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Volume 30. Toronto, April 27, 1916. Contents of this issue on page 5.

The Canadian Engineer

A weekly paper for Canadian civil engineers and contractors

MILWAUKEE ACTIVATED SLUDGE INVESTIGATIONS

A RESUME OF RESULTS OF EXPERIMENTS CARRIED ON DURING THE YEAR 1915 BY THE MILWAUKEE SEWERAGE COMMISSION.

By R. O. WYNNE-ROBERTS, M.Can.Soc.C.E.

THE second annual report of the Milwaukee Sewerage Commission (see *The Canadian Engineer*, October 28, 1915) has just been published. It is a volume of over 200 pages and has many drawings, diagrams, photos and tables which afford the reader abundant matter to ponder over.

The activated sludge process has been investigated in various scales of magnitude ranging from the laboratory to a large working installation, and also by the intermittent and continuous methods of charging. The writer well remembers visiting Exeter and Yeovil (England) in 1897 to study the septic tanks and filters, and has watched the vicissitudes of that system up to the present with interest, because great and excellent results were anticipated by enthusiasts who had not fully considered the problem. The septic tank is capable of doing good work when carefully managed, and the biological filters have proved satisfactory when operated properly. The septic tank was boomed and the predictions were great, but its originators were not entirely to blame for the undue boosting it received. The public was then seeking a solution of the sewage problem as it is doing to-day, although in the meantime much progress has been made.

The activated sludge process is capable, under scientific control, of producing such wonderful results, that the public is apt to enthuse and raise too high expectations to be realized in practice. Hence the fortunate fact that the process is receiving careful and scientific investigations in its early stages before errors are made on any serious scale. On the other hand, the Milwaukee Sewerage Commission is to be congratulated on its enterprise in undertaking such investigations in a comprehensive manner.

Fig. 1.—Panoramic View of Tanks.

A resumé of the experiments tried out during the year was as follows: Fine and coarse screening; grit chambers; sedimentation and sludge digestion in Imhoff tank; colloidal treatment by slate tanks; chemical precipitation using lime and iron; electrolytic treatment by Lautzenheiser process; percolating filters and final sedimentation; sterilization by liquid chlorine; activated sludge process by fill and draw method; activated sludge process by continuous flow method; dehydrating sludge by pressing, gravity and by draining on beds.

In the present review experiments other than those on the activated sludge process will not be discussed. These experiments were started on March 1st, 1915, by means of two 1¼-inch glass tubes 6 ft. long, and next in a tank 32 ft. 0 in. x 10 ft. 6 in. and 9 ft. average depth, on the fill and draw method which was put into operation on March 26th, 1915. The continuous flow tank was put into commission on June 28th, and had the capacity of 22,600 U.S. gallons (18,830 Imperial gallons).

The foregoing experiments produced such promising results that the commission decided to install a plant capable of treating two million (U.S.) gallons per day, with the view to ascertaining the results under normal working conditions. This plant consists of eleven reinforced circular concrete tanks 30 ft. internal diameter by 13 ft. deep, eight of which are used as aerating tanks, one as a final sedimentation tank and two as sludge aerating tanks. The layout is shown in Figs. 1 and 2. The total capacity of the eight aerating tanks is 360,000 U.S. gallons, two sludge tanks 88,200 U.S. gallons,

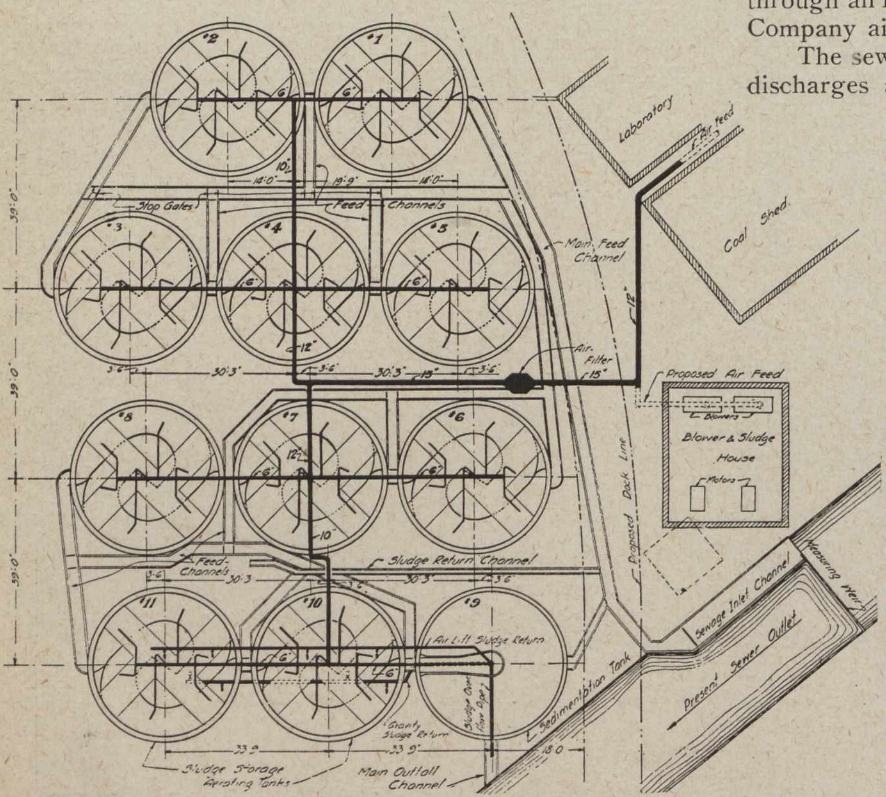


Fig. 2.—Plan of Tanks.

and the sedimentation tank 33,000 U.S. gallons. The daily working capacity of the plant with 25 per cent. activated sludge in the aerating tanks and four-hour tank passage is 1,620,000 U.S. gallons, and by reducing the tank passage period to three hours the working capacity is increased to 2,160,000 U.S. gallons.

Each of the aerating and sludge tanks is divided by a baffle wall which makes a spiral running through chamber about 6 ft. wide and 114 ft. long. Each chamber has a sloping bottom in the apex of which 12-in. x 12-in. filtros plates are set in castings built in units containing from five to seven plates. These castings have an air duct cast in them which discharges the air through a brass orifice to the under side of the plate. This orifice is designed to pass 2 cu. ft. of air per minute under 5 pounds pressure per square inch. This capacity being based upon our experiments showing maximum air required to be .25 cu. ft. per minute per square foot of tank surface.

The baffle walls separating the running through chambers of the eight aerating tanks are 2 ins. thick, built of Hyrib plastered with cement mortar. Those in the two sludge tanks are 6 ins. thick, built of the same material. The extra thickness is here necessary because each of the sludge tanks is divided into two distinct compartments permitting one compartment to be emptied while the other is being filled and aerated.

The sedimentation tank is built with a hopper bottom terminating in a 4-ft. diameter cast iron pipe 24 ft. below bottom of tank, from near the bottom of which a 12-in. pipe extends to the top of the tank. Inside of this 12-in. pipe is a 1-in. pipe for delivering air to the sludge by which it is lifted from the bottom of the 4-ft. pipe and delivered to the sludge tanks, or to the sludge presses.

The compressed air for the two-million-gallon plant is furnished by means of a Connorsville blower having a capacity of 2,400 cu. ft. of free air per minute to five pounds per square inch pressure. This is operated by a 75 h.p., a.c., variable speed motor. The air, after passing through an Excelsior filter, is measured by General Electric Company air meters.

The sewage is taken from an intercepting sewer which discharges about 12,000,000 gallons of sewage per day and some of this originates seven miles above the outlet and is quite septic on reaching the works.

As this plant was not completed until the end of 1915, not much information is available as to the results obtained.

Without in any way minimizing the excellent work done at Milwaukee, and before discussing some of the results obtained there it will be instructive to refer to a few of the engineering considerations, which require to be further and more fully developed. These are referred to in the report and go to prove that to obtain the maximum efficiency at the least cost it involves many studies and experiments.

"Activated sludge accomplishes four principal functions: The clarification of the liquor, removal of the putrescible organic matter, reduction of bacteria, and finally, if the process be continued a sufficient period, oxidizes the ammoniacal compounds into nitrates."

William R. Copeland, the chief chemist, defines the process as follows:—

"The sludge embodied in sewage, and consisting of suspended organic solids, including those of a colloidal nature, when agitated with air for a sufficient period, assumes a flocculent appearance very similar to small pieces of sponge. Aerobic and focultative aerobic bacteria gather in these flocculi in immense numbers, from 12 to 14 million per c.c.; some having been strained from the sewage, and others developed by natural growth. Among the latter are species which possess the power to decompose organic matter, especially of an albuminoid or nitrogenous nature, setting the nitrogen free; and others, absorbing this nitrogen, convert it into nitrites and nitrates. These biological processes require time, air and favorable environments, such as suitable temperature, food supply and sufficient agitation to distribute them throughout all parts of the sewage."

As the supply of air under suitable conditions is a primordial requirement, experiments were made with air jets, filtros plates, monel metal cloth, and Kisselghur, to ascertain the best practicable method of diffusing the air and the relative area of the diffusers to that of the tank was investigated. Whether superactivated sludge will lead to an economy in the supply of air in the tanks is a most interesting problem to study. The most effective depth of sewage under aeration to absorb the maximum of oxygen as the air passes through, as well as the effects of low temperature of the air on the efficiency of the process, are receiving attention, whilst the best method of applying the process according to the varying hourly flows of sewage and to the fluctuating strengths of the liquor will afford engineers and chemists ample scope for their ability and ingenuity. The advantages of continuous flow over intermittent flow methods do not appear to be very pronounced except as to the cost of construction and operation, where the continuous flow tanks are superior, although "with a wide variation in strength of sewage and rate of flow a more uniform standard of effluent can be obtained with the fill and draw method because it is susceptible of better control."

The question of how best to reduce the sludge to a fertilizer and extracting the grease is a most important one, because it is anticipated that sludge, which is now often an abomination to be got rid of by any means, will in future be saleable at profit, and if this is accomplished, then the ancient slogan of "back to the land" will be realized with advantage to the municipal authorities and to the farmers.

If space is available, fuller references will later on be made to the various engineering problems referred to, because the success of a sewage treatment plant depends largely on the careful development of details. A fifty-million-gallon plant is not constructed very often and, furthermore, what might answer admirably under scientific management which can be obtained for large works, may not be equally attainable at average installations.

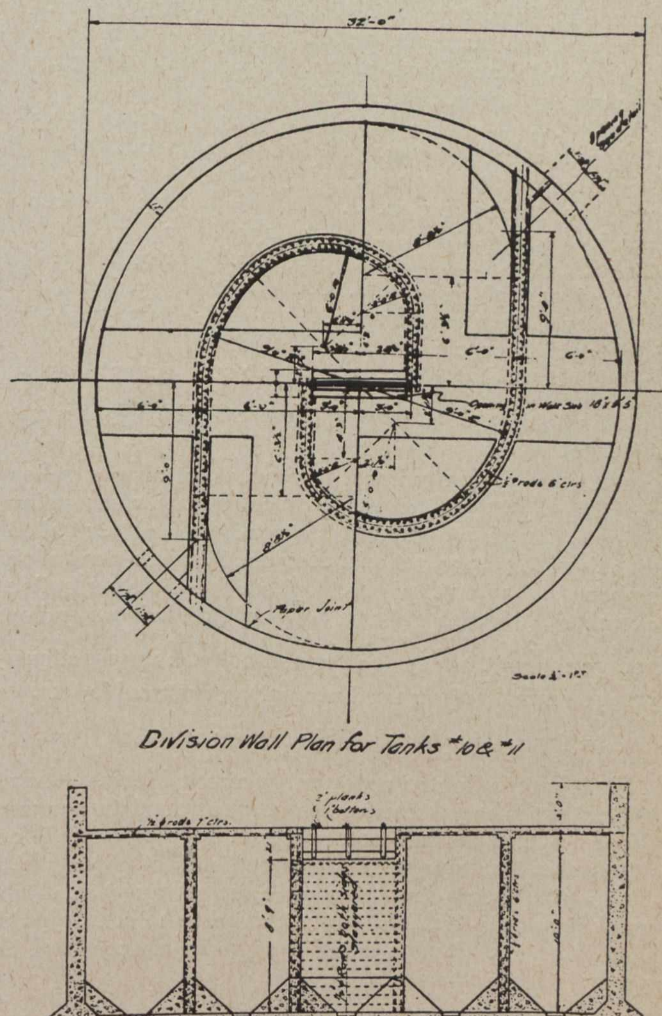
Mr. Copeland's report is a comprehensive one and provides statistics which show what results were obtained, and these will now be discussed.

The sewage was screened through a ¾-in. bar screen to remove the coarse materials, passed through a grit chamber to settle out mineral substances and sampled every hour in a gallon measure. A representative portion of the sample—about 250 c.c.—was taken out each hour, chloroformed and put into a bottle which was packed in ice so as to suspend biological changes pending the time when a 24-hour collection of samples was available for analysis. Settleable solids were measured in tapering glass vessels; portions of sewage were filtered through filter paper, and these, as well as unfiltered sewage, were evaporated to dryness to determine the weights of the total and soluble solids—the difference being recorded as suspended matter. Free ammonia was determined by direct Nesslerization. The tests for numbers of bacteria contained by the sewage were made upon agar incubated at 20° C. for 48 hours, the sample being diluted with sterile distilled water.

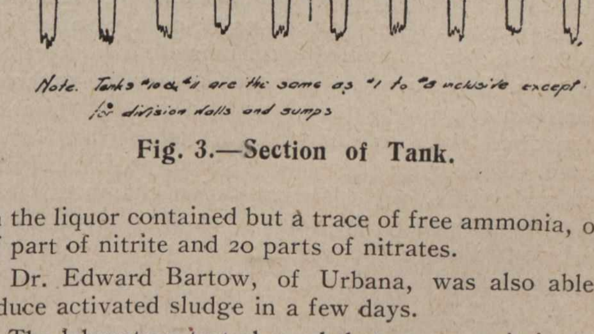
From the results obtained at Manchester by the originator of the activated sludge process, Messrs. Adern and Lockett, it would appear that the time required for the maturing of sludge was in the first instance about six months, but this period has been reduced considerably. As already stated, the first experiments upon this process at Milwaukee were started in the laboratory about March 1st, 1915. The apparatus used consisted of two glass tubes 6 ft. long by 1¼ ins. diameter. At the bottom of one tube a filtros plate was placed to diffuse the air through the mixture. A small glass tube was placed inside the other tube to carry the air to and discharge it near the bottom of the tube in an open jet.

On March 6th these tubes were filled with raw, coarse screened sewage and some sludge from the final sedimentation tank of the 8-ft. sprinkling filter, air was turned on, of unknown quantity, but sufficient to keep the mixture in violent agitation. On March 10th, or at the end of four days' continuous aeration, the sewage was clarified, the sludge had a brown color and settled readily. The clear liquor was decanted off, raw sewage substituted and the mixture continuously aerated for another 24 hours, when the air was shut off.

Within one-half hour the sludge had settled, leaving a clear supernatant liquor, containing 20 parts per million of nitrates. Fresh sewage was again placed in the tubes; within 12 hours after aeration began nitrites and nitrates were present and at the end of 24 hours' continuous aeration the liquor contained but a trace of free ammonia, one-half part of nitrite and 20 parts of nitrates.



Division Wall Plan for Tanks #10 & #11



Note. Tanks #10 & #11 are the same as #1 to #9 inclusive except for division walls and sumps

Fig. 3.—Section of Tank.

Dr. Edward Bartow, of Urbana, was also able to produce activated sludge in a few days.

The laboratory test showed that an open air jet gave about equal results as the filtros plate diffuser. The results gave such promise that a tank which had been used for chemical precipitation experiments was converted into a fill and draw tank for trying out the activated sludge process. This tank has a capacity of 22,200 (U.S.) gallons, or 18,500 Imperial gallons. There are 50 filtros plates, each 1 sq. ft. in area. The area of the tank is 336 sq. ft. and filtros plates 50 sq. ft. or a ratio of 1 to 6.7. The air was measured by a venturi meter and controlled by a hand valve. The cycle of operation was, roughly, as follows:—Filling, 1 hour; aeration, 3½ hours; settling, ½ hour; decanting, 1 hour. Samples were collected before and after treatment and the average monthly results of the analyses were as follows:—

	Crude Sewage	Effluent from Tank	Percentage Removed
Settleable solids in two hours, cu. yds. per million gallons	17.5	0.8	95.4
Suspended matter, in p.p.m.	250	12	95.3
Total solids, in p.p.m.	1,067	777	27.1
Nitrogen as free ammonia, p.p.m.	14.61	9.70	32.4
Nitrogen as alb. ammonia, p.p.m.	8.79	2.84	72.3
Nitrogen as organic nitrogen, p.p.m.	30.3	13.5	55.5
Nitrogen as nitrite, p.p.m.	0.24	0.81	
Nitrogen as nitrate, p.p.m.	0.42	2.51	
Oxygen consumed, p.p.m.	116	23	80.0
Alkalinity, p.p.m.	255	240	
Chlorine, p.p.m.	185	183	
Dissolved oxygen, p.p.m.	1.1	5.2	
Temperature, degrees Fahr.	62°	63°	
No. bacteria per c.c. at 20° C. in millions	2.100	0.115	95.3

This tank treated sewage at the following average daily rates:—

June	52,911 gallons,	1.76 cu. ft. of air per gallon
July	56,308 gallons,	1.91 cu. ft. of air per gallon
August	72,539 gallons,	2.05 cu. ft. of air per gallon
September .	76,950 gallons,	2.00 cu. ft. of air per gallon
October ...	57,097 gallons,	1.36 cu. ft. of air per gallon
November ..	60,824 gallons,	2.14 cu. ft. of air per gallon

Average amount of sewage treated daily, 62,771 gallons.
Average amount of air used per gallon, 1.87 cubic feet.

The figures for May and December are not given.

It is interesting to note that whereas Messrs. Adern and Lockett, in their experiments in 1914, found the amount of free air used did not exceed 15 cu. ft. per square foot of tank area per hour with a sewage depth of about 5 ft., whereas the average at Milwaukee for sewage 9 ft. deep was about 25 cu. ft., Mr. Adern thought 12 cu. ft. would suffice, and Dr. Bartow is reported to have succeeded in using still less quantity of air.

Turning now to the continuous flow method. Another of the former chemical precipitation tanks was remodelled for this purpose. This tank is 32 ft. 0 in. x 10 ft. 6 ins. x 10 ft. 0 in. deep, divided longitudinally into three compartments. The sewage is admitted into and flows through the left-hand into the right-hand and out by the central compartment, and in doing so it travels 81 ft. and is aerated. The sludge, being very flocculent, is carried forward and settles in the sedimentation chambers whence it is pumped back to the point of sewage inlet. The air is distributed and diffused in the same way as in the fill and draw tank.

The continuous flow tank was operated by filling it with sewage on June 28th, 1915, running in 1,200 gallons of sludge from the Imhoff tank and from the secondary sedimentation tanks of the sprinkling filters. More sludge was run in on July 13th and 16th, and by the 19th July the black sludge had by aeration turned brown. The tank was put into working commission on August 5th. Samples were taken and analyzed and the following figures show what were the average results during four months, August to November inclusive.

	Crude Sewage	Effluent from Tank	Percentage Removed
Settleable solids in two hours, cu. yds. per million gallons..	20.77	2.4	87.7
Suspended matter, p.p.m.	310	15	95.2
Total solids, p.p.m.	1,165	834	28.3
Nitrogen as free ammonia, p.p.m.	15.7	7.16	55.0
Nitrogen as alb. ammonia, p.p.m.	9.53	4.77	50.0
Nitrogen as organic nitrogen, p.p.m.	34.6	11.1	67.7
Nitrogen as nitrite, p.p.m. ...	0.20	0.41	
Nitrogen as nitrate, p.p.m. ...	0.17	5.94	
Oxygen consumed, p.p.m. ...	123.0	22.0	82.3
Alkalinity, p.p.m.		192	
Chlorine, p.p.m.		196	
Dissolved oxygen, p.p.m.	1.09	4.3	
Temperature, deg. Fahr.	64	64	
No. of bacteria at 20° C., mil.	1.620	0.086	95.0

The continuous flow tank treated sewage at the following average daily rates:—

August	19,745 gallons,	4.52 cu. ft. of air per gallon
September ..	47,755 gallons,	2.01 cu. ft. of air per gallon
October ...	59,137 gallons,	1.62 cu. ft. of air per gallon
November .	60,393 gallons,	2.09 cu. ft. of air per gallon

Average amount of sewage treated daily, 46,760 gallons.
Average quantity of air used per gallon, 2.56 cubic feet.

Omitting August, the averages are: Amount of sewage treated, 55,762 gallons; quantity of air used, 1.91 cu. ft. per gallon.

It is instructive to compare the results obtained by the two methods.

	Fill and Draw Method	Continuous Method
Reduction in settleable solids	95.4%	87.7%
Reduction in suspended matter ..	95.3%	95.2%
Reduction in total solids	27.1%	28.3%
Reduction in free ammonia	32.4%	55.0%
Reduction in alb. ammonia	72.3%	50.0%
Reduction in organic nitrogen ...	55.5%	67.7%
Reduction in oxygen consumed ..	80.0%	82.3%
Reduction in bacteria	95.3%	95.0%
Average number of tank volumes treated daily	2.8	2.5
Average quantity of air per gallon in cubic feet	1.87	1.91

There would appear to be but little difference in the results obtained by the fill and draw or the continuous flow methods. A number of experiments, however, were made apart from the general tests and the results point to possibilities of great interest.

The cost of furnishing compressed air at five pounds pressure is estimated by Mr. Halton at $2.50 per million cubic feet of free air and on this basis the cost of treating sewage on the fill and draw method, using 1.87 cu. ft. per gallon, would be about $4.67 per million U.S. gallons, and by the continuous method, using 1.91 cu. ft. per gallon, $4.78 per million U.S. gallons, but Mr. Copeland states that 1,000,000 (U.S.) gallons can be clarified, freed from 95 per cent. of its bacteria and rendered stable for five days by the application of 1.75 cu. ft. of air per gallon at a cost of $4.38, which includes overhead charges upon that portion of the plant devoted exclusively to treatment of sewage but excludes plant and engine room labor and cost of disposing of the sludge.

GRAPHICAL TREATMENT OF ELASTIC RIBS.*

II. TWO-HINGED ARCHES.

In the preceding article a graphical method for obtaining the elastic curve of any beam or rib was given and the application of this method to the solution of two-hinged arches will now be shown. The method itself is perfectly general and applies to oblique and unsymmetrical arch ribs, but in order to simplify the case and make it as practical as possible, a common symmetrical arch will be taken as an example. When applied to unsymmetrical arches the procedure is slightly different but not more difficult.

Ths example of a two-hinged arch rib given in Merriman & Jacoby's "Roofs and Bridges," Part IV., will be taken so that the graphical results may be compared with the true values. The rib is a solid web parabolic rib of uniform depth, 258-foot span and 26-foot rise. The moment of inertia of the rib is assumed to vary as the secant of the angle of inclination of its axis with the horizontal. In this case there are 20 panel points and as 20 is a convenient number of divisions of the arch rib, they were made the same; but the number of divisions need not, and usually does not, correspond to the number of panel points. The rib was laid out to scale as in Fig. 1 and divided into 20 parts such that $\frac{\Delta s}{EI}$ is a constant. The centre points of the divisions were then projected in parallel lines to the right and downward.

The horizontal reaction is obtained in the same manner as in the graphical method for spandrel braced arches as explained in "Roofs and Bridges," Part IV., except, of course, the displacements of the arch rib must be obtained in a different way. The theory is the same as that given in the previous article. Consider the horizontal reaction as a redundant element and put the left end of the rib on rollers so that it is free to move horizontally. The rib is then statically determinate. If a vertical load of unit intensity be placed at any point, O, the left end will be displaced horizontally by a certain amount δ_{AO} and the value of H must be just great enough to produce an equal and opposite displacement. Let the horizontal displacement of the left end A under a unit horizontal force at A be δ_{AA}, then

$$H = P\frac{\delta_{AO}}{\delta_{AA}}$$

which gives the true value of H for the vertical load P at any point. The effect of horizontal or oblique loads will be considered later. It follows from Maxwell's Theorem that δ_{AO} the horizontal displacement of A under a unit vertical load at O is equal to δ_{OA} the vertical displacement of O under a unit horizontal load at A, and hence,

$$H = \frac{P\delta_{OA}}{\delta_{AA}}$$

The solution of this equation requires the displacement of the arch rib when acted on by a unit horizontal force alone and these may most easily be obtained graphically by constructing the elastic curve for the rib under that loading. If y is the ordinate of the neutral axis of the arch at any point relative to the line through the hinges the moment at any point is equal to $Hy = y$, since H is unity. The equation of the elastic curve is therefore $\Delta' y = \frac{\Delta s}{EI} \sum_{0}^{c} yx$ which gives the y-displacements of any point O

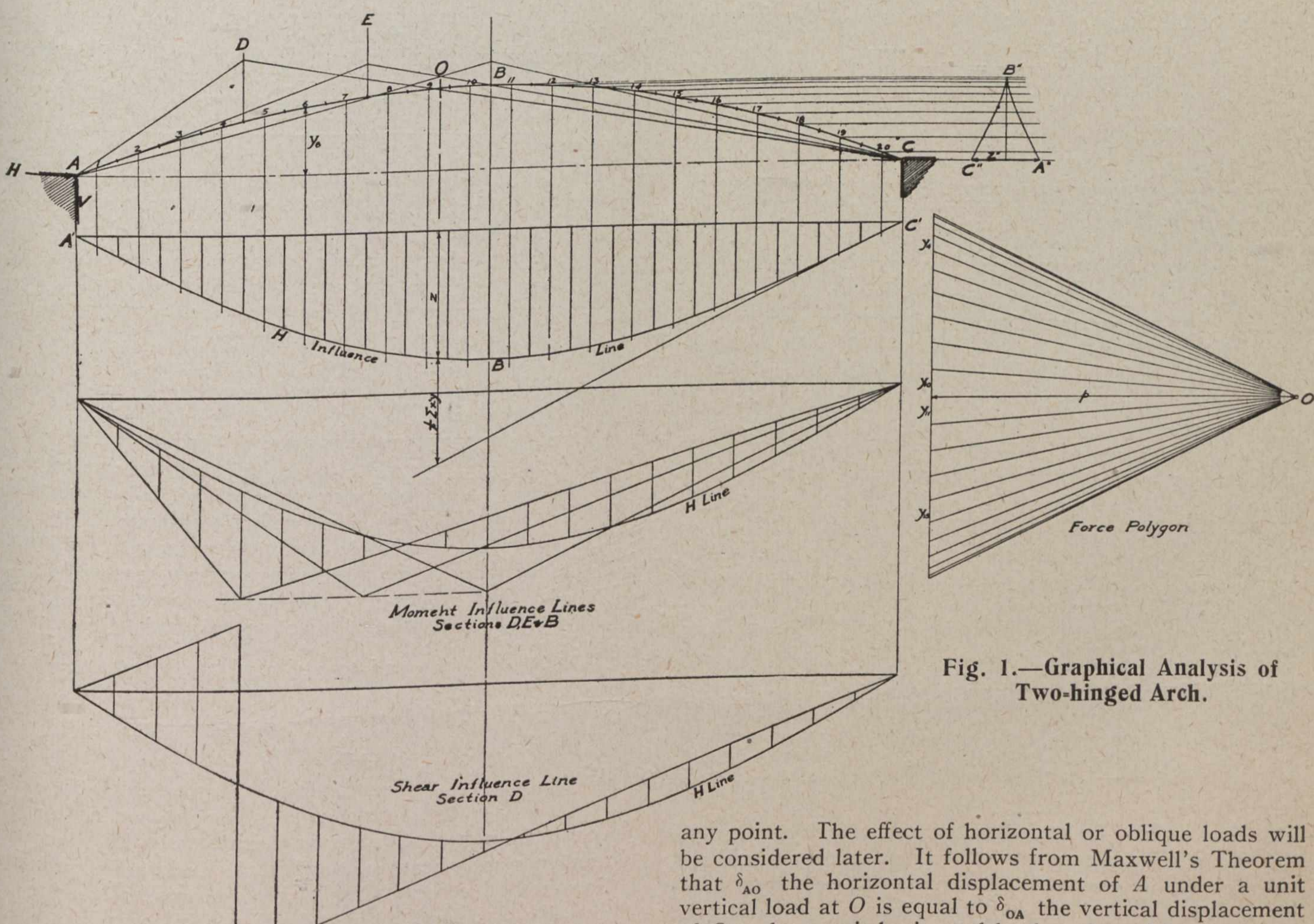


Fig. 1.—Graphical Analysis of Two-hinged Arch.

*Second article by C. S. Whitney, M.C.E., in "The Cornell Civil Engineer."

relative to the tangent at C, the left end. The value of x is measured from the point O.

The elastic line is constructed as before merely by laying off the values of the moments y on the load line, selecting a convenient pole and drawing the funicular polygon $A'B'C'$ with its sides parallel to the rays of the force polygon. The vertical ordinate between the curve tangent to the sides of the funicular polygon and the tangent to it at C' is then equal to $\frac{\Sigma y x}{p}$, which gives the displacement relative to the tangent to the arch rib at C. The displacement relative to the line through the hinges will therefore be given by the ordinate between the curve $A'B'C'$ and the straight line $A'C'$ and

$$\delta_{OA} = \frac{z p \Delta s}{E I}.$$

The value of z is measured to the same scale as the arch rib and the pole distance p is measured to the same scale as the load line.

The value δ_{AA} is obtained by the use of the formula

$$\Delta x = \int_A^C \frac{M y d s}{E I} = \frac{\Delta s}{E I} \sum_A^C y^2.$$

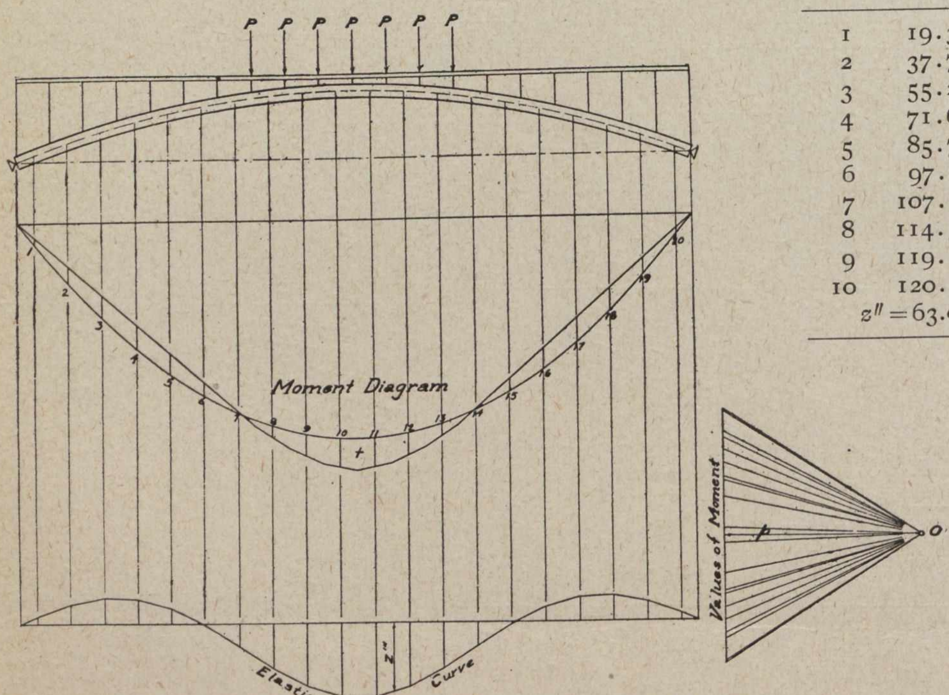


Fig. 2.—Construction of Elastic Curve—Two-hinged Arch.

This summation is performed graphically by means of the funicular polygon $A''B''C''$ which is drawn with its sides perpendicular to the rays of the force polygon previously used. It should not be necessary to go into the properties of funicular polygons here. They are fully explained in Church's "Mechanics" and other texts. The smooth curve tangent to the sides of the funicular polygon is the x-elastic curve and from it the x or horizontal displacement of any point relative to any other point can be obtained by measuring the horizontal distance between the two corresponding points on the elastic curve. The horizontal displacement of A relative to C is equal to

$$\delta_{AA} = \frac{\overline{A''C''} p \Delta s}{E I} = \frac{z'' p \Delta s}{E I}.$$

The values of δ_{OA} and δ_{AA} having been obtained, we may write for the value of H the following expression, since the same pole length p was used for both

$$H = P\frac{\delta_{OA}}{\delta_{AA}} = P \frac{\frac{z p \Delta s}{E I}}{\frac{z'' p \Delta s}{E I}} = P\frac{z}{z''}.$$

The y elastic curve $A'B'C'$ is thus seen to be the influence line of the horizontal reaction and the horizontal reaction produced by a load P at any point is equal to the corresponding y elastic curve ordinate multiplied by the constant $\frac{P}{z''}$.

The remarkable simplicity of this method must be apparent to any one who has computed reactions analytically. Starting with a clean sheet of paper, the writer made the analysis shown in Fig. 1 and determined the reactions for unit loads at each of the 19 panel points in just seventy minutes. The results tabulated below show the degree of accuracy which was obtained with the small scale diagrams, the length of the arch rib being only about 13 inches. The flatness of the arch rib also decreased the size of z'' and increased the error.

Comparison of Graphical with True Theoretical Reactions.

Load at	z	H/P Graph.	H/P True.	Per cent. error.
1	19.3	0.306	0.3089	0.94
2	37.75	0.599	0.6084	1.54
3	55.25	0.878	0.8918	1.55
4	71.60	1.137	1.1511	1.23
5	85.75	1.361	1.3812	1.46
6	97.75	1.551	1.5759	1.58
7	107.5	1.719	1.7322	0.76
8	114.5	1.818	1.8457	1.50
9	119.1	1.891	1.9152	1.26
10	120.5	1.913	1.9381	1.29
	$z''=63.0$			

The horizontal reaction due to temperature change and rib shortening can also easily be computed. If d is the change in chord length of the arch rib due to any cause when the left end is on rollers (*i.e.*, unrestrained), then the H reaction required to return the end to its original position is $\frac{d}{\delta_{AA}}$ or

$$H = \frac{d E I}{z'' p \Delta s}.$$

Using the horizontal reaction influence line, the moment and shear influence lines for any section may be very readily drawn, as shown in Fig. 1, and the maximum moments and shears obtained from them. The influence line method of obtaining maximum stresses has the advantage of being simple and sufficiently accurate and the graphic representations are easily checked.

Deflection of Arch Rib.—Graphical methods of obtaining the deflection of arch ribs have been used, such as the method of Henry DeDion ("The Washington Bridge" by W. R. Hutton) and that explained by Mr. E. E. Howard, Pro.Am.Soc.C.E., May, 1915, but these methods are quite laborious and indirect. The y elastic curve of an arch rib under any load may be drawn directly just as it was drawn for the continuous beam in the previous article. Fig. 2 shows the elastic curve of the arch under consideration when loaded with equal panel loads at each of the seven central panel points. The reactions are found from the H influence line and the moment diagram is constructed. The arch rib is divided as before so that $\frac{\Delta s}{EI}$ is constant and the average moment for each division is laid off algebraically on the load line of the force polygon, positive moments downward and negative moments upward. The funicular polygon is constructed exactly as before and the ordinates between it and the straight closing line give the amount of rise or fall of every point on the neutral axis. The deflection is equal to

$$D = z''' P \frac{\Delta s}{EI}.$$

The elastic line in Fig. 2 shows how the rib sinks at the crown and rises near the haunches.

Effect of Horizontal or Oblique Load.—It is sometimes necessary to consider the effect of horizontal loading on an arch rib as in the case of the building arch shown in Fig. 3. The effect of oblique loads may be determined directly but it will usually be simpler to resolve them into concentrated horizontal loads and the reactions can be found directly from it, as shown in Fig. 3.

The graphical method of analysis outlined in this article will save an immense amount of time, particularly when applied to ribs which are in the least irregular, and it makes the analysis of two-hinged arches practically as simple as that of three-hinged arches. With slight modifications, the method may be applied to braced arches. Its practical value is shown by the fact that it was used to determine the stresses in the Hell Gate arch, the largest two-hinged arch in the world. One of its greatest advantages is that it at once gives influence lines for the reactions produced by a load at any point while an analytical solution is confined to one particular condition of loading and the solution must be repeated for each change in loading.

The graphical method may also be applied to fixed arches and the influence lines for thrust, shear and moment can easily be drawn. In the foregoing brief description it has not been possible to explain the theory in full, but the writer believes that the method can be readily understood by one who is familiar with the ordinary methods as given in the standard texts mentioned. When the graphical theory is once understood, the general application of the method is very simple.

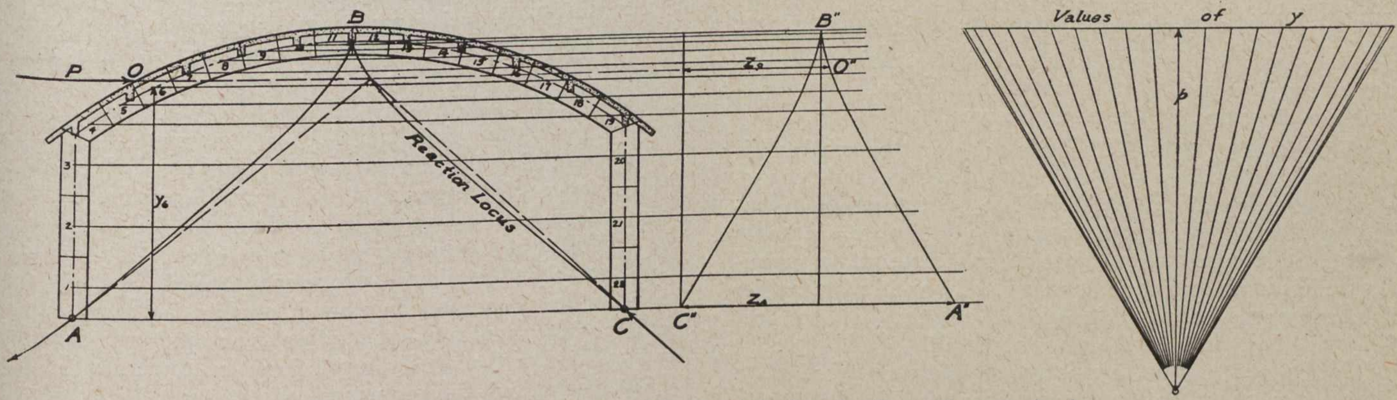


Fig. 3.—Reactions Under Horizontal Load—Two-hinged Arch.

horizontal and vertical components and determine their effect on the reactions separately.

The arch shown in Fig. 3 consists of columns hinged at the bottom and a segmental arch rib supporting beams and slabs. To determine the effect of horizontal loads, the rib and columns are divided up into small parts so that $\frac{\Delta s}{EI}$ is constant and the centre points of these divisions are projected horizontally as before. To determine the reactions under horizontal load, it is necessary to draw only one funicular polygon $A''B''C''$. The same theory is applied as before. The horizontal displacement at A produced by H must be equal to that produced by the horizontal force P acting at any point O again considering A on rollers, or as before

$$H_A = P \frac{\delta_{OA}}{\delta_{AA}}.$$

The x elastic curve for unit value of H is again constructed as in Fig. 1 from the expression $\Delta x = \frac{\Delta s}{EI} \sum y^2$. The x displacement of the point O relative to B is then equal to $\frac{z_O p \Delta s}{EI}$ and that of A is $\frac{z_A p \Delta s}{EI}$. The value of the left hand reaction is then

$$H = P \frac{z_O}{z_A}.$$

From this relation, the effect of any combination of horizontal loads can be easily determined. It is very interesting to note that if the funicular polygon be redrawn so that it passes through the end hinges and the centre crown point of the arch it becomes the reaction locus for

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In an action before a United States court for the value of colts struck by a freight train consisting of 16 cars not heavily loaded, and going at about 30 miles an hour, the evidence showed a reasonable effort to stop the train. The engineer testified as to braking power, but said it was very variable. The trial court held as a matter of law that the train could have been stopped within 600 or 650 feet. On appeal to a higher court, however, it was held that the finding of the trial court was in error as there was no positive testimony to sustain it.

The Canadian Fairbanks-Morse Company, Limited, have secured the sole rights in Canada for the Garrow Lamp for the use of contractors. This light is of 8,000 candle power capacity, and is made entirely of steel and cast iron, being welded by the oxy-acetylyne process. One important point of merit about the lamp is that it is possible to use this light in places such as tunnels without danger, as any excess gas that is generated cannot escape but is led to the burner and there ignited at the main flame, thus obviating the danger of gas being generated faster than it can be consumed.

The total number of persons killed from every cause on the railways of the United States during the year 1915 was 8,621, of whom 5,084 were trespassers. The number killed is the smallest since 1902, when 8,588 were killed, although now the mileage is 28 per cent. greater, the gross revenue, which represents traffic volume, 72 per cent. higher, the number of passengers 52 per cent. greater, the tonnage 61 per cent. greater, and 51 per cent. more men are employed.

PRICE OF "BLEACH" ADVANCING.

Waterworks officials and hydraulic and sanitary engineers are aware of the tremendous increase in the cost of calcium hypochlorite and liquid chlorine during the past eight months, and this increase has been viewed with alarm by those interested in the use of these chemicals for water purification purposes.

Practically all of the chlorine now manufactured is formed by the electrolytic decomposition of salt solutions, there being two by-products—chlorine gas and caustic soda.

Liquid chlorine is formed by drying and compressing the chlorine gas evolved from the electrolytic cell.

Calcium hypochlorite is formed by passing chlorine gas over lime, the lime absorbing the chlorine and acting merely as an inert "carrier."

The war is directly responsible for the increase. Over 50,000,000 pounds of calcium hypochlorite were imported annually by the United States and Canada from England and Germany, and a considerable part of such importations is used by waterworks.

The normal demand for bleach was considerably increased by the use of this material in certain new processes in the manufacture of explosives.

The supply of Canadian and American "bleach" available was not sufficient to meet the demand, and consequently the price increased. When quotations on hypochlorite reached the present figure, it was more profitable for the manufacturers to take the gas required to manufacture liquid chlorine and turn it into hypochlorite, rather than to compress and sell it as liquid chlorine. Therefore, the price of liquid chlorine also increased.

Eight months ago, hypochlorite sold for 1¾ cents to 2 cents per pound in small quantities and for 1½ cents per pound in carload lots. To-day it is bringing 12 cents to 14 cents per pound in small quantities and 11 cents to 12 cents per pound in carload lots.

Eight months ago, liquid chlorine sold for 10 cents per pound in small quantities and for 8 cents to 9 cents per pound in large shipments. To-day it is quoted at from 18 cents to 20 cents per pound on small quantities and 15 cents and upward per pound on large yearly contracts.

Both calcium hypochlorite and liquid chlorine are used in considerable quantities to accomplish bacterial purification of water supplies. Although the amounts so used form only a fraction of the quantities required in various industries, the waterworks demand for these materials is increasing continually.

In the manufacture of hypochlorite, the lime will only carry a certain percentage of its weight of chlorine—approximately one-third—so that to obtain one pound of chlorine for water purification, three pounds of hypochlorite must be used. Liquid chlorine is 100 per cent. pure chlorine.

Both calcium hypochlorite and liquid chlorine require special apparatus for their application to water supplies; hypochlorite apparatus being known as "hypochlorite dosing devices," and that for liquid chlorine as "chlorine control apparatus" or "chlorinators."

The Canadian Engineer is indebted for the above information to Messrs. Wallace and Tiernan, of New York City, manufacturers of chlorinators.

Hydraulic pressure for forcing antiseptics into wood was first used in 1831 by a Frenchman named Breant. He used a closed, vertical cylinder, in which the wood was placed upright on end and the pressure applied.

LETTER TO THE EDITOR.

Sir,—In connection with the editorial in your issue of April 13th concerning the status of the firm of Escher Wyss and Co., we would esteem it a great favor if you would publish the following facts in justice to our firm:—

Up to September, 1915, there was not the slightest doubt in Great Britain regarding the nationality of our firm. A great number of orders from the British and Allied Governments were placed with us and executed until the trouble started through the denunciations of one of our competitors. Immediately, our directors took the necessary steps, through the Swiss Legation in London and the British Consulate in Switzerland, to institute an official investigation. The British and the Canadian Governments were requested through the Embassy in London and the Swiss Consul-General in Montreal, respectively, to suspend any action until the investigation was concluded. The name of our firm was in the meantime placed on the "Suspensory 'B' List."

The investigation was carried out by a British delegate on behalf of the Foreign Office, and as soon as his report reached the Foreign Trade Department, we were informed officially by Sir Edward Grey that no further objections to our firm would be entertained. The Canadian Government, unfortunately, was not informed of this fact until February of this year through the Canadian High Commissioner in London.

While the denunciations have caused both our works and ourselves considerable annoyance and loss of business, it has, on the other hand, enabled us to obtain an official investigation and subsequent declaration which will undoubtedly satisfy any of our customers who may have been doubtful regarding our status. The majority of our customers have always been satisfied with our statements, as the number of contracts obtained by us since the commencement of the war prove conclusively.

ESCHER WYSS & CO.,
Head Office for Canada.
Th. Seidl, Chief Engineer.

Montreal, April 17th, 1916.

RAILROAD EARNINGS.

The following are the railroad earnings for the first week of April:—

Canadian Pacific Railway.

	1916.	1915.	
April 7	$2,482,000	$1,766,000	+ $716,000
April 14	2,577,000	1,701,000	+ 876,000

Grand Trunk Railway.

April 7	$1,155,486	$1,008,320	+ $147,166
April 14	1,024,505	864,658	+ 159,847

Canadian Northern Railway.

April 7	$ 677,000	$ 457,000	+ $220,000
April 14	668,900	463,700	+ 205,200

According to the annual blue book of the Railway Department giving telephone statistics, there is now one telephone for every 15.1 persons in Canada. The increase in the use of the telephone has been steady during the past few years, and war conditions do not seem to have interrupted the progress. The number of telephones reported as being in use in 1915 was 533,090, an increase of 11,946 over 1914. The principal growth was in rural districts. The net earnings of the 1,396 companies in Canada totalled $4,764,957, which was $350,091 better than the result of 1914. The total capitalization of Canadian telephone companies now amounts to $74,285,000.

AMERICAN RAILROAD BRIDGES.*

AMERICAN railroad bridges as now constructed are the results of an evolution, during the course of which many types found to be undesirable were abandoned; some types found to be good were maintained and new features and types were introduced, until, finally, the 1915 standards represent the culmination, at the end of more than three-quarters of a century of railroad bridge history. During the first period, extending to 1865, there was no real science of proportioning members and the best that builders could do was to be guided by judgment based on experiment or precedent, and to make all new bridges stronger than before. During the second period, 1865 to 1890, scientific designing became general and the typical American railroad bridge, "a skeleton structure pin-connected at all the principal articulations," was brought to a fair state of development. The present standards were essentially developed during the third period, 1890 to 1915. The scope of the present sketch will be confined to the third period, ending in 1915.

Naturally, the trend of improvements in bridge construction has been controlled by a number of definite influences, some of which are still in operation, and will undoubtedly continue long into the future. American railroad bridges, therefore, although substantial, economical and durable, are still in a state of development, the final culmination of which cannot as yet be foretold. The most persistent of these influences has been the constantly increasing weight of rolling loads. It has far exceeded anything which was anticipated in the past, and has been the direct cause of the renewal of many bridges which would have been still serviceable under the loads for which they were designed.

All of the earlier types of patented bridges were tested in service to the full extent of their capacity and endurance and it was observed that while they were good enough for the light loads and traffic of their day, their flimsiness, due to the inherent defects of their designs, and their action under traffic made them very unsatisfactory structures for heavier loads. They, therefore, became obsolete and were replaced by the improved types of single-intersection, pin-connected trusses, and by riveted, lattice and plate girders, which were evidently much superior and which had been developed to such a state of perfection by the year 1890 that engineers believed they had established standards of design which would endure. These more modern bridges have also been tested in service under increasing loads to the full extent of their capacity, as was the case with the earlier bridges, and it has been learned that, while these later bridges were also well adapted to the traffic of their day, their designs embodied features and details which prevented them giving long and satisfactory service under the heavier loads which were constantly being placed upon them. The trusses had too many adjustable members and light bars to shake loose, too many hinged joints to wear away, and too much motion of parts to inspire confidence under the fast speed of heavy engines and trains. The necessity for less looseness and greater stiffness became apparent, and it was found that when the flimsy, adjustable bracing was replaced with stiff bracing with riveted connections, and the shaky eye-bars were tied together so as to reduce motion, the stiffened structure gave much more satisfactory service. Therefore, the effects of the influence of the constantly increasing loads on railroad bridge development is evidenced by the elimination of adjustable members and short span trusses, and by the general stability and solidity of construction which are the essential characteristics of present standards.

Another influence in American bridge development has been the introduction of new materials of construction. In the old abandoned types, wrought iron rods or links were used generally for tension, and wood or cast iron for compression members. The substitution of wrought iron for the cast iron and wood enabled the construction of the improved types which were standard in 1890, and which had details and connections far superior to anything which could be obtained by the use of cast iron or wood. Since 1890, rolled structural steel has entirely supplanted wrought iron in metal bridge work, and on account of its greater strength and economy it has had an influence on the construction of longer lengths of spans, both in girders and in trusses, than were attempted with wrought iron. The standard structural steel, at the present time, has an ultimate strength averaging about 60,000 lbs.; and the longest simple span so far constructed of it is 620 ft. This span is in the Kentucky and Indiana Terminal Railroad Company's bridge across the Ohio River at Louisville, built in 1912.

Alloys and special steels, with much greater strength than standard structural steel, are now used in long-span trusses for the purpose of keeping the dimensions and weights of members within the limits of commercial and economical production. For instance, nickel steel was used in the construction of 668-ft. spans of the Municipal Bridge at St. Louis, built in 1912. Nickel steel eye-bars and so-called silicon steel compression members will be used in the Ohio River Bridge at Metropolis, the longest span being 725 ft.; high carbon steel is used in the 977.5-ft. span of the Hell Gate Bridge; and Mayarí steel, which contains nickel, and is made from the Mayarí ore from the north coast of Cuba, is being used in the construction of a large bridge which is to span the Mississippi River at Memphis. These alloys and special steels have not, as yet, exerted any material influence on the development of railroad bridges, except, perhaps, in the direction of greater span lengths than can be economically, or even practically, constructed of the standard structural steel.

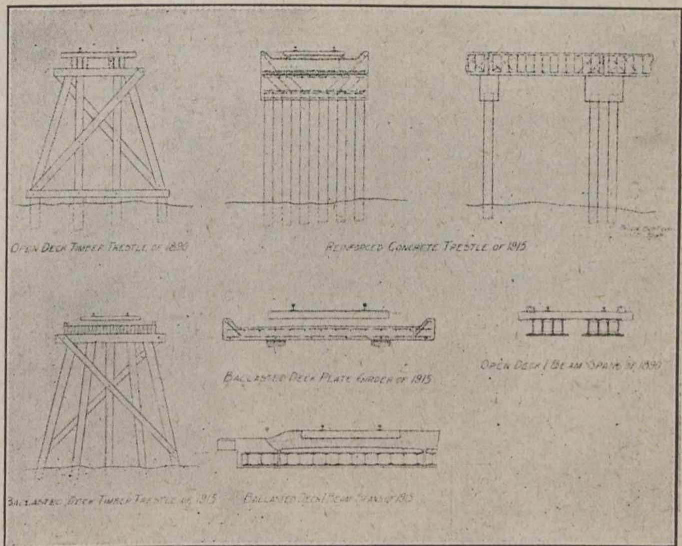

Fig. 1.—Trestle and I-Beam Bridges of 1890-1915.

A material which has come into general use during the past few years is reinforced concrete. It has had a very decided effect on bridge development, since it has influenced the adoption of a new type of short-span bridge having a ballasted deck and a solidity of construction with

*Abstract from a paper read by J. E. Greiner, M.Am.Soc. C.E., at the International Engineering Congress.

an economy impossible to be obtained by the use of any other available material.

Another influence on bridge development is the improvement in tools and machinery, especially in pneumatic tools and self-propelling erection derricks. Pneumatic drills, reamers and riveters are now generally used in erection work in place of the old-time hand tools, and has a consequence, field-riveted connections are no longer avoided, as was the case in 1890, since they can now be easily and quickly made. By the use of self-propelling erecting derricks, plate girders and bridge members of a weight far beyond what was formerly practicable can now be handled and erected with safety, facility and economy.

At the beginning of the period (1890), pile and framed timber trestles were being constructed on main lines. The design differed in no material respect from the earliest types, except as to number and dimensions of timbers, the floor deck being composed of cross-ties resting on groups of timber joists. In suitable locations, they were economical, easy to maintain under their light traffic and regarded as all-sufficient for the purpose. Howe truss bridges were also being built on main lines of some roads.

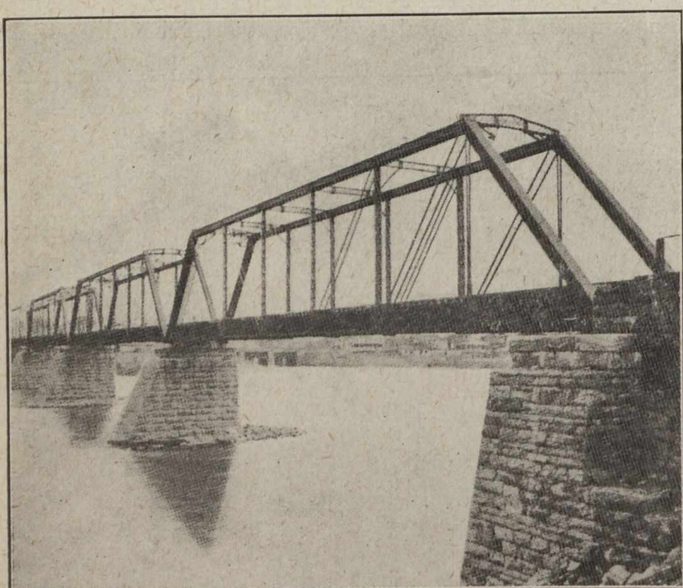

Fig. 2.—153-ft. Span Pin-connected Trusses. Typical of 1890 Construction.

On other roads, combination bridges, with all the tension members of wrought iron, and all, or most, of the compression members of wood, were used. They were cheaper than all-iron bridges, and more durable than Howe trusses.

I-beam bridges composed of groups of from two to four beams under each rail, the beams being held together by means of cast iron separators bolted between the webs, and with cross-ties resting directly on the upper flanges of the beams, were commonly used for spans having a length of from 10 to 20 ft. Plate girders were acceptable for spans up to 65 ft., which was about the limit for economical construction and handling, although some few roads constructed girders of a greater length. Single or double intersection riveted low truss bridges, or latticed girders, as they were called, were used for spans between 65 ft. and 100 ft., and in some cases up to 120 ft.; but the longer spans were not acceptable to many engineers on account of the inability to ship the trusses in one piece and the necessity of so much field riveting of important connections, and the increased risks and cost of erection. For spans over 100 ft. the practice, with very few exceptions, was to construct trusses of the pin-connected type. The principal characteristics, in addition to the pin-connections, being the minimum ambiguity of strains, the concentration of parts, facility of manufacture, perfection of length and fitting of all the members, a minimum of riveting and mechanical work in the field, and the readiness with which the individual members can be assembled during erection. Typical American railway viaducts, with 30-ft. towers and 30-ft. or 60-ft. free spans, were regarded favorably. Movable bridges were of the swing type, revolving in a horizontal plane on a centre pier. Lateral bracing for truss bridges, viaducts and in many through plate girders had adjustable rods for the tension members and the counters in truss bridges were also made adjustable. Wrought iron was still used for built-up members, but eye-bars and wide web-plates of girders were generally made of soft steel.

Bridge piers and abutments were generally of cut stone masonry construction, and arches were of cut stone work throughout or had their rings made of brickwork. The arch was then recognized (as it is now) as the very best type of railroad bridge, but cut stone work was very expensive in first cost as compared with steel, and as a consequence relatively few arch bridges were being built.

Nearly every railroad in America constructed its bridges in accordance with specifications peculiar to the individual road; consequently, there were practically as many kinds of bridge specifications as there were important railroads. The makers desired to be thought original, and therefore displayed their ingenuity in those parts of bridge specifications that gave them the most leeway, *viz.*, in the permissible working stresses, column formulas, grades of steel, impacts and in the typical engines used as a basis for proportioning. In these numerous specifications every conceivable kind of typical locomotives was specified, some with practically the same total weight, but with a different distribution of loads on the wheels and a different wheel spacing. There were no generally recognized standards for loading, impact allowances, permissible working stresses, or for the quality of material used and methods of testing same. Contracts were based on a total price for the completed work, and as the total price depended largely on the amount of material which entered into the construction, successful competition frequently depended upon a design which gave the lightest possible structure.

At the close of this period (1915) open deck framed timber trestles are seldom built except on light traffic or branch lines or as temporary expedients, with the expectation of replacing them with permanent structures in a short time. In many sections good timbers can no longer be obtained except at excessive cost; the general upkeep is expensive and they are an undesirable type for heavy loading. Some roads now build wooden trestles of a different type, inasmuch as they have ballasted decks on solid timber flooring and are constructed of creosoted timbers. These modern types are more durable and easier to maintain than the old open-deck structures and represent the best practice for timber trestle construction, but they cannot as yet be considered as general standards. Some western railroads are replacing timber trestles with a type made of reinforced concrete with ballasted decks. This is a distinctive type as compared with the trestles of 1890. Howe truss bridges and combination bridges are no longer constructed, except in very isolated cases or on unimportant branches. They are ill-suited for heavy loading and good timbers are difficult to obtain.

I-beam bridges as now constructed are generally encased in concrete. Open decks with wooden cross-ties are avoided, stone ballast on concrete being used as a substitute; and on some roads short spans are reinforced concrete girders or slabs. Plate girders are being built and shipped in one piece in spans up to 120 ft, and, in some cases, of even longer length; the ability of the railroad companies which handle them being still the governing condition. Shipping conditions require a limit in the depth of these girders to about 10 ft., and for this depth they are now more economical than riveted trusses of the same depth for spans between 100 ft. and 120 ft. The standard practice in regard to riveted trusses is to use them for spans between 120 ft. and 200 ft., although much longer

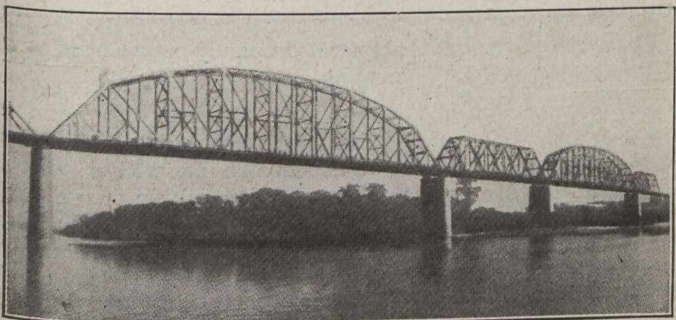

Fig. 3.—620-ft. Span Pin-connected Trusses. Typical of 1915 Construction.

spans are built. The pin-connected truss bridges may still be considered typical of American practice, but only for spans greater than 200 ft. Many of the characteristics which were so favorable to the construction of this type in 1890 are no longer peculiar to it, since the improvements in tools and machinery and in methods of handling and doing the work now enable the construction of riveted bridges having practically all the good characteristics of pin-connected structures, with the exception of the number of rivets, and this is no longer an objectionable feature. Riveted trusses have the additional favorable characteristic in the harmonious working of the various sections and parts of members, a condition which is not always obtained in the pin-connected type. The superiority of the riveted truss, which for a long time has been recognized in Europe, is now quite generally conceded by American railway bridge engineers, except for spans of such lengths as to require riveted connections to be too cumbersome for practical and effective construction. The typical American railway viaduct, with its steel towers, is still considered a good type when all bracing is stiff; but concrete piers, in a number of cases, have been constructed in preference to the steel towers, since they are less expensive to maintain, and, in favorable locations, are not much more expensive in first cost.

Swing bridges, revolving in a horizontal plane, are still being constructed; as are several patented types of bascule bridges, revolving in vertical planes. Another recent type of movable bridge is hauled up and down with wire ropes and counterbalanced by masses of concrete suspended over the tracks from steel cables. These are special types designed to compete with bascule bridges, and there are some locations and conditions which are particularly favorable to their construction.

All lateral bracing is now made of stiff members with riveted connections. Adjustable members, even for counters, are preferably avoided; and metal bridges are entirely of steel, wrought iron having for a number of years past been an uncommercial product for bridge construction. Open decks, with cross-ties resting directly on top flanges of beams or girders, while still used to a considerable extent, are undesirable for short spans under the present heavy traffic; the preference being for a solid ballasted deck, so as to maintain a continuous ballasted road bed.

Monolithic concrete masonry with a few rods imbedded for tying the mass has practically replaced cut stone work for piers and abutments; and reinforced concrete arches are replacing short-span steel bridges and stone arches, since the cost of this type of bridge, in locations suitable for its construction, is but little more than the cost of a steel bridge with a solid floor, and in many cases the cost may be even less.

In regard to present tendencies, it may be stated that the introduction of new grades of structural steel and the improvements in machinery and in methods of construction are still influences to be considered in future developments. There is a tendency toward the use of alloys with high ultimate strength in the long-span bridges, and when these new materials inspire general confidence in their uniformity and reliability for lighter work and their production commercially becomes less expensive, they may gradually replace the present standard structural steel, just as the latter has superseded wrought iron. This, in turn, may require some different types of metal bridges to be designed, so as to take advantage of the greater strength of the metal without sacrificing stiffness in the structure as a whole; or perhaps the present quality of stiffness in metal structures will give place to more elasticity. Another tendency is toward the use of reinforced concrete construction in preference to steel work wherever the conditions are suitable for this type of bridge, and toward continuous ballasted roadbeds over all bridges. There is also a tendency toward the construction of movable bridges revolving in vertical planes instead of in horizontal planes.

These tendencies indicate that the evolution of the American railroad bridges has not as yet reached its final stage, but is still in progress under influences which will continue to direct its trend toward meeting changes in physical and economic conditions.

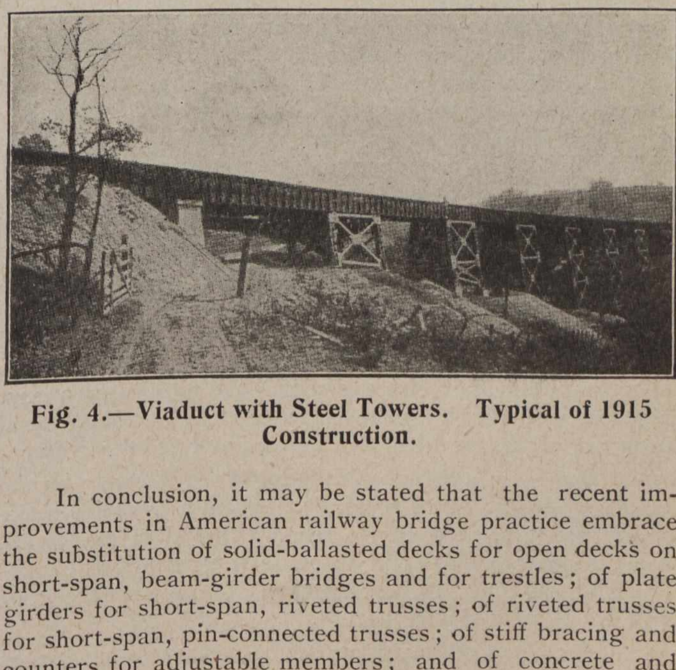

Fig. 4.—Viaduct with Steel Towers. Typical of 1915 Construction.

In conclusion, it may be stated that the recent improvements in American railway bridge practice embrace the substitution of solid-ballasted decks for open decks on short-span, beam-girder bridges and for trestles; of plate girders for short-span, riveted trusses; of riveted trusses for short-span, pin-connected trusses; of stiff bracing and counters for adjustable members; and of concrete and reinforced concrete masonry for cut stone work. While a few years ago the dominating characteristics of American railroad bridge construction were lightness, flimsiness and cheapness, the characteristics of the present-day standards are stability, solidity and permanence.

PRECISE LEVELLING BY THE GEODETIC SURVEY.

By F. B. Reid, D.L.S., Supervisor of Levelling.

(Concluded from last issue.)

"On all sections upon which the forward and backward measures differ by more than 0'.017 $\sqrt{M}$ (M being the distance in miles between adjacent bench marks) both the forward and backward measures are to be repeated until the difference between two such measures falls within the limit. No one of the questioned measures is to be used with a new measure in order to get this agreement. In this way, four, six or more measures are made, the mean of all being taken and the individual residuals determined. Reject all measures whose residuals are greater than 0'.017 $\sqrt{M}$; then take a mean of all remaining forward measures for a final forward result and a mean of all remaining backward measures for a final backward result. . . .

"No rejection shall be made on account of a residual smaller than aforesaid unless there is some other good reason for suspecting an error in this particular measure, and in such case the reason for rejection must be stated in the record.

"Between two adjacent permanent bench marks the same rule as to agreement of forward and backward levelling is to be applied; consequently it may be necessary, at times, to relevel sections which are themselves within the allowable limit of error in order to bring the longer section between permanent benches within such limit. . . .

"When a blunder is discovered, such as a misreading of one foot or one-tenth, or an interchange of sights (a backsight being recorded as a foresight, the correction should be made by recovering the old turning points and making the readings anew. The figures in error should then be struck out (not erased) and the correct figures inserted, the leveller initialing the change. . . . In the event of one or more blunders being discovered in both the forward and backward measures of a section, or in any other case in which there is any uncertainty whatever, the leveller is to follow the safe course and relevel the section in one direction after the corrections have been made.

"If, in the progress of the work, the difference between the forward and backward levelling shows a constant tendency as to sign, the leveller should not spend time relevelling sections which are themselves within the allowable limit in an effort to reduce the total discrepancy. He must rather look for the source of trouble in his general program of observations and in the habits of the rodmen.

"The daily mileage is influenced very largely by the length of sight; but if a leveller, through desire to make rapid progress, attempts to read farther than he should, the thread intervals will become irregular and his relevelling will probably be excessive. In any case the work will not be of a precise nature. . . .

"The line of sight must be removed as far as possible from the abnormal boiling of the atmosphere near the ground. In this connection especial care must be exercised when levelling along grades since the rod readings in one direction are necessarily nearer the ground than those in the other. The unequal refraction of the lines of sight will then tend to introduce a systematic error in the results, which is all the more serious since it will not be apparent if the levelling in the two directions is done under similar atmospheric conditions. If any unsteadiness in definition is noticeable, the rod reading of the lowest thread should never be within one foot of the ground. This will often mean shortening the sights considerably, but it must not be forgotten that, though speed is desirable, the work is of a precise nature and results of the highest order are of the first importance."

The requirement that the discrepancy between forward and backward levelling shall be within 0'.017 $\sqrt{\text{distance in miles}}$ has been adhered to as closely as possible throughout the work. This means that for 1 mile the forward and backward shall correspond within 0'.017, for 4 miles within 0'.034, for 100 miles within 0'.170, and so on. Quite frequently the total discrepancy of a line shows a constant, and often unaccountable tendency to accumulate in one direction; that is to say, the up-hill runnings persistently give larger results than the down-hill runnings, or vice versâ, without regard to whether the up-hill running happens to constitute forward levelling or

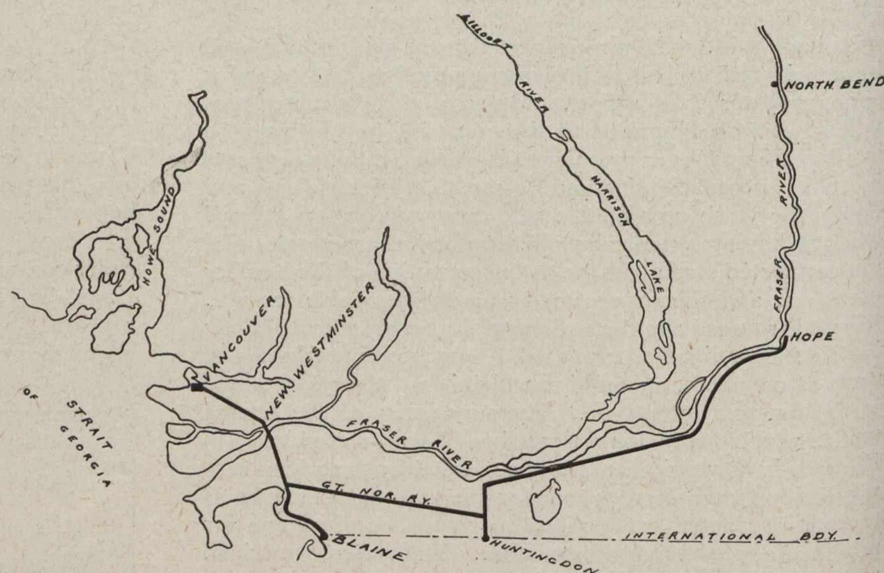

Fig. 5.—District Covered by Levels Run from Mean Sea-Level, as Established by the Tidal Survey at Vancouver, B.C.

backward levelling. Various precautions are used to guard against this. If, when reading from the successive instrument stations or set-up points, the rear rod were always read first, and the forward rod last, any settlement of the level between the backsight and foresight would have a constant tendency to make the foresights too small, and on the backward levelling this effect would be repeated, causing the discrepancy between the two runnings to accumulate rapidly. This is obviated by reading on the rear rod first at one station and on the forward rod first at the next station, so that any settlement at one will be counteracted by the settlement at the next. This method also has the advantage of eliminating the effect of a uniformly changing refraction in the atmosphere, such as usually occurs most noticeably in the early morning and late afternoon hours. It, of course, has the effect of holding back the progress of the work considerably, as at every second set-up the leveller has to wait for the front rodman to reach his turning point, and afterwards wait for the rear rodman to overtake him before going forward.

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*Read before the Royal Astronomical Society of Canada, at Ottawa, March 31, 1916.

Another source of error would be a systematic rising or settling of the rod supports. This would have a similar effect to the movement of the level, and cannot be guarded against in the same way. It is essential that rod supports should be as solid and immovable as possible. In running along a railway the most solid supports are also the most convenient, namely, the top of the rails. The rodman holds the rod with its semi-circular knob on a cross made on top of the rail, about midway between the rail joints. This has been found to be more satisfactory for a turning point than anything else. Upon a track in ordinary condition the passing of a train appears to have no effect. The rail may rise and fall an inch or more under the passage of the wheels, but careful comparison of the elevation of the point on the rail with some solid point to one side, before and after a train has passed, shows that the rail returns to sensibly the same elevation. Of course, when the track has been freshly ballasted and is, consequently, likely to settle down under a train, a turning point is taken to one side when a train is known to be approaching. When following a highway, as when running branch lines into a town, suitable steel pins, driven solidly into the ground, are used. The verticality of the rod, while readings are in progress, is maintained by means of a small spirit level.

Regarding the paragraph in the instructions which deals with levelling along grades, it is evident that when running up a steep grade the point read on the forward rod is much nearer the ground than on the rear rod, consequently the effect of refraction, or boiling of the atmosphere, is to distort the foresights more than the backsights. By taking very short sights, and thus keeping the line of sight away from the ground as much as possible, the effect is minimized but not by any means eliminated. The only way to do the latter would be to wait for cool, cloudy weather, when there is no perceptible refraction—which is not usually practicable. If one makes the forward levelling in such weather and the backward in a bright, hot sun, or vice versâ, the discrepancy is usually very noticeable. If both measures were made under the unfavorable conditions the results would probably show a good accordance, but both would be in error. This error would be compensated on the next down grade only if the weather conditions were similar. Atmospheric refraction affects the readings on the levelling rods most noticeably in two ways: Firstly, when the ground is being rapidly heated by the rays of the rising sun, the lowest stratum of air becomes, in its turn, heated by the ground and begins to flow upward. This has the effect of making the readings appear to rise and fall vertically, and even to remain for a minute or so in quite abnormal positions. Such conditions are unsuitable for observations. Secondly, when the air is bubbling, the graduations on the rods appear to dance or vibrate; they are then difficult to subdivide, but no systematic error is to be feared.

The length of sight taken depends upon the atmospheric conditions. Under the influence of a bright sun, without any breeze, especially when following a cold night, the boiling of the atmosphere is so severe that the divisions on the rod often cannot be subdivided with accuracy at a greater distance than 200 feet. Under average conditions sights vary from 300 to 400 feet. On a very favorable day these may be lengthened to 500 or 550 feet, or even more. The above remarks apply, naturally, to a level, or almost level, track. On a 2 per cent. grade, sights of 200 feet could not safely be exceeded in the best of weather.

The average progress for one month's work should be 60 or 65 miles of completed line. The amount of relevelling required should not amount to more than 10 or 12 per cent., provided weather conditions are at all favorable.

This class of work is so dependent for speed and precision upon the weather that it is found necessary to discontinue it in the autumn when the weather gets cold and storms become prevalent.

When carrying the line of levels along the railways the elevation of the top of the rail is taken opposite each station and at the crossings of intersecting railways, whether diamond, overhead or under crossings; in the latter cases, the distance to the rail of the intersecting railway is measured with a tape. When rivers or arms of lakes are crossed by bridges the rail level is taken on the bridge and the distance to the water measured. The rail elevations are tabulated in the office in a separate form of record from the bench marks and are useful as giving permanent records of the work in addition to those furnished by the bench marks. They are also very useful to the companies, since they furnish a means of comparing their profiles with our levels without the necessity of making any actual connections on the ground as would be necessary in the case of bench marks.

The elevations furnished in this way are only tabulated to the nearest tenth of a foot. They furnish a very practical record, nevertheless, and are in demand by engineers and others.

When the final elevations for the junction points have been fixed by an adjustment by the method of least squares or other means, the new elevations for the intermediate points may be fixed by interpolating between the junction points. The results thus obtained will be satisfactory only until more levelling is performed and still more circuits are introduced into the net, thus upsetting to a greater or less degree the results of the adjustment.

Regarding the precise level net of the United States the following paragraph from the report of the Coast and Geodetic Survey on the fourth (or 1912) general adjustment will be of interest: "When extensive additions are made to the precise level net of the country a readjustment of the level net must be made in order to obtain the best practicable elevations of bench marks and to eliminate the differences in the elevation of a bench mark which is on several lines of levels. Theoretically, the best method of procedure is to readjust the entire net and not to hold fixed any elevations resulting from the previous adjustment. This method, however, is impracticable, for the surveyors, engineers, and others whose operations are based on the elevations furnished by the precise levelling, wish to have the elevations used in any particular case held as fixed for an indefinite period or for all time."

The following plan was adopted in the 1912 adjustment: An adjustment of the entire net was made, then a comparison was made of the elevations resulting from that adjustment and from the last previous (or 1907) adjustment. This showed that the elevations of the bench marks lying to the eastward of an imaginary line running (approximately) from the middle of Lake Superior to the Gulf of Mexico near New Orleans might he held without change. Sixty-nine junction points were enabled to be held and of these only 14 had a difference of more than one-third of a foot from the elevations given by the new adjustment. A special adjustment was then made which included that portion of the net to the westward of the imaginary line mentioned above. "The elevations in the western part of the country resulting from the special adjustment and those held from the 1907 adjustment in the eastern part of the country are assumed to be standard elevations and are expected to be held without change. It is believed that the precise levelling net is sufficiently extended and of such strength that this may be done and that any new levelling in the future can be fitted to the standard elevations."

Quoting now from Special Publication No. 22 of the Coast and Geodetic Survey: "From time to time in the future, general adjustments of the level net will no doubt be made in order to obtain the theoretically best elevations of the junction points; but such adjustments will not disturb the standard elevations, unless they are found to be greatly in error on account of blunders in the levelling or due to the rising or settling of the bench marks from earthquake disturbances or the operations of man."

In India, where a system of levelling has been carried on since 1858, a complete report was published a few years ago by the Great Triangulation Survey. This gives the results of a thorough adjustment of all precise levelling up to 1909 by the method of least squares. Before this publication, arbitrary methods of adjustment were adopted, in most cases by giving infinite weight to the older lines and then fitting the new levelling into the old. So great discrepancies arose, however, that a complete readjustment, by a scientific method, was found to be necessary.

No adjustment has as yet been made of our system of levels in Canada. While a very considerable mileage has been levelled, it is, nevertheless, pretty well scattered all across the country and many additions to the system are still contemplated in each of the provinces. In view of this and of the rapidity with which new lines are being completed and new circuits closed, it would be premature at the present time to make an adjustment, only to have it upset in the near future. Fifteen circuits have, up to the present, been closed.

One of these circuits had a perimeter of 1,184 miles and a closing error of 1.285 feet, giving a closing error per mile of .00109 feet. The lengths of the other circuits ranged from 14 miles to 697 miles and the closing errors per mile from .00025 to .00503.

One circuit is composed of two lines starting from the village of Kipp, Alta. Both are carried over the summit of the Rocky Mountains, one via Calgary and the Kicking Horse Pass, the other via the more southerly route through the Crows Nest Pass. Coming together at the town of Golden, B.C., the two lines give elevations for the junction bench mark differing by less than 1½ inches, the total distance around the circuit being 623 miles. No one, of course, would be justified in saying that this result was due entirely to the accuracy of the levelling, which, by the way, was done by two different levellers working independently. No doubt errors counterbalancing one another have a good deal to do with it.

Progress and Publication of Results.—Levelling operations have been carried on each year by the Geodetic Survey since 1906. During the last two seasons six parties were in the field, while during the two seasons previous to that (*i.e.*, 1912 and 1913) four were employed. The total amount of levelling accomplished to date is 8,405 miles; that is to say, this distance has been run forward and the same distance backward, no account being taken of re-levelling. Of the above amount a little over 1,800 miles was done during the season of 1915. This is considerably the largest amount so far in one season. Two thousand three hundred and seventy permanent bench marks have been established, all being of the copper-bolt variety described earlier in this paper.

In order to give the public the benefit of our work, publications have been issued in pamphlet form each winter for the past four years. These give the results of the levelling in the different parts of the country as far as they are ready for publication and also include an index and map which are revised each year to indicate both the new work and that previously published.

For reasons previously stated, the elevations are not adjusted before publication. Where a new line is closed upon a previously published line the amount of the closing error is clearly shown so that anyone using the elevations will have evidence of the degree of precision obtained. Further, it is an easy matter to make a correction, equal in amount to the closing error, to any bench marks in the immediate vicinity of the junction point.

ORGANIZATION OF THE HYDROMETRIC SURVEY.*

THE chief features of the stream measurement work are the collection of data relating to the flow of surface waters and a study of the conditions affecting this flow. Information is also collected concerning river profiles, the duration and magnitude of floods, irrigation, water-power, storage, seepage, etc., which may be of use in hydrometric studies.

This information is obtained by a series of observations at regular gauging stations, which are established at suitable points. The selection of sites for these gauging stations and their maintenance depend largely upon the physical features and needs of the locality. If water is to be used for irrigation purposes the summer flow receives special attention; where it is required for power purposes, it becomes necessary to determine the minimum flow; if water is to be stored, information is obtained regarding the maximum flow. In all cases the duration of the different stages of the streams is recorded. Throughout the country gauging stations are maintained for general statistical purposes to show the conditions existing through long periods. They are also used as primary stations, and their records in connection with short series of measurements will serve as bases for estimating the flow at other points in the drainage basin. Local residents are engaged to observe the gauge heights at regular stations. These observations are recorded in a book supplied by the department, and at the end of each week the observer copies the week's records on a postal card, which he forwards to the Calgary office by the first convenient mail.

District hydrometric engineers make regular visits to the gauging stations, usually once in every three weeks. On these visits they examine the observers' records, make discharge measurements, and collect such information and data as would be of use in making estimates of the daily flow at the station. The results of the discharge measurements and all data collected are forwarded as soon as possible after being completed to the Calgary office, where all reports are copied on regular forms and filed.

During the winter no records are taken at a number of the gauging stations, which makes it possible to reduce the field staff and have each engineer spend some time in the office and assist in the final computations and estimates of run-off. As far as possible, the same engineer that did the field work makes or checks the office com-

*From the report of Progress of Stream Measurements, 1914, by P. M. Sauder, G. H. Whyte and G. R. Elliott.

putations, so as to eliminate any chance of error through lack of knowledge of the conditions at the gauging station.

Gauge height-area, gauge height-mean velocity, and gauge height-discharge curves are plotted and rating tables constructed. Tables of discharge measurements, daily gauge height and discharge, and monthly discharges are also compiled. These records have been collected and are embodied in the Sixth Annual Report of Progress of Stream Measurements.

The staff consists of the chief hydrometric engineer, two assistant engineers, one recorder. one computer, and one clerk in the office, and thirteen assistant engineers in the field.

During 1914 the territory was divided for administrative purposes into eleven districts, viz., Banff, Calgary, Macleod, Cardston, Milk River, Western Cypress Hills, Eastern Cypress Hills, Wood Mountain, Saskatoon, Edmonton and Athabaska. In each district there was one engineer, who while in the field employed temporary assistance and was equipped with the necessary gauging and surveying instruments. In Banff, Calgary, Macleod, Saskatoon, Edmonton and Athabaska districts the engineers travelled by train and hired livery, and stopped at hotels and stopping-houses; while in the other districts they were supplied with a team, democrat and camping outfit.

During the open-water season of 1914 records were taken at one hundred and seventy-four regular gauging stations on various streams in Alberta and Saskatchewan, and at sixty-five regular gauging stations on irrigation ditches and canals. Winter records, which are so valuable for power investigations and municipal water supplies, received special attention, and records were secured on almost all the important streams in the two provinces throughout the year.

Special investigations, which were commenced in 1913 to determine the absorption and seepage losses in canals, have been continued. The officials of the Canadian Pacific Railway and the Alberta Railway and Irrigation Company have assisted the engineers of the government considerably in work done on the irrigation tracts of their respective companies. In addition to measuring the flow of the canals, the temperature of the water has also been taken. Results of these observations will produce valuable data in a few years.

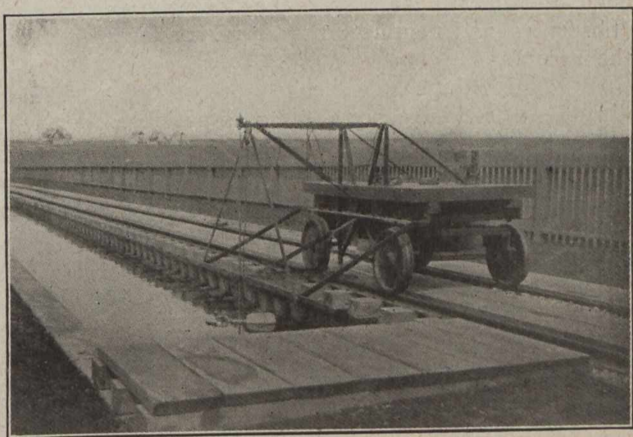
The current-meter rating station, which is located at Calgary, has rendered valuable service not only to the Hydrometric Survey, but to the British Columbia Government, the Manitoba Hydrographic Survey, the Department of Public Works of Canada, and to the Canadian Pacific Railway Company.

Each meter is rated before being used, in order to determine the relation between the revolutions of the wheel and the velocity of the water. The meter is driven at a uniform rate of speed through still water for a given distance, and the number of revolutions of the wheel and the time are recorded. From this data the number of revolutions per second and the corresponding velocity per second are computed. Tests are made for speeds varying from the slowest which will cause the wheel to revolve to several feet per second. The results of these runs, when plotted with revolutions per second as abscissae, and velocity in feet per second as ordinates, locate points that define the meter rating-curve, which for all meters is practically a straight line. From this curve a meter rating table is prepared. Theoretically, the rating for all meters of the same make and type should be the same, but as the result of slight variations in construction and in the bearing of the wheel on the axis at different velocities the ratings differ.

After a meter has been in use for some time the cups may have received small injuries, or the bearing of the wheel on the axis may have changed owing to unavoidable rough usage. These changes will affect the running of the meter and change its rating. As a consequence, each meter is re-rated at regular intervals and a new rating curve and table prepared. Rating tables are prepared for each rating of a meter and blueprints made, which are sent out with the instrument, while the originals are filed for reference in the office.

In addition to the regular work a few experiments on rating meters have been carried out. These gave results which will be of assistance in future rating and field work. It is the intention, however, to make further and more extensive investigations before publishing the results.

When the stream measurement work was first started the gauges were usually referred to bench-marks on wooden stakes or stumps of trees. These were easily shifted or destroyed, and were not satisfactory. In 1911



View of the Car at the Current Meter Rating Station at Calgary, Alberta, Showing the Apparatus for Suspending the Current Meter in the Tank.

an iron bench-mark was adopted by the branch, and now almost all the gauges are either referred to bench-marks on concrete piers or other permanent structures, or to one of these iron bench-marks. Whenever an opportunity is afforded, these are tied to the Canadian Pacific Railway or Dominion Government levels, to determine their elevation above sea level, and they are, therefore, also a convenient reference for local levelling operations.

As above intimated, the reports of the gauge-height observers and the hydrometric engineers are transmitted to the office by mail. These are copied on office forms and filed in a cabinet, which is carefully indexed, and where they can be referred to at any time without trouble. As the engineers complete their computations, the results are entered on convenient forms and filed in the same cabinet.

A cabinet made up of four styles of drawers is used for filing the records. The top section is used for filing the gauge height books of the observers and the current meter notes of the engineers. The gauge height books and current meter notes are filed alphabetically, according to the names of the streams. The next section contains the postal cards sent in by the observers, and these are also filed alphabetically according to the names of the streams. The third section is made up of map drawers, and contains the gauge height-area, gauge height-mean velocity and gauge height-discharge curves, and plotted cross-sections, which are filed alphabetically, according to the names of the streams. The same section contains the maps showing the outlines of the drainage basins, filed numerically according to the number of the sectional sheet. The rating curves for the current meters are also filed in this section numerically, according to the office numbers of the meters. The bottom section of the cabinet consists of letter-size pockets, alphabetically arranged for each gauging station. The tables of gauge heights, discharge measurements, daily gauge height and discharge, monthly discharge, a description of the station, and memos of any changes are filed in these pockets. The different rating tables for each meter are also filed numerically in this section, and another drawer contains the daily and monthly reports of the meterological service.

The copying and filing of the reports of the gauge height observers and the engineers is entrusted to the office recorder. While doing this he carefully examines all records to see that there are no errors, and where there are doubtful or impossible records it is his duty to have the data corrected or ascertain the cause of the unusual condition. He also makes out the pay list for the observers and conducts the correspondence relating to the records.

All computations are checked before being used or published. For this reason, as far as possible, men with some technical education, or students in science, are engaged as helpers. The gaugings are computed by the helper and his work is checked by the engineer. In some instances, where there is a great deal of driving and camping out, the engineer cannot secure a helper who can compute discharges, and in that case he computes the discharges himself, and his computations are checked in the office.

Gaugings of the flow under ice are usually made by using the multiple point method, and vertical velocity curves have to be plotted to determine the mean velocity in the vertical. The computation by this method is long and tedious and cannot be done by the engineer in the field. There are, therefore, a great many computations to be made in the office, and the services of a computer are required.

The results of the discharge measurements are plotted on cross-section paper by one of the assistant engineers as soon as they are received in the office, and thus a very close check is kept on the records, and errors can be detected at once, and in most cases can be rectified. At the same time the records are kept up to date, and demands for provisional estimates can be met at an early date. Important changes in the flow are also detected at once, and instructions are issued without delay to the field men to obtain further gaugings. The methods used in gauging streams will be discussed in a future article.

Several articles describing special applications for searchlights, which have been developed during the war, are contained in a recent issue of *Popular Mechanics*. The first of these describes a method, developed by an American, to locate submerged mines. A powerful enclosed searchlight is mounted under water to one side of the vessel and near the bow. Slightly above the searchlight there is a periscope mirror arrangement, enclosed in a tube coming up to the deck, through which, it is claimed, the observer can see any object illuminated by the searchlight beam at a distance as great as 2,000 feet.

PROPER METHODS OF LAYING WOOD PIPE.

By John H. Curzon, A.M.Can.Soc.C.E.

FROM the earliest days of civilization, when man found it necessary to convey water from one point to another, wood pipe has been used for the purpose. Probably the man who thus converted the great forces in Nature to the use and convenience of man became the first civil engineer. At any rate, his actions in building the first pipe line certainly fulfilled the great definition as laid down by the Institution of Civil Engineers, and which has ever since remained the principal foundation-stone of the great profession of civil engineering.

One would think that wood pipe would have increased in efficiency from the start, but such is not the case. For many years it did increase in quality and efficiency as a water carrier, but when iron pipe became a possibility, the curve of progress in efficiency of wood pipe flattened out considerably. For some time the metallic pipe held sway until market conditions and other reasons again brought wood pipe into use. For the last thirty years the curve of efficiency of use and manufacture of wood pipe has gradually had an upward trend, until to-day it is the equal of any other pipe, under suitable conditions, of course. Wood pipe is not suited

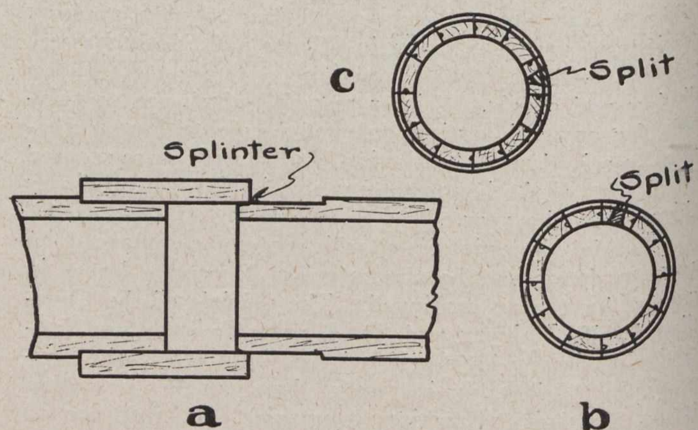


Fig. 1.

to all uses, and will not always be economical in places where iron, concrete or vitrified clay pipe could be used.

Assuming that the pipe has been properly manufactured, and that it is being put to use under favorable conditions, then the method of laying it becomes of prime importance. Wood pipe, that is, the stock sizes, which are manufactured ready to lay, and not only in staves to be bound together, is one of the simplest and easiest forms of pipe to lay. It requires no caulking or the use of any other material in making the joint absolutely watertight.

Pipe which has been well finished and not damaged in transit and has been kept dry can be easily driven by a plug and dolley. If the pipe has been manufactured with ends oversize, and sometimes this is done in order to protect the ends during shipment to the job, then it is only necessary to use a rasp or paring-knife to prepare the ends for driving. Each individual joint should be tried before preparing the ends, as the pipes are very seldom uniform throughout. The wood in one pipe may be dried a little more than the wood in the next pipe, or the cellular texture of two adjoining pipes may be different, necessitating different degree in preparation of the ends. Axle grease or tallow, when used in moderation, may be smeared on the spigot ends to aid in driving the pipes together. The grease will not reduce the efficiency of the joints, and will help in preventing splinters from turning back, and thus causing leaks.

The inspector on the work must look carefully for split or broomed ends of pipe, as even a small splinter turned back in driving the pipes together will cause leakage. The section of a joint shown in Fig. I. (*a*) illustrates this. Splits may be forced in by driving and form very large leaks. In Fig. 1 (*b*) and (*c*) is shown two forms of splits which are often caused by the pipe being roughly handled in transporting. In case (*b*) the split portion is likely to be forced inward by driving and by the expansion of the wood in the pipe when it becomes damp. Such a leak may not show in a short test, but will develop with use. A leak formed by such a split is likely to run back into the pipe for several feet. The asphalt coating will be blown off if any great pressure is put on the pipe. In case (*c*) the split is not likely to affect the watertightness of the pipe, as when the collar or bell is driven over it, it will force the pieces together and prevent leakage. For small heads such a defect should not cull the pipe, but for heavy pressures it, of course, is not as desirable as solid pipe. Where splits such as these occur it is well to cut off the damaged end of the pipe and re-form the spigot. This is done by clinching a staple over thé wire back of the injured part. The wire is then cut and unwrapped from the pipe, leaving the wood ready to be sawn. The end is then pared off and filed to the proper size.

The method of driving the pipes together is by means of a plug and dolley. The plug is a piece of hardwood, about 18 inches long, with iron bands shrunk on each end to prevent splitting and swelling in wet work. The dolley is made of a fir or tamarack railroad tie, about 4 feet long, and should have iron rings shrunk on the battering end to prevent brooming. The apparatus is illustrated in Fig. 2. The dolley is suspended from a wooden horse or frame placed across the ditch. The plug, which is inserted in the pipe to be driven, is battered by the dolley, which is pulled backward and forward by several men. Usually one man stands ahead in the ditch and pulls the dolley back after each blow. One or two men stand on the pipe while battering the plug with the dolley. One man on top regulates the length of the suspending rope or chain.

This method is very effective, and great speed is possible when the pipe-laying gang have been trained to the work. On an 8-foot ditch 1,629 feet of pipe were laid in a day of 10 hours, the gang of eight men being distributed as follows: One foreman; one man part time preparing pipe-ends, filing, greasing, etc., and part time tamping earth around the finished line; two men on surface dropping pipe in the ditch; three men in the ditch driving pipe, and one man clearing out bottom of ditch before the pipe-laying crew. It was necessary for the whole crew to go back to help with the tamping a couple of times. The ditch was in exceptionally good ground, and had been dug by an Austin trenching machine. Averse to this record should be placed another, in which twelve men in 10 hours laid only 61 feet of pipe. This was over ground that had to be hand-dug, as it was yellow clay, and the machine was so heavy that the sides caved in as soon as dug out, necessitating close sheathing. It would have been easier to handle if the machine had not started at all in this kind of ground. A fairer average for wet trench, which had to be partly mucked out and stones removed, is 360 feet laid by five men in 10 hours. The above data are from the records of an 8-inch wood pipe line laid in Southern Saskatchewan by the J. A. Broley Contracting Company for the Canadian Pacific Railway Company.

Before backfilling the pipe should be well surrounded by earth, being well tamped in place. This will prevent the pipe from shifting its alignment, and will to some extent preclude the possibility of stones working their way down to the pipe. Backfilling is usually done with a team and Fresno or buck scraper. A new backfilling machine has been put on the market by the Austin company which should help considerably in the work.

If the pipe is subject to shocks due to valves or gates, or is on a pressure line which is subject to the throb of pumping, great care must be exercised to prevent any stones or rock from coming in contact with the pipe. Stones which touch the pipe are a source of subsequent leakage, caused by them wearing through the wire and allowing the staves to open out. If stones are in the backfill, they must be carefully placed with 2 feet or more of tamped earth between them and the top of the pipe.

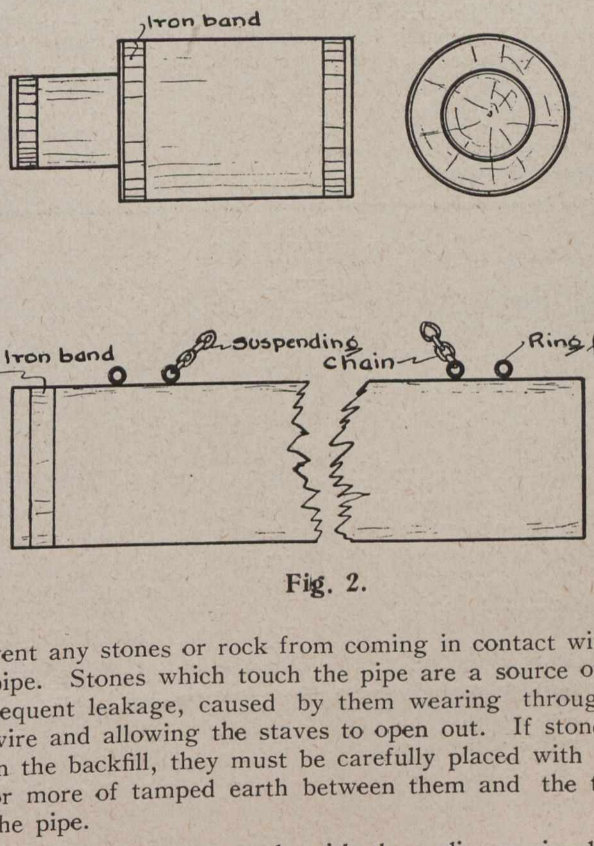


Fig. 2.

Curves may be made with the ordinary pipe by deflecting each pipe about 2 inches. This will not materially reduce the efficiency of the connection. The above applies to sleeve-connected pipe, in which the sockets are deep. For mortise-and-tenon joints probably about one-half this amount is all that can be deflected with safety.

In laying the pipe a small amount of water in the trench is not detrimental to the work, as it would be in metal pipe, the quantity allowable only being limited by the buoyancy of the pipe and the discomfort to the workmen caused by splashing water in driving. Owing to the buoyancy of wood pipe, it is necessary to keep the backfillers close behind the pipe-layers. One contractor at least has had occasion to regret that he did not do this, as a rainstorm filled the low parts of his ditch and lifted the pipe, allowing the tamped material and other washed-in-sand to get below the pipe. This necessitated the removal and replacing of over a thousand feet of pipe.

The Engineer's Library

Any book reviewed in these columns may be obtained through the Book Department of The Canadian Engineer, 62 Church Street, Toronto.

CONTENTS.

BOOK REVIEWS.

Wiring Houses for the Electric Light, together with special references to low-voltage battery systems. By Norman H. Schneider. Published by Spon & Chamberlain, New York. Second edition, revised and enlarged. 112 pages, 5 x 7 ins., cloth, illustrated. Price, 55 cents.

A handbook of practical information for those who wish to install their own lighting plants. The book deals with low-voltage systems as the one most suited to household use. For the man who has a hobby for doing things about the house the book should contain some valuable information on wiring.

Oxy-Acetylene Welding and Cutting, Electric and Thermit Welding.—By Harold P. Manly, Chief Engineer the American Bureau of Engineering. Published by Frederick J. Drake & Co., Chicago. 216 pages, 4½ x 7 ins., illustrated. Price cloth, $1.00; leather, $1.50.

The author states in the preface that his object in preparing the book has been to cover not only the several processes of welding, but also those other processes whose methods are so closely allied as to make them a part of the whole subject of joining metal to metal with the aid of heat.

The book commences by describing the various metals, their properties and uses. Then the production and handling of gases and other materials and the use of tools and accessories is taken up. The use of the gases in connection with welding and cutting is then explained, along with some very practical instructions for the proper handling of work of this nature. The instructions are very easily understood and are placed in the order in which they would occur in actual practice. To those who are engaged in this trade the book will be found to be of great practical value. It is of a handy size, well bound, and the information is readily accessible without wading through a mass of unnecessary reading matter.

Dictionary of Altitudes in the Dominion of Canada.—By James White, F.R.S.C., F.R.G.S., Deputy Head and assistant to chairman Commission of Conservation. Published by the Commission. Second edition. 251 pages, 6 x 9 ins., cloth.

The second edition of this work, in which the elevations have been thoroughly checked and brought up to date. The dictionary has also been considerably enlarged. The book is supplementary to "Altitudes in Canada" by the same author, and the information contained therein is more conveniently arranged than that in "Altitudes in Canada." With this arrangement it is only necessary to know the province in which a certain station is located in order to find its elevation. The station names are arranged alphabetically for each province and territory. Latitudes and longitudes of the points are also given for some of the provinces. For a quick reference book of elevations its value is apparent.

Pole and Tower Lines for Electric Power Transmission.—By R. D. Coombs, C.E. Published by McGraw-Hill Book Co. 272 pages, 6 x 9 ins., 162 illustrations and 30 tables, cloth. Price $2.50. Reviewed by J. H. Mackay, Engineer, Toronto Power Co.

It is worthy of remark that, during the last decade, since the advent of long-distance, high-tension transmission of electrical energy, there have been very few worthy publications brought out (other than the proceedings of the A.I.E.E.) that have kept pace with the rapid advancement in this branch of engineering, particularly in connection with the design and construction of the transmission line itself.

Here, in America, existing conditions are such that a continuity of service must be maintained between the source of energy and the market, often hundreds of miles apart, and the thousands of horse-power transmitted necessitate voltages greatly in excess of those of a few years ago, and, in fact, greater than the present-day requirements of the more thickly-populated countries of Middle Europe. This fact, combined with the widely different character of the territory passed through, and the great range of temperature often to be considered along with other climatic conditions, has called forth the best efforts of our engineers in this connection to design and construct transmission lines that will successfully fulfil the requirements of our own continent.

The book by R. D. Coombs, C.E., "Pole and Tower Lines for Electric Power Transmission" (just issued), has been written from the standpoint of American practice, and in a short review of same the following comments are offered:—

The subject matter of the volume, covering some fourteen chapters is suitably arranged under proper headings, the discussions interesting, and the data compiled in a clear, concise and readable manner. As the author states, his object is more to give the reader a clearer perception of the application of the laws of mechanics as applied to the case in hand than to deal with purely electrical problems.

The design of the supporting structures or towers, along with the construction methods and various materials employed in connection with many of the American transmission lines, are described at some length, and the many tables and computations incorporated in these chapters are valuable.

Tables are contained in Chapter 6 which are of interest and value to the engineer, and, in fact, to anyone interested or connected with the transmission of electrical energy these tables, giving all the principal data relative to the higher voltage lines throughout the world. There is a slight error in two places in Table 28a, giving the gauge of the Toronto Power Co.'s copper conductors as 198,000 C.M., which, to be correct, should read 190,000 C.M., but before the next edition of the book goes to press this small error may be corrected.

The chapters devoted to wooden poles, concrete poles, steel poles and towers and special structures are all creditable, giving, as they do, all the most approved methods of present-day construction along these lines. In connection with the use of wooden poles, the various methods of impregnation or preservative treatment are described, the relative values of the pressure, open-tank and brush treatments being discussed.

Foundation work receives due consideration, the chapter devoted to same being replete with illustrations showing the most approved practice in this connection; and again, the chapter on erection and costs, and on general specifications, is creditable.

From an operating standpoint the question of insulators is of vital importance, and the relative values of the suspension and pin-types receives consideration.

During the past year some of the larger American companies have introduced some radical changes in the mechanical design of pin-type insulators for higher voltages, and these, we trust, will eliminate, to some extent, the defects that have developed in the past. However, the practical limit of the pin-type, as at present developed, is in the neighborhood of 85,000 volts, as, beyond this voltage, the leverage, caused by the excessive length of pin required, becomes too great, the small amount of porcelain separating pin and conductor solicits puncture, and the weight and manufacturing cost become excessive; therefore, for transmission lines to be operated above 85,000 volts, the suspension type is as yet the only solution of the insulator problem.

In conclusion, it may be said that Mr. Coombs has covered the field in a manner creditable to any writer, and is to be complimented on the arrangement of his subject matter and the general excellence of the photographs selected with which to illustrate his book.

The Caisson as a New Element in Concrete Dam Construction.—A proposal made in connection with the Columbia River Power Project. By O. G. Aichel. Published by Spon & Chamberlain, New York. 32 pages, 10 x 7 ins, paper, six folding plates. Price, $1.00 net.

An essay describing a proposed scheme of construction of a concrete and steel arch dam on the Columbia River, near The Dalles, Oregon. The proposal presents some novel features, the erection of a caisson in tunnel under the river-bed and its subsequent raising being a new method for carrying out work of this nature. The author has eliminated any preliminary studies as to the reasons for adopting the scheme. The proposed method of construction is given with much detail, the work being divided up into five periods of construction as follows: shaft-sinking and tunnelling; erection of caisson and building of base of dam; excavation of main tunnel chamber; blasting of the roof of the main tunnel chamber; lifting of the caisson and building up of the dam. The essay should be of interest and value to those engaged in the design and construction of large dams.

The Metallography and Heat Treatment of Iron and Steel. By Albert Sauveur, Professor of Metallurgy and Metallography in Harvard University and the Massachusetts Institute of Technology. Published by Sauveur and Boylston, Cambridge, Mass. 504 pages, 7¼ x 10½ ins., 438 illustrations, cloth. Price, $6.00 net. (Reviewed by John B. Temple, B.A.Sc., Toronto Iron Works.)

Three years ago the first edition of this educational treatise appeared, and in order to keep abreast with this fast-growing science the author now offers a revised edition which has been almost entirely re-written and presents much new material.

This book will commend itself possibly more to the student or the teacher than to the metallographist, as each chapter is arranged somewhat after the style of a series of lectures dealing with the subject from the ground up. However, the metallographist or engineer who wishes to brush up his knowledge of the subject will find much valuable information condensed in its pages.

The first three chapters deal entirely with the apparatus and manipulation of same for the modern metallographic laboratory. The next two chapters have as their chief object the explanation of the facts and theories regarding crystallization. The more serious work of the book is continued from this point on.

We would possibly advise the reading of the last three chapters first. These deal with the equilibrium diagram, the phrase rule, and the nomenclature of microscopic constituents. On account of their complexities, these discussions have been left till the last, but on a clear understanding of these chapters (particularly the equilibrium diagram) hinges the whole subject.

A noteworthy feature of the book is the many excellent photomicrographic illustrations setting forth clearly the structures of iron and steel in their many forms.

Altogether, Mr. Sauveur presents an excellent, well-balanced treatise and covers the subject very thoroughly.

Oil Fuel Equipment for Locomotives and Principles of Application. By Alfred H. Gibbings, A.M.Inst. C.E. Published by Constable & Company, Ltd., London. 125 pages, 5½ x 8½ ins., 42 figures and 16 tables, cloth. Price, $2.00.

This book covers the principles of combustion as applied to oil-burning locomotives. The various methods of burning oil fuel by steam jet; compressed air jet, and pressure jet systems are fully described and the advantages and disadvantages of each are taken up. The pressure jet system is enlarged upon in a whole chapter in which several types are described. Burners, fire-boxes and draughts are studied and their effect upon the efficiency of operation is noted. The proper disposition of the apparatus connected with a pressure jet system is shown, and illustrated on a diagram. The author states that the publication is intended chiefly for the use of locomotive superintendents and others who have the control of railway engines using oil as fuel.

The book deals with its subject in a clear and practical manner and is to be recommended to railroad men and others who are interested in the widely increasing use of oil as a fuel for locomotives.

Proceedings of the American Electric Railway Engineering Association, 1915.—Published by the Association, E. B. Burritt, secretary, 8 West 40th Street, New York. 623 pages, 6 x 9 ins., cloth, 166 illustrations.

These proceedings contain the complete report of the thirteenth annual convention of the Association, held in San Francisco last October. The committee reports include a widely diversified list of subjects. Among them are reports on many matters in which the results of investigations carried on as to the proper foundations for car tracks on paved streets are shown. Other reports are on Building and Structures; Lightning Protection; Power Distribution; Block Signals; Equipment; Power Generation, and Heavy Electric Traction. The last-named report is largely given over to a study of modern electric locomotives, and with it there are given 37 views and plans of American and foreign electric engines.

Dams and Weirs. By W. G. Bligh, Inspecting Engineer of Irrigation Works, Department of Interior, Canada. Published by American Technical Society, Chicago. 206 pages, 122 figures, 5½ x 8½ ins., cloth. Price, $1.50. (Reviewed by Thos. H. Hogg, Hydraulic Engineer, Ontario Hydro-Electric Commission.

This little volume comprises an analytical and practical treatment of gravity dams and weirs, arch and buttress dams, submerged weirs, and barrages. Each different type of profile is given a careful analysis followed by typical examples which are studied in relation to the theory, showing the good and bad points of the design.

Perhaps one of the most valuable features of the book is the interesting comments on actual work, based on what the author's experience has shown to him to be practical and based on good practice.

This brief but authoritative treatise should be well received by those of the profession interested in the design of dams and weirs.

PUBLICATIONS RECEIVED.

Railway Statistics.—Returns of the Canadian Railway Companies for 1915.

Abstracts of Current Decisions on Mines and Mining.—Bulletin No. 113 of the United States Bureau of Mines.

Hydro-Electric Power Commission of Ontario.—Eighth annual report for year 1915. 466 pages, illustrated.

Report of the Minister of Public Works for the Province of Ontario, 1915. Illustrated report of work done during the year. 186 pages.

Manufacture of Gasoline and Benzine-Toluene from Petroleum and other Hydrocarbons.—Bulletin No. 114 of the United States Bureau of Mines.

Methods for the Determination of the Physical Properties of Road-Building Rock.—Bulletin No. 347 of the United States Department of Agriculture.

Texada Island, B.C.—Memoir No. 58, by R. G. McConnell, of the Geological Survey of Canada. Published by the Department of Mines. 112 pages, illustrated.

Relation of Mineral Composition and Rock Structure to the Physical Properties of Road Materials.—Bulletin No. 348 of the United States Bureau of Agriculture.

The Electrical Resistances and Temperature Coefficients of Nickel-Copper-Chromium Alloys.—By Frederick M. Sebort. Published by the Rensselaer Polytechnic Institute.

Report of the Minister of Lands, Forests and Mines.—The report of operations of the Department of Lands, Forests and Mines of the Province of Ontario for 1915. 90 pages, illustrated.

Geology of Cranbrook Map-Area, British Columbia.—Memoir No. 76, by Stuart J. Schofield, of the Geological Survey of Canada. Published by the Department of Mines. 246 pages, illustrated.

Contributions to Canadian Biology, being a report of studies carried on at the biological stations of Canada during 1914-15. Supplement to the fifth annual report of the Department of Naval Service, Fisheries Branch. 172 pages, illustrated.

The Artesian Wells of Montreal.—Memoir No. 72, by C. L. Cumming, of the Geological Survey of Canada. A report of deep borings made and other investigations of the subterranean waters in the vicinity of Montreal. Published by the Department of Mines. 154 pages, illustrated.

CATALOGUES RECEIVED.

Permanent Concrete Roads.—A pamphlet describing and illustrating the various devices used for concrete paving. Published by the Trussed Concrete Steel Company of Canada.

The Nordberg High Compression Two-Cycle Oil Engine.—Bulletin describing the engine and its operation. Issued by the Nordberg Manufacturing Co., of Milwaukee, Wis., U.S.A.

Imperial Asphalt.—A 24-page and cover illustrated booklet, distributed free by the Imperial Oil Co., Limited, Toronto. It discusses various types of asphaltic roadways and streets, and gives directions for construction. A plan of the company's new refinery at Montreal and 15 other illustrations are included. Printed in four colors.

Concrete Roads.—A 38-page, illustrated booklet, distributed free by The Canada Cement Co., 782 Herald Building, Montreal. It discusses, in a most interesting manner, the need for good roads and the utility of concrete as a road material. There are thirty-seven illustrations, and the general appearance of the booklet is attractive. Specifications and construction pointers are included. A list of concrete lanes, streets and roads in Canada totals 2,259,081 sq. yds., of which 682,414 sq. yds. were laid in 1915, an increase of about 24 per cent. over 1914.

CANADIAN SOCIETY OF CIVIL ENGINEERS.

At a meeting of the Society held on April 13th an informal talk on the difficulties experienced in building the Panama Canal was given by John Murphy, chairman of the Ottawa Branch. The talk was illustrated with slides.

Col. Snyder drew diagrams explaining in an interesting manner the preparation of military maps.

Editorial

CALGARY ENGINEERS SETTLE DISPUTE.

Certain action recently taken by the Calgary Branch of the Canadian Society of Civil Engineers, and approved of by the Council of the Society, deserves special publicity as illustrating one of the many ways in which such a society serves the interests of the engineering profession as well as of the public in general.

G. W. Craig, city engineer of Calgary, Alta., had been seriously criticized in regard to a reinforced concrete arch bridge over the Bow River. The city council had ordered the Board of Commissioners to investigate the charges, and the citizens of Calgary believed, as a result of the discussion, that the safety of the bridge, which was under construction, was endangered. The controversy was very technical, and the public could not judge of its merits.

At that stage the Calgary Branch held a general meeting and passed a resolution offering the gratuitous services of the branch in determining the technical questions involved. The city accepted the offer, and the branch named a committee of three of its prominent members, who were independent of all civic politics. The report of the committee, stating that they could "find no reason for the charges, and are unable to understand why they should ever have been made," was adopted by the city council, and the city engineer was thus fully exonerated.

"Mr. Craig," says the committee, "showed a very complete knowledge of the general questions of the design and of the history of the particular questions in controversy."

Mr. Greene, the city's bridge engineer, and Mr. Field, the city chemist, were examined. The committee then visited the work, where various employees were questioned, and a visit was paid to the city laboratory, where samples of steel were tested, and the equipment at the laboratory and methods of tests were noted.

The charges that had been made in connection with the bridge were as follows:—

(1) The use of unsuitable steel in a portion of the structure, and extravagance in cost of testing the same.

(2) Neglect or carelessness in not carrying the foundations of the north retaining wall or abutment to rock.

(3) Failure on the part of the engineering department to submit the design to a consulting engineer for endorsement, "it having always been understood that such a course would be followed."

(4) Purchase of unsuitable cable at a higher price than suitable cable could have been bought for.

In regard to the testing of the steel, the committee "cannot see how any private firm could make the necessary tests and inspection any cheaper than the city has done in this case." The committee's report goes very fully into the character of the material used in the bridge and deals with the questions of physical tests, specifications for steel, re-rolled steel, process of manufacture, significance of tests, and so on. In regard to the use of re-rolled steel, the report says:—

"It has been used as reinforcement in the construction of the retaining wall which forms a part of the north abutment. It has also been used, or is contemplated, as dowels to furnish a bond between successive pourings of concrete in the river piers and springings. It was also used, or contemplated, in the curtain walls of the main piers and pylons of the river arches, and as carriers or spacing rods in various other parts of the work. With the exception of the retaining walls, the function of the steel is arbitrary, and the material is subject to no definite stresses. In the pylons, the curtain walls are a mere architectural effect and have no structural functions. The steel is used merely to prevent unsightly cracks due to temperature and shrinkage stresses, and its section is in most cases far in excess of possible requirements."

In regard to carrying the foundations of the north retaining wall or abutment to rock, the committee "are of the opinion that the wall is reasonably safe against failure, and that the additional expenditure necessary to carry this wall to rock would not be justified by the returns."

The stresses in the retaining walls were checked, and the possibility of failure investigated. The calculated loads are moderate, and the methods of calculation adopted are conservative. The committee are of the opinion that failure from any of the causes mentioned in the charges is a very remote possibility.

As to the submission of the design to a consulting engineer, the committee found that there was no common understanding to that effect. "As to the advisability of such a course," says the report, "the decision must be made by the parties who pay for the work. In general, when a proposed structure departs widely from well-established precedents, or the designer has not had the necessary progressive experience in the design of structures of such magnitude or importance, it is usually considered wise to employ an outside opinion to check over the design, or to pass on some particular feature of the construction. When the structure is well within precedent as well as the experience of its designer, the expense of a consulting opinion may not be justified. It might be remarked at this point that no consulting engineer whose opinion would carry any weight, would guarantee the safety of a structure any more than a counsel would guarantee the result of a suit at law, or a surgeon the result of a major operation. The decision as to the employment of a consulting engineer does not and should not rest on the designing or executive engineer. It is his duty in certain cases to suggest an outside opinion and in others to point out to his employers or clients, on request, the facts which may or may not justify the expense of such an opinion, but it is seldom his duty to insist on it."

The responsibility for the purchase of the cable was assumed by the city commissioners, and the opinion of the Calgary Branch on this matter was not required.

The Canadian Engineer has had the opportunity of perusing the voluminous details of the case, as brought out by the committee, and it can be readily seen that they undoubtedly represent a great deal of painstaking work. The Calgary Branch are to be congratulated upon their initiative. The unselfishness of their action is proven by the fact that Mr. Craig is not a member of the Canadian Society of Civil Engineers.

PERSONAL.

C. L. GIBBS, architect, of Edmonton, has enlisted with the University of Alberta Company.

A. H. BROWN has resigned as manager of the Hudson Bay Mines, Limited, Porcupine, Ont.

JOHN H. KILMER, A.M.Can.Soc.C.E., has been appointed city engineer and inspector of waterworks construction at Port Moody, B.C.

LUCIUS C. ALLEN, consulting engineer, Belleville, Ont., announces the removal of his office to the new Bank of Commerce Building in that city.

CHARLES P. LIGHT, who for some years has been field secretary of the American Highway Association, has resigned to enter the business of life insurance.

GEO. D. MACKIE, city engineer of Moose Jaw, Sask., has been appointed a member of the Royal Commission to investigate the Saskatchewan Highways Department.

W. D. MACKAY, NORMAN E. LYCHE, M. H. RAMSAY and FRANCIS B. MONTEITH have qualified for commissions as B.C. Land Surveyors at the April examinations.

H. K. WICKSTEED, M.Can.Soc.C.E., chief engineer of surveys, Mackenzie, Mann & Company, Limited, has been in Venezuela in connection with a coal mining and railway proposition.

W. J. RENIX, district master mechanic at Revelstoke, B.C., and who was formerly shop foreman of the C.P.R. at Moose Jaw, Sask., has been promoted to the position of divisional master mechanic at Moose Jaw.

HENRY HARVIE has resigned from his position as designing engineer for the Rochester Railroad & Light Company to become chief draftsman for the hydraulic department of the Hydro-Electric Power Commission of Ontario, with headquarters at Toronto.

ROBERT McKILLOP, who was appointed superintendent of District No. 2, Atlantic Division at Woodstock, N.B., has been in the service of the C.P.R. since 1905. Mr. McKillop held the post of assistant engineer and chief draftsman of the engineering department at Montreal until February, 1915, when he was appointed division engineer of the eastern division.

Lieut.-Col. J. A. HESKETH, M.Can.Soc.C.E., formerly Assistant engineer, C.P.R., Winnipeg, and District Intelligence Officer and Officer Commanding the Corps of Guides, with headquarters at Winnipeg, who went overseas with the Canadian Expeditionary Force shortly after war broke out, and who is now in Strathcona's Horse, was married in England, March 14, while on leave from the front, to the widow of J. E. Schwitzer, who, when he died in 1911, was chief engineer, C.P.R., Montreal.

Major A. G. L. McNAUGHTON, of Montreal, has been appointed to a command, according to a London cable. Major McNaughton, who was seriously wounded at Ypres, was in practice as an electrical engineer in Montreal before joining the overseas forces. He graduated from McGill University, where he was for some time a demonstrator in the electrical course. At the battle of Langemarck, despite a serious wound in the arm, he stayed with his battery for twelve hours and directed its operations. He had two orderlies hold his maps in front of him, and he kept two telephones going in despatching orders.

OBITUARY.

SIR COLIN CAMPBELL SCOTT-MONCRIEFF, well known as an authority on irrigation, died in London, England, April 6, at the age of 80. He was the creator of the present system of irrigation in British India, where the canals aggregate, in extent, the circumference of the globe, and he also inaugurated a similar system in Egypt. Since these works, which took almost half a century to complete, he has been consulted in irrigation projects by the Turkish, German, and Russian governments, and was largely responsible for the idea carried out by Russia in the river regulation and canal construction of its transcaspian and central Asian possessions.

SCHOOL OF MINING BECOMES A FACULTY OF QUEEN'S UNIVERSITY.

The School of Mining at Kingston, Ont., has been amalgamated with Queen's University and will be conducted as a regular faculty of the university, under the direction of the trustees. At the final meeting of the shareholders and board of governors of the school some of the members were elected trustees of the university.

COAST TO COAST

Ottawa, Ont.—J. D. McArthur, promoter and builder of the Edmonton, Dunvegan and Peace River Railway, is in the capital urging on the government that the usual federal subsidy of $6,400 per mile be granted his enterprise. Mr. McArthur pointed out that the road was necessary to the development of the country and the cost had been greater owing to the number of bridges required.

Toronto, Ont.—The Ontario Government plans to devote several million dollars to the development of New Ontario. Intimation to this effect was made in the Legislature by Hon. Edward Ferguson, Minister of Land, Forests and Mines. The government expects to make arrangements whereby it will loan settlers money for development purposes.

Edmonton, Alta.—An experimental sewage disposal plant which will treat part of the city's sewage by the activated sludge system has been completed at a cost of $50,000.

St. John, N.B.—At a meeting of the Board of Trade a strong vote in favor of the Valley Railroad entering the city by the original east side route was recorded.

Montreal, P.Q.—The Montreal and Southern Counties Railway has been completed to the town of Granby. Traffic will open on April 29.

Quebec, Que.—The new C.P.R. Union Station at the Palais is nearly completed, and it is expected that the various freight, ticket and steamship offices of the company will be installed in the new quarters early in May.

Ottawa, Ont.—The chief provision of the bill recently introduced to amend the Railway Act is one giving to the railway board the power to fix the general location of a railway line as well as the right to say whether or not it is in the public interest that it should be constructed.