us anxious to be again in the cooler atmosphere of the mountains, where we were comparatively free from their attentions.

On Saturday, July 23rd, we reached the Brazeau River, a large tributary of the Saskatchewan, crossed it, and then followed the left bank for ten or twelve miles, and camped for Sunday on a spot of prairie near a small stream flowing into the river. On Sunday Dr. and Mr. Coleman and I climbed to the top of a mountain to the north of our camp, and reached a height of over 9,000 feet. The walking was good, the broken rock affording very good footing, so that in two hours we climbed about 4,000 feet, the height of the summit above our camp. Unfortunately, we were prevented by low-lying clouds from obtaining a very distant view—the object of our ascent—but we caught occasional glimpses through rifts in the clouds of distant snowclad peaks, and we descended to camp satisfied that we were now travelling in the right direction. On Monday we moved on up the river, but were caught in a heavy downpour of rain, which obliged us to pitch camp in a hurry, having travelled only about eight miles.

At this point our difficulties began. Mr. P. was taken ill, and, having learned from our guides that there was a party of Indians on their way to Morley, about a day's journey distant from us, he decided to overtake them and return with them to Morley. The next day he started, accompanied by Jimmy Jacob (one of our guides) and Mr. Coleman, and we promised to remain where we were for a week to allow Mr. C. and Jimmy time to rejoin us, and at the end of that time to move on slowly.

The week was spent rather pleasantly, climbing mountains and exploring the neighborhood, the only drawback being the bulldogs, a species of horsefly, that kept our horses about our camp fire endeavoring to get rid of them, and kept us busy trying to keep the horses away. At the end of a week we began to think of moving, but here we were met by a fresh difficulty. Our remaining guide, Mark Two Young Men, could speak no English, or professed to be entirely ignorant of our language, and we could obtain no information respecting the nature of the country in advance of us, so that we were obliged to ride ahead and choose a camp ground before moving. In this way we moved forward about eighteen miles to a place where the river forks, and here we resolved to remain for a few days to explore. We found that the more northerly branch of the river flows from a lake a few miles above the forks, which we named Brazeau Lake, and on climbing a mountain near us we could follow by the eye the southerly branch for twelve or fifteen miles, until it was lost to view by a bend of the valley. A considerable distance beyond we could see a lofty mountain, capped by a huge mass of ice and snow, and the possibility occurred to us that this might be one of the mountains of which we were in search.

The next day, August 8th, Dr. Coleman and I set out to explore the southerly branch of the river to see if there was any way of reaching this distant mountain. We walked for 18 or 20 miles, and then seeing that we could not accomplish much in one day we returned to camp, and on the following day we saddled our horses, and packed another horse with our blankets and four days' provisions, intending to travel up the river as far as possible in that way, and then send Mark back to our main camp with the horses, with instructions to come for us in four days, and then explore ahead on foot. We were destined, however, not to complete this programme, for after riding about fifteen miles we met Mr. Coleman and Jimmy on their way back to join us, having returned by a different route. They had gained some information at Morley that led us to change our plans; so we turned our horses' heads towards camp again, and arrived early in the afternoon.

Sunrise the next morning saw us all astir, preparing for a move in another direction, and in an hour or two we were again in the saddle. We followed the westerly branch of the river to where it leaves Brazeau Lake, forded it that point, and then skirted the shore of the lake for some miles, to where a torrent enters, which we followed for several miles through a narrow gorge between lofty mountains. We camped that night not far below the line at a height of about 6,900 feet, and on the following morning pushed on up the valley a mile or two, and then turned to the right, crossed a height of land, and soon reached a small stream, flowing in a northwesterly direction. We were now across the watershed that separates the Saskatchewan and the Athabasca systems. Our stream, after flowing about twenty miles, enters another, which, on Saturday, August 13th, brought us to a large river, flowing northwest, which the Indians call the Sun Wapta, and which we decided to be the Athabasca itself. We here spent Sunday, August 14th.

On Monday, as we were packing up, the Indians came to us and began bidding us an affectionate farewell, saying that they were going home, thinking, no doubt, that they had fulfilled their contract. Dr. Coleman produced a copy of their agreement, and explained to them that they had promised to guide us to Mount Brown and back to Morley, and I explained, moreover, that if they did not fulfil their agreement they would be paid nothing on our return. This brought them to time, and they went to work as cheerfully as if nothing had been further from their thoughts than leaving us in the lurch.

We travelled that day about twenty miles, and stopped sooner than we intended, the trail being blocked with fallen timber. We had cleared the trail the next morning, and were preparing to push on, when we found that Mr. Coleman's horse had met with an accident during the night having nearly strangled himself with his tie-rope. As there was a possibility of his recovery, we decided to wait there a day or two.

I then set to work to obtain our geographical position, and found that we were about in the latitude of Mount Brown, and twenty miles east of it, assuming its position on the maps as correct. By climbing a neighboring mountain, we saw a valley extending away to the southwest, through which a river flows, joining the Sun Wapta a few miles below our camp. Anything was better than inaction, so we resolved to explore this valley on foot, taking our blankets and provisions for ten days, and to endeavor to reach our destination in that way. Most of the next day was spent in making preparations, and about 4 p.m. we started, Dr. and Mr. Coleman and myself, leaving Dr. Laird and the Indians in charge of camp. Fording the river in front of camp with horses, and then having driven them back to the other side, we waved a farewell to those in camp and struck into the woods. After a couple of hours' hard scrambling through an exceedingly rough country, we reached the river we had seen joining the Sun Wapta. We had the pleasure of sleeping that night without a tent, but the night was fine, and there were no mosquitoes. The next day we marched on up the river about ten miles; not a very long day's journey on a good trail, but long enough when one is climbing over fallen timber and up and down cut banks with fifty or sixty pounds on his shoulders.

As the valley of the river now took a turn to the south we were obliged to cross, so we set to work the following morning to build a raft. We cut half-a-dozen logs, a foot in diameter and fifteen or twenty feet in length, and lashed them to cross pieces with ropes, and in a couple of hours from the time we began we were on the other side of the river. We pulled the logs up on the bank of the river to use on our return, shouldered our packs again, and struck into the woods.

On August 20th, we reached a lake about nine miles in length and a mile or two in width, at a distance of about twenty-five miles from our main camp. The scenery here was indescribably grand, the lake was of a beautiful blue-green color, and surrounded by huge mountains, from 10,000 to 12,000 feet in height, surmounted by glaciers. One mountain was particularly striking, bearing a certain resemblance to a huge fortified castle, with round towers and battlements, which we named Fortress Mountain, and the lake we named Fortress Lake. We attempted to climb this mountain to obtain a distant view, but found it impracticable; so the next day we followed the east shore of the lake for two or three miles, and then ascended along the course of a stream into a valley above tree line, lying between two mountain ridges. Following the ascent of the valley, we soon found ourselves on a ridge overlooking another valley, from which we obtained quite an extensive view. To the west and northwest the mountains appeared comparatively low, while to the west and southwest towered a succession of lofty snowclad peaks, and we concluded that Mount Brown most probably lay in that direction. One mountain to the south of us appeared considerably higher than its neighbors, and a rough triangulation placed it at a distance of thirteen or fourteen miles, and its height at a trifle over 12,000 feet. We resolved to reach this mountain, and, if it were not either Brown or Hooker, we expected at least to obtain a view of those mountains from its summit. Before descending, we moved to another spot from which we could get a good view of Fortress Lake. On the opposite side a mountain torrent could be seen entering the lake and giving its blue-green waters a milky hue, showing its source to be a glacier. The gorge through which it flowed seemed the most practicable route to the distant peak; so, on the following morning, we built a raft and paddled to the mouth of the torrent, preferring that mode of travelling to making our way through the dense forest that surrounded the lake. Here we camped for the night, making our bed, as usual, under the widest spreading tree we could find; and the next day, having cached all of our property that could be dispensed with for a few days, we set out along the course of the torrent, and by the middle of the afternoon reached the glacier from which it takes its rise, issuing from an immense ice cave. We then ascended the glacier to near tree line, and camped at a height of about 7,000 feet under a gnarled and twisted tree, that bore evidence of having braved many a storm. In the morning, after an early breakfast, we set out to climb the glacier; and after a very difficult and dangerous ascent among crevices, many of them covered with snow that made them doubly dangerous, we reached a bare ridge of rock above the glacier, and at a height of 10,000 feet. By this time a dense fog, accompanied by snow, had arisen, so that we could not see fifty feet ahead of us. We waited for some time, shivering behind a ledge of rock, and in a few minutes the snow stopped falling, but the fog remained. Nothing could be seen beyond the ridge but a sea of fog. By throwing stones over the edge and noting the time it took them to reach the rock below, we found that we were on the verge of a precipice, 700 or 800 feet in height; then as nothing further could be done we returned to camp.

By 11 a.m. the following day, we were again at the top of the ridge, and this time we were fortunate enough to have a perfectly clear day. About two miles to the southwest stood our mountain, separated from us, however, by an impassable valley, several thousand feet in depth, with the precipice to begin with. Here was a disappointment: our mountain stood before us, apparently not a rifle shot away, while it would be necessary to travel at least twenty-five miles in order to reach it; we would be obliged to return to Fortress Lake and ascend the next valley to the west. Any one exploring the Rockies without a guide will often find himself in a predicament similar to that in which we were placed, but probably no guides could have been procured that would have been of any assistance to us; in all probability, we were the first human beings that had ever set foot on that glacier.

Determined not to be beaten, we descended to our camp, packed up hastily, and set out for Fortress Lake, where we arrived in time to make ourselves comfortable for the night. On looking over our supplies, we found that we had only about two days' provisions; so that instead of carrying out the programme indicated above, it was necessary to beat a retreat. It is doubtful if the mountain we saw was one of the mountains we were in search of; but it is certain that if they are as high as they are said to be, we would have been able, at least, to obtain a good view of them from its summit.

With feelings of great disappointment, we prepared to return. The following morning was wet, but in the afternoon it cleared, and we put our raft together and paddled back to the end of the lake, where we spent the night. In the morning we shouldered our packs again for the last time, and by noon reached the point where we had crossed the river on our way up. After lunch, we rebuilt our raft and pushed out into the river. We soon found it useless to attempt to guide the raft in the swift current, and were obliged to let it take its own course, and after an exciting run of two hours we arrived at the spot where we had camped first after leaving the main camp, thus covering in two hours a distance that had required about five on our way up. On landing a distant shout was heard, and on a hill about a quarter of a mile away we saw our two Indians, who had been watching our arrival. They had brought two horses as far as the nature of the country would permit, and we were glad to transfer our loads to the back of one of them, having improvised a pack saddle with our straps. In about an hour we reached camp, where we found Dr. Laird busy preparing supper, to which we did ample justice.

The forenoon of the next day was spent in making preparations for our homeward journey, and in the afternoon we walked a couple of miles down the river to see a very fine canon, through which the river flows in a series of cataracts, making a wild and picturesque scene.

On Monday, August 29th, we began our homeward trip, and, after an uneventful journey of ten days, reached Morley on September 8th, having been away from there two months and two days.

On my return to Toronto, I set to work to make a map of our route from my notes and observations. Having reduced all the latitude observations and those for variation of the compass, I then plotted in the polyconic projection the meridians and parallels of the country traversed, on a scale of five miles to an inch. The position of the starting point was then fixed from the most reliable maps in my possession, and the courses given by the pedometer and compass plotted, the lengths being reduced by one-third. The plotting was continued until the first point whose latitude had been determined was reached. This point was then joined to the starting point by a straight line and the parallel of latitude passing through it drawn ; the intersection of these two lines gave the true position of the terminal point. The plotting of the traverse was then continued to the next point of known latitude, and the above operation repeated. In so doing I merely assumed that the general direction of an extended piece of traverse was correct, although its length might be considerably in error ; this depends upon the assumption that the length of any course in a straight line bears a constant ratio to its length, as given by the pedometer. I found that ratio to be about 6 to 10. After the framework of the map was thus constructed, the topography was easily added from the notes taken on the ground.

## NOTES AND COMMENTS.

The degree of B.A.Sc. is now connected with the post-graduate year of the school.

This degree, besides a regular course in one of the recognized departments of the school, represents an additional year of original research in the various laboratories of the school.

The subjects of study in this year are arranged in the following groups and subdivisions:

A. { Astronomy.
Geodesy and Metrology.

B. { Architecture.
Strength and Elasticity of Materials.
Hydraulics.
Thermodynamics and Theory of Heat Engines.
Electricity and Magnetism.

C. { Industrial Chemistry.
Sanitary and Forensic Chemistry.
Inorganic and Organic Chemistry.

D. { Mineralogy and Geology.
Metallurgy and Assaying.

Each student is required to confine his studies during the session to one of the above groups. He is not allowed to take less than two nor more than three of the subdivisions in any group—Inorganic and Organic Chemistry being obligatory on all students who select group C.

It is expected that the men taking up this work will from time to time favor the Society with the results of their investigations in the form of papers and discussions. These are sure to prove of interest and value, not only to students, but equally so to the profession in general.

A distinction has been made in the standing of students at examinations; successful candidates being now classed as honor men and pass men. This gives permanent recognition of special merit, and promotes thoroughness. Honor graduates also have special privileges in becoming members of the Canadian Society of Civil Engineers—a society which has done much to elevate the engineering profession in this country, and which, we trust, will be well patronized by the members of our Society.

We take the following extract from a letter to the Society by T. Kennard Thomson, C.E., 192 Broadway, New York, September 29th, 1892 :

While our Society is undoubtedly a success, it has not accomplished, as yet, all that I hoped it would. Last winter a graduate wrote me that it had become purely an undergraduate affair. This is not to the advantage of either the graduates or the undergraduates, and I have been wondering how it could be remedied.

The only encouragement you can give an active engineer to contribute papers is to ensure their prompt publication and dissemination. This applies to all engineering societies, and is a well-recognized fact. Will you kindly put a motion to the Society for me, suggesting the advisability of publishing a weekly, or at least a fortnightly, paper, which would contain as much personal news of the movements of our members as possible—noting their change of address, occupation, etc.; and, in addition, such other matters as is usually found in such a periodical, and contain *all papers read before the Society in full, as soon as read?* This would give absent members a chance to discuss the papers in the following issues, and would probably attract many additional short, but valuable, articles. The papers, with their discussion, could then be published at the end of the year, and would be 100 per cent. more valuable.

If this paper is started, I should be glad to furnish a leaf out of my own book, showing how I have succeeded in getting situations, having my salary increased, etc. I should also be glad to subscribe for a copy, and pay $5.00 for inserting my business card. I know that the undergraduates have their hands full with the regular studies, but the experience they would gain from editing such a paper would be of infinite value to them.

The preface to our Transactions No. 5 state that some of the papers "elicited lively discussion." To send the papers to the graduates without this discussion is like handing a man a glass of milk with the remark that you have taken all the cream off.

* * * * *

In compliance with Mr. Thomson's request, the matter was brought before the Society, and a committee appointed to enquire into the matter.

This committee, after careful consideration of the question, called for tenders for a monthly publication.

The conclusions arrived at were that, financially, the scheme might probably be carried out, though they were unprepared to say what support it would receive. The chief difficulty in the way was that the "work which would be the outcome of the extra publications—receiving, arranging, and answering correspondence, mailing, proof-reading, etc.—would demand more of the editor's time than the Society could conscientiously ask for."

In regard to discussions on the papers, attempts have been made to put the more important in form for publication, but with little success.

In explanation, it may be stated that no advance sheets of the papers are printed, and accordingly they are not in the hands of the graduates until published at the end of the year; and the discussion on them is confined to those who are present at the meetings at which the papers are read. These discussions are entirely impromptu, and although interesting at the time are not in suitable form for publication. It has also been found impracticable to collect them afterwards.

The only practicable solution would appear to be more frequent publication, as previously indicated.

This, perhaps, in the near future, the Society may feel itself in a position to undertake. If so, we would ask for the hearty co-operation of the graduates in making it a success.

For the benefit of those who may wish to attend the Society's meetings, we call attention to the fact that the time of meeting has been changed from every second Tuesday to every second Wednesday afternoon. This change was found necessary to suit the regular work of the school.

We are indebted to the Provincial Land Surveyors' Association for their exchange, which contains a number of very valuable papers by prominent members of that society, which has now been incorporated as the Ontario Land Surveyors' Association—a step in the right direction, and which must be heartily commended.

## Note on the Brake Dynamometer in use in the Engineering Laboratory of The School of Practical Science.

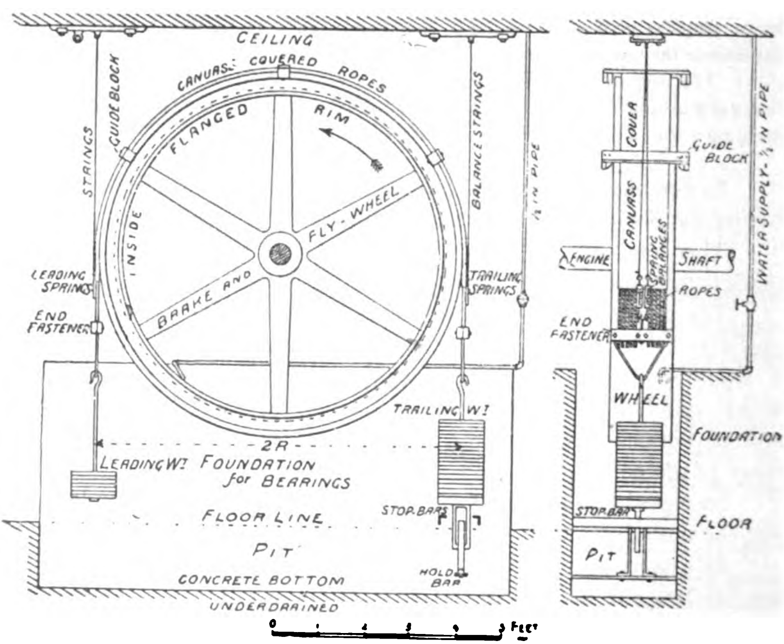



Fig. 21.

This brake, which was designed to determine the work done by a fifty horse power experimental engine, has given such satisfactory results in use, and shown so great a durability with the little attention required, that a brief description of its construction, with a few words on points of special interest, is given here.

The cast-iron brake-wheel is also the fly-wheel of the engine, being mounted directly on the crank-shaft, and is heavy, especially in the rim, which is flanged inside so as to retain the cooling water when the wheel is in motion. The brake-strap consists of ten lengths of ¾-inch manilla hemp rope fastened at the ends by wooden clamps, so that there are five lengths close together on either side of the centre of the brake-wheel, which is crown-faced. These ropes are covered by No. 3 schooner sail canvas, which is folded lengthwise over the ropes and stitched on the back, and held in place by being tied with cord to the three wooden guide blocks. The friction necessary for the conversion of power is obtained between the surface of the wheel and the canvas by suspending weights from the end clamps. These weights are made of lead, and are circular discs with a slot to the centre like the weights of an ordinary weigh-scale, so that they can be easily and centrally put on the hangers. The Salterspring balances which are attached to the end fasteners act contrary to the weights, and serve to equalize and adapt themselves to the slight irregularities which always occur.

In using this brake the trailing end is loaded down, and the total weight noted ; then known weights are put upon the leading hanger till the end clamp on that side is on a level with that on the other side, when the spring balances are hooked in.

The power absorbed by the brake is then proportionate to the difference in tension of the two ends and the speed of the engine. This difference of tension is evidently the reading of the trailing-spring added to the leading weight, and this total taken from the sum of the readings of the leading springs and trailing-weight. The radius $R$, at which this force must be supposed to act so as to give the power, is found by taking half of the measure of the distance between the centres of gravity of the leading and trailing weights, which, if the weights are centrally placed, is the distance between the centres of the hanger rods.

The brake is cooled by admitting water through a pipe on the inside of the rim, and the water is similarly allowed to evaporate, and not drawn off ; the wheel is never allowed to get quite dry inside.

It is interesting to know that although the rubbing surfaces were never lubricated, and though the one piece of canvas may be looked upon as having travelled over 3,000 miles of wheel surface since first put on, with a trailing-weight of about 900 pounds, it is still in splendid condition for use, though somewhat browned, mostly by rust off the wheel face. All the great variations in power caused by non-uniform lubrication of the rubbing surfaces, as well as all the constant attention of proper lubrication, is avoided in this brake; and when once worn-out the canvas is replaced with little work, and at a trifling expense.