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Pressure Rise Caused by Gradual Gate Closure

Application of Professor Joukovsky's Theory of Maximum Water-Hammer—Solution of Problem by Arithmetic Integration—Derivation of Formulas—Paper Presented to the American Society of Civil Engineers

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THE purpose of this paper is to show how the excess pressure in penstocks caused by the gradual closing of turbine gates may be determined from Professor Joukovsky's theory of water-hammer. It will be assumed that the theory of pressure waves, their amplitudes, and speeds of propagation, as formulated by him and proved by his experiments, may be accepted as correct.

At the risk of wearying the reader who is familiar with Joukovskys' work, it is necessary, in connection with what is to follow, to summarize as briefly as possible the principles demonstrated a number of years ago by the distinguished Russian. For a partial translation of his work, the reader is referred to Miss O. Simin's paper entitled "Water Hammer," in the Proceedings of the American Water Works Association, 1904, page 341, which should be examined carefully by every student of this subject.

Joukovsky's experiments, made in 1908 at Moscow, were confined to the instantaneous stopping of the flow of water in long pipes. By his experiments he was able to prove the soundness of his analytical determination of the maximum rise of pressure that would occur when the flow of water in a pipe was suddenly arrested. The casual thinker at first would imagine that—as force is equal to the product of mass by acceleration—an infinite pressure would be produced in a pipe if the water flowing in it were stopped instantaneously. On second thought, he would realize that neither the water column nor the walls of the pipe are rigid, and therefore the pressure caused by the shock of stopping the flow suddenly is relieved by the slight compression of the water and the expansion of the walls of the pipe. It was the effect of these two factors that was determined by Professor Joukovsky. He showed that the shock pressure is transmitted along the column of water in the pipe in waves similar to sound waves; and that the shock pressure is proportional to the destroyed velocity of flow and to the speed of propagation of the pressure waves. This speed depends on the compressibility of water, on the elasticity of the materials of the pipe, and on the ratio of thickness of the walls of the pipe to its diameter. In other words, if the speed of the pressure wave is known, the maximum pressure produced (called water-hammer) by instantaneously stopping water flowing in a pipe at any velocity may be calculated.

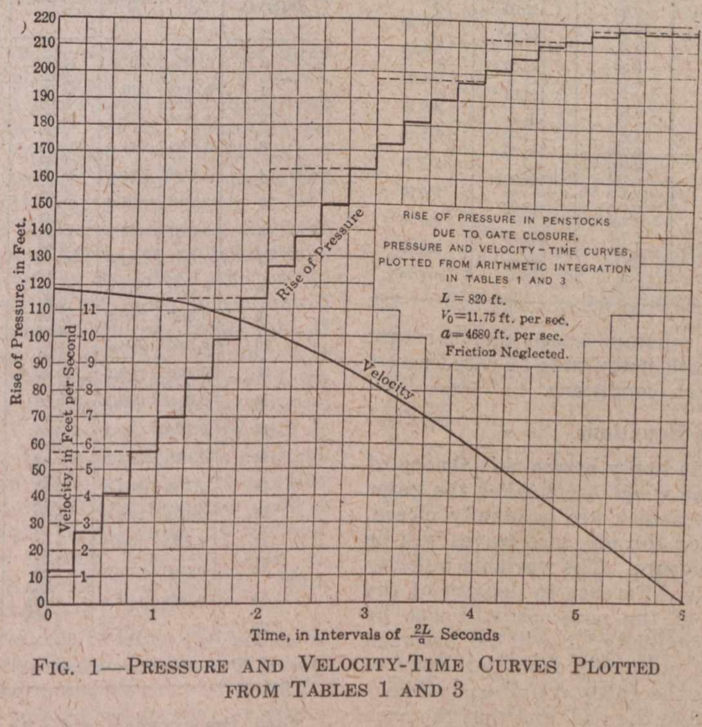


FIG. 1—PRESSURE AND VELOCITY-TIME CURVES PLOTTED FROM TABLES 1 AND 3

Joukovsky's formula for water-hammer is:—

$$h = aV/g \qquad (1)$$

where h = excess pressure, in feet;

V = velocity of flow in the pipe, in feet per second;

g = gravitational unit, in feet per second per second;

and a = velocity of the pressure wave, in feet per second, which is determined by the formula:—

$$a = 12 \div [(W/g)(1/k+d/Ee)]^{1/2} \qquad (2)$$

where W = weight of a cubic foot of water, in pounds;

k = voluminal modulus of water, in pounds per square inch;

d = diameter of pipe, in inches;

e = thickness of pipe walls, in inches;

E = modulus of elasticity of material of pipe walls, in pounds per square inch.

Joukovsky showed also that the shock pressure is transmitted along the pipe with constant intensity and "at constant velocity, which seems to be independent of the intensity of the shock."

"The speed of propagation of the pressure wave remains the same, whether the shock is caused by arresting the flow of a column of water moving in a pipe, or by suddenly changing the pressure in the column of water (flowing or standing) in any part and by any other means."

"If the water column continues flowing, such flow exerts no noticeable influence upon the shock pressure. In a pipe from which water is flowing, the pressure wave is reflected from the open end of the pipe, in the same way as from a reservoir with constant pressure."

"The phenomenon of periodical vibration of the shock pressure is completely explained by the reflection of the pressure wave from the ends of the pipe, i.e., from the gate and from the origin [of the pipe]."

(These quotations are from Miss Simin's "Water Hammer.")

Pressure waves, after travelling up the penstock to the origin or point of relief and back to the gate, are reflected and transmitted again over the same course, as waves of rarefaction or sub-normal pressure. In this manner pressure waves, alternately super-normal and sub-normal, travel up and down the penstock until damped out by friction. During the time taken by the wave to traverse its course from gate to origin the pressure at the gate remains at its full value, either super-normal or sub-normal, as the case may be.

Briefly stated, then, the premises are: that when water flowing in a pipe is suddenly arrested, certain pressure waves, the characteristics of which are known, are produced and propagated along the pipe at constant speed and constant magnitude, and that the speed and magnitude of these waves may be calculated for any given conditions.

TABLE 1—BY ARITHMETIC INTEGRATION

Data: L = 820 ft. V_0 = 11.75 ft. per sec. H_0 = 165 ft. T = 2.1 sec. a = 4,680 ft. per sec. Friction neglected.

(1) Interval.	(2) Time, t.	(3) Gate, B.	(4) Head, H.	(5) Velocity, V.	(6) 145 Δ V, Δ h.	(7) Σ (Δ h), h_t.
0	0.0000	0.91476	165.00	11.75		
		0.03811		0.085	12.32	
¼	0.0875	0.87665	177.32	11.665		12.32
		0.03811		0.095	18.78	
½	0.1750	0.83854	191.10	11.570		26.10
		0.03811		0.10	14.50	
¾	0.2625	0.80043	205.60	11.47		40.60
		0.03811		0.112	16.20	
1	0.3500	0.76232	221.80	11.358		56.80
		0.03811		0.258	37.40	
1¼	0.4375	0.72421	234.56	11.10		69.56
		0.03811		0.29	42.10	
1½	0.5250	0.68610	249.10	10.81		84.10
		0.03811		0.30	43.50	
1¾	0.6125	0.64799	263.60	10.51		98.60
		0.03811		0.33	47.80	
2	0.7000	0.60988	279.00	10.18		114.00
		0.03811		0.43	62.30	
2¼	0.7875	0.57177	291.14	9.75		126.14
		0.03811		0.47	68.20	
2½	0.8750	0.53366	302.70	9.28		137.70
		0.03811		0.48	69.60	
2¾	0 9625	0.49555	314.30	8.80		149.30
		0.03811		0.53	76.80	
3	1.0500	0.45744	327.90	8.27		162.90
		0.03811		0.58	84.00	
3¼	1 1375	0.41933	337.46	7.69		172.46
		0.03811		0.61	88.40	
3½	1.2250	0.38111	346.10	7.08		181.10
		0.03811		0.62	90.00	
3¾	1.3125	0.34300	354.90	6.46		189.90
		0 03811		0.67	97.10	
4	1.4000	0.30489	361.60	5.79		196.60
		0.03811		0.68	98.60	
4¼	1.4875	0.26678	366.60	5.11		201.64
		0 03811		0.70	101.50	
4½	1.5750	0.22867	371.10	4.41		206.10
		0.03811		0.715	103.80	
4¾	1.6625	0.19056	376.10	3.695		211.10
		0 03811		0.730	106.00	
5	1.7500	0.15245	378.30	2.965		213.30
		0.03811		0.730	106.00	
5¼	1.8375	0.11434	380.66	2.235		215.66
		0.03811		0.745	108.00	
5½	1.9250	0.07623	382.70	1.490		217.70
		0.03811		0.745	108.00	
5¾	2.0125	0.03812	381.90	0 745		216.90
				0.745	108.00	
6	2.1000	0.0	381.70	0.0		216.70

Fundamental Equations

It is the writer's intention to apply herein this theory of pressure waves to the phenomena which occur when the gates of a turbine at the end of a penstock are gradually closed. The damping effect of friction on the pressure waves will be neglected during the time of closure. The variable velocity of the pressure wave due to the difference in density of the water at the top and bottom of the penstock will also be neglected. For the sake of simplicity, it will be assumed that the gate opening is closed uniformly from full open to shut by a governor which moves the gates at uniform velocity from the beginning of its stroke to the end, and that the area of gate opening is directly proportional to the amount of gate movement. It may be stated here, parenthetically, that the resulting formulas may be modified, easily, to suit any method of gate closure, whether the speed of closing and the relation of governor movement to area of gate opening is uniform or variable.

When the gates of a turbine are closed gradually the velocity of the water in the penstock is reduced to zero and the pressure in the penstock rises. It is frequently assumed that the reduction in velocity takes place uniformly, but the rise of pressure, which commences immediately after the gates begin to move, increases the velocity of discharge through the gate opening, and, during the early part of the gate movement, tends to diminish the rate at which the flow of the water is retarded. This variable rate of retardation, during the time the gates are being closed, has an important bearing on the resulting rise of pressure, and it is necessary to take it into consideration by determining the relation between the velocity of flow and the pressure in the penstock. This relation may be expressed by the equation:—

$$V_0 = B_0(H_0)^{1/2} \quad \ldots\ldots\ldots\ldots (3)$$

where V_0 = initial velocity, in feet per second, of the water in the penstock before shut down;

H_0 = normal net head, in feet;

and B_0 = a number representing the gate opening. The value of B_0 is best determined from the known value of V_0 and H_0, but, in fact, B_0 is the ratio of the area of the penstock multiplied by $(2g)^{1/2}$ times the coefficient of discharge of the gate opening.

At any time during the closing of the gates the relation between V, B, and H would be expressed by the general formula, $V = B(H)^{1/2}$. If the gates are closed in the time, T, and t is the time from the beginning of the stroke to any time before the end of the stroke, the value of B_t (that is, B at the end of the time, t) for uniform closing, would be $(1-t/T)B_0$. During the time, t, the pressure in the penstock has risen an amount, h_t, so that the net head, H_t (that is, H at the end of the time, t) would be equal to H_0+h_t. Therefore, the expression for the value of V_t (that is V at the end of the time, t) is:

$$V_t = (1-t/T)B_0(H_0+h_t)^{1/2} \quad \ldots\ldots\ldots\ldots (4)$$

TABLE 2—BY ARITHMETIC INTEGRATION

Data: L = 6,337 ft. V_0 15,055 ft. per sec. H_0 = 1,260 ft. T = 69.5 sec. a = 3,647 ft. per sec. Friction head h_f = 81 ft.

(1) Interval.	(2) Gate,* B.	(3) Head, H.	(4) Velocity, V	(5) 113 Δ V, Δ h.	(6) Σ Δ h.	(7) 3 574 V^2, h_f.	(8) Δ h_f.	(9) Σ(Δh + Δh_f) h_t.
0	0.4211	1260.0	15.055		....	81.0	....	....
			0.155	17.5				
1	0.4168	1279.2	14.90		17.5	79.3	1.7	19.2
			0.29	32.8				
2	0.4084	1279.8	14.61		15.3	76.5	4.5	19.8
			0.28	31.7				
3	0.3995	1284.0	14.33		16.4	73.4	7.6	24.0
			0.33	37.3				
4	0.3895	1291.8	14.00		20.9	70.1	10.9	31.8
			0.37	41.8				
5	0.3784	1295.5	13.63		20.9	66.4	14.6	35.5
			0.42	47.5				
6	0.3657	1305.3	13.21		26.6	62.3	18.7	45.3
			0.49	55.4				
7	0.3513	1311.8	12.72		28.6	58.0	23.0	51.8
			0.53	59.8				
8	0.3354	1319.0	12.19		31.0	53.0	28.0	59.0
			0.60	67.8				
9	0.3180	1329.8	11.59		36.8	48.0	33.0	69.8
			0.65	73.5				
10	0.2991	1334.9	10.94		36.7	42.8	38.2	74.9
			0.72	81.3				
11	0.2781	1348.2	10.22		44.6	37.4	43.6	88.2
			0.84	94.8				
12	0.2544	1359.7	9.38		50.2	31.5	49.5	99.7
			0.92	104.0				
13	0.2285	1369.2	8.46		53.8	25.6	55.4	109.2
			0.97	109.5				
14	0.2009	1376.6	7.49		55.7	20.1	60.9	116.6
			1.07	121.0				
15	0.1719	1391.6	6.42		65.3	14.7	66.3	131.6
			1.15	130.0				
16	0.1411	1395.8	5.27		64.7	9.9	71.1	135.8
			1.21	136.8				
17	0.1083	1407.2	4.06		72.1	5.9	75.1	147.2
			1.33	150.1				
18	0.0725	1416.3	2.73		78.0	2.7	78.3	156.3
			1.365	154.2				
19	0.0368	1416.5	1.365		76.2	0.7	80.3	156.5
			1.365	154.2				
20	0.	1419.0	0.		78.0	0.	81.0	159.0

* Non-uniform gate motion.

Calculation by Arithmetic Integration

Before proceeding with the analytical determination of h_t, it will perhaps make the work clearer to show first, by a numerical example, how h_t may be obtained by the trial-and-error method of arithmetic integration. Assume that the gate, instead of being moved in a continuous uniform manner, is closed by a series of small instantaneous movements with a slight pause between each movement. Each little movement of the gate would destroy instantaneously a small part, ΔV, of the velocity, V_0, and, since this part of the velocity is destroyed instantaneously, the rise of pressure, according to Joukovsky, would be $h = a\Delta V/g$. When the first instantaneous movement has taken place, let a pause of time, t, elapse before the next movement. Then $\Delta V = V_0 - V_t$, and $h_t = a(V_0 - V_t)/g$.

By these equations and Equation (4) a numerical example may now be solved, and at the same time there will be explained other interesting phenomena caused by the closing of the gates and the pressure waves produced thereby. The analytical work may then be more readily understood.

Let $L = 820$ ft.;
$V_0 = 11.75$ ft. per sec.;
$H_0 = 165$ ft.;
$T = 2.1$ sec. (For convenience, T has been chosen an even multiple of $2L/a$).
$a = 4,680$ ft. per sec. (This value of a is chosen simply because this example was worked out by the writer for a pipe in a tunnel and concreted in. The expansion of the pipe walls, therefore, was neglected. For any condition, a may be obtained by Equation (2).

Since $V_0 = B_0(H_0)^{1/2}$, then $B_0 = 0.91476$.

Assume that the gates are closed in 24 successive instantaneous movements. The time elapsing between each movement would then be 0.0875 sec. After the first of these movements had taken place the gates would have been closed one-twenty-fourth of their opening, and the number representing the gate opening would have been reduced by one-twenty-fourth of its value, that is, 0.91476/24 = 0.038115. At each of the successive movements the value of B is reduced by the same amount, as the gate motion is assumed to be uniform. It will be necessary, however, to use more than the first three significant figures, and the work may be done on the slide-rule. In this example the recovery of the friction head in the penstock will be neglected.

From the foregoing may now be written the first three columns of Table 1, and the first line of Columns 4 and 5. The table may then be completed as follows: Assume a trial reduction in velocity, caused by the initial instantaneous movement of the gate, and set the figure down in Column 5 under the value of V_0 and subtract it from V_0, placing the difference immediately underneath. This trial figure is ΔV, and is assumed to be destroyed instantaneously by the first movement of the gate. A pressure wave, Δh, of magnitude, $a\Delta v/g = 4,680(\Delta V)/32.2 = 145\Delta V$, is therefore started up the pipe. The product of 145 ΔV is set down in Column 6 opposite ΔV. In Column 7 is recorded the algebraic sum of the value of Δh. Having obtained the figure in Column 7, it is added to the net head, $H_0 = 165$, and the sum is set down in the next line lower in Column 4. The result must now be checked, to see that $B(H)^{1/2} = V$, where B is 0.8766 and H and V have the values recorded in their respective columns opposite B. If the relation is not satisfied, a new trial value of ΔV must be chosen, and the operations repeated until a check is obtained. After trial, the initial value of ΔV was found to be 0.085. Proceeding in this way, the rise of pressure at the end of 0.35 sec. is found to be 56.80 ft. This rise has taken place in four successive jumps.

At this point it becomes necessary to trace the course of the pressure wave started up the penstock by the initial movement of the gate. This wave has a velocity of 4,680 ft. per sec., and travels at that rate toward the forebay or origin of the penstock; after arriving at the origin it is reflected and returns to the gate at the same velocity. The distance from gate to forebay and return is 1,640 ft., so that the pressure wave takes 0.35 sec. to cover this distance. On its arrival at the gate it is reflected immediately as a wave of sub-normal pressure, and commences its journey again from gate to forebay and back. At the instant the wave becomes sub-normal, however, the gate is given one of its instantaneous closing movements, causing a further reduction in the velocity of the water flowing in the penstock and the consequent rise of pressure incident thereto. Thus, at this instant, two factors have to be taken into consideration: the rise of pressure caused by the fifth little instantaneous movement of the gate and the fall in pressure caused by the change from super-normal to sub-normal of the pressure wave produced by the first or initial movement of the gate which occurred 0.35 sec. before.

By trial-and-error the velocity that has been destroyed by the fifth movement of the gate is found to be 0.258 ft. per sec., and the result is checked as follows. Multiplying 0.258 by 145, the magnitude of the resulting pressure wave is 37.4 ft., and this added to 56.80 would make the total excess pressure existing equal to 94.20 ft., were it not for the fact that the initial wave has returned to the gate and become sub-normal. The amount of the initial wave, as shown by the second line of Table 1, is 12.32, and since it not only falls to

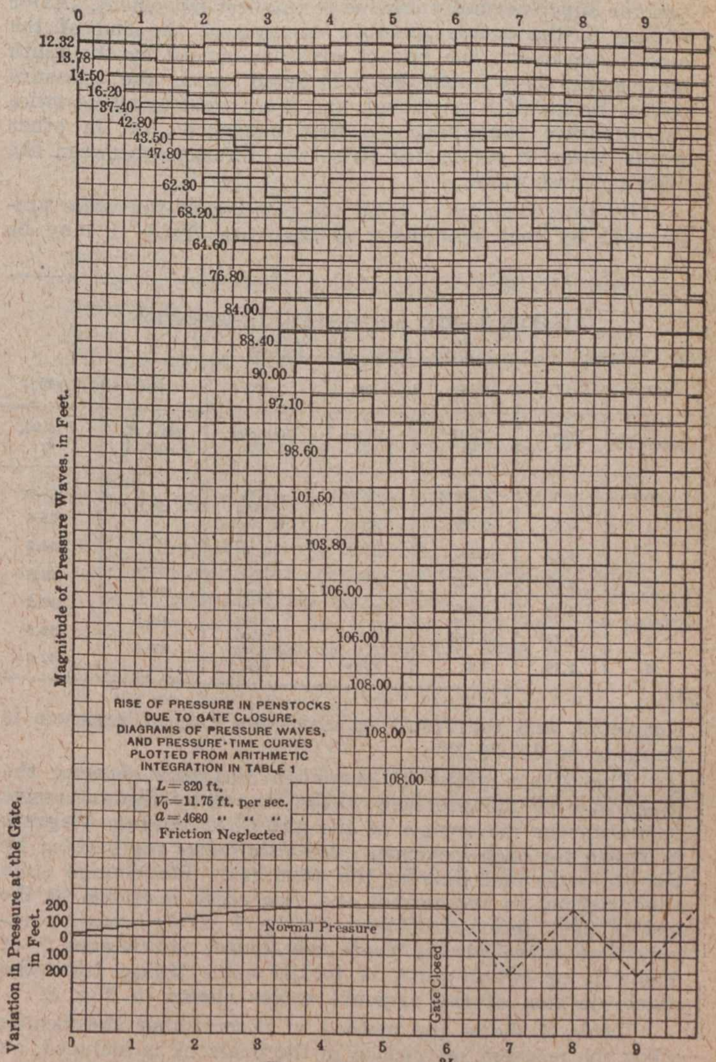


FIG. 2—DIAGRAMS OF PRESSURE WAVES AND PRESSURE-TIME CURVES PLOTTED FROM TABLE 1

zero but passes below zero to a sub-normal pressure of equal amount, there must be subtracted twice 12.32 from 94.20, making the net excess pressure existing at that instant 69.56 ft. Adding this to the initial net head $H_0 = 165$, the value of V is checked as before by the formula, $V = B(H)^{1/2}$.

Proceeding then as before, and remembering that the pressure rise caused by the sixth movement of the gate is reduced by the fall to sub-normal of the wave produced by the second movement of the gate, and the pressure rise of the seventh movement is reduced by the wave produced by the third movement, and so on, there may be calculated the successive increments of pressure.

For convenience, the time required by the pressure waves to travel from the gate to the origin of the pipe and return to the gate again will be called one interval. The interfering waves referred to in the foregoing paragraph are then always one interval apart.

After the eighth movement of the gate has taken place, it is found that the next excess pressure has reached 114.00 ft. At the instant the ninth movement takes place it must be noted that the pressure wave produced by the first movement of the gate, which has traveled, during the first interval, from the gate to the origin and back as a wave of super-normal pressure, and during the second interval over the same course as a wave of sub-normal pressure, has now returned to the gate and, again becoming super-normal, is again reflected and commences its journey from gate to origin and back. Thus, at the ninth movement of the gate, there must be taken into consideration the pressure wave caused by the instantaneous destruction of the velocity at that instant, the sub-normal wave due to the fifth movement, and the super-normal wave due to the first movement. After adding to the excess pressure existing at the end of the eighth movement, the rise of pressure caused by the ninth movement, there must be subtracted twice the pressure caused by the fifth movement, and there must be added twice the pressure caused by the first movement, or, in other words, there is subtracted twice the difference between the fifth and first waves.

By thus keeping in mind the position of the wave propagated by each movement of the gate, Table 1 may be completed, and the resulting maximum rise of pressure is found to be 217.70 ft.

TABLE 3—BY ARITHMETIC INTEGRATION
For Data, see Table 1.

(1) Interval.	(2) Time, T.	(3) Gate, B.	(4) Head, H.	(5) Velocity, V	(6) $145\ \Delta V$, Δh.	(7) $\Sigma(\Delta h)$, h_t.
0	0.0	0.91476	165.00	11.75		.....
				0.392	56.8	
1	0.35	0.762	221.8	11.358		56.8
				1.178	171.0	
2	0.70	0.608	279.2	10.18		114.2
				1.91	277.0	
3	1.05	0.457	327.8	8.27		162.8
				2.48	360.0	
4	1.40	0.304	362.20	5.79		197.2
				2.825	410.0	
5	1.75	0.1525	377.8	2.965		212.8
				2.965	430.0	
6	2.10	0.0	382.2	0.00		217.2

Fig. 2 is a series of graphical diagrams showing the magnitude of the pressure waves caused by the successive instantaneous movements of the gate. A separate diagram is drawn for each movement, pressure being represented by the ordinates and time by the abscissas. The change from super-normal to sub-normal and *vice versa* is shown at the end of each interval of time. Fig. 1 is the excess pressure-time curve plotted from the figures in Column 7 of Table 1, or, what amounts to the same thing, from the algebraic sum of the pressure waves shown in Fig. 2.

Table 2 shows the method of determining the results when the recovery of friction in the penstock is included, an example being selected where the friction head is an appreciable quantity. The operations are almost identical with those just described, up to Columns 6 and 7. To avoid reference to the foregoing, however, the formation of Table 2 will be described from the beginning. In the first line, opposite $B = 0.4241$, set down Columns 3, 4, and 7, the known values of H_0, V_0, and h_f (friction head). Next, assume a trial reduction in velocity, caused by the initial instantaneous movement of the gate, and set the figures down in Column 4 under the value of V_0, and subtract it from V_0, placing the difference immediately underneath. This trial figure is ΔV, and is assumed to be destroyed instantaneously by the first movement of the gate. A pressure wave, Δh, of magnitude $= (\Delta V)a/g = (\Delta V)3647/32.2 = 113\Delta V$, therefore, is started up the pipe. The product of 113 ΔV is set down in Column 5 opposite ΔV. In Column 6 is recorded the algebraic sum of the values of Δh. In Column 7 the total friction head, due to the velocity shown in Column 4, is set down, and, in Column 8, the friction head recovered at each operation is shown. For convenience, h_f may be made equal to FV^2, in which F is a coefficient obtained from the known values at the beginning. In the example, $F = 0.3574$. Column 9 shows the sum of the opposite items in Columns 6 and 8. Having obtained the figure in Column 9, it is added to the net head, $H_0 =$ 1,260, and the sum is set down in the next lower line in Column 3. The result must now be checked, to see that $B(H)^{1/2} = V$, where B is now 0.4168, and H and V are the values opposite. If the relation is not satisfied, a new trial value of ΔV must be chosen, and the operations repeated until a check is obtained. After trial, the initial value of ΔV was found to be 0.155. The operations for obtaining the figures on the third line are not quite the same as those just described because, after assuming the next trial value of ΔV, and multiplying it by 113, it must be remembered that the resulting pressure at the gate is reduced by the return of the first wave, which has traveled up to the forebay and back, and now changes to sub-normal and repeats the journey. The time at which the gate is given its second movement has been selected purposely to coincide with the return of the first wave. The item opposite Interval 2, in Column 6, therefore, is the difference between the first two figures in Column 5. The other operations are similar to those already described, and the resulting figures in Columns 3 and 4 are checked similarly with the value of $B = 0.4084$. The succeeding lines are filled in by the same process, always keeping in mind the return of the preceding waves, and whether they change to sub-normal or super-normal. A little study will disclose the fact that the figure in the second line of Column 6 may be obtained by subtracting the figure in the first line of Column 6 from the figure in the second line of Column 5. Similarly, the figure in the third line of Column 6 may be obtained by subtracting the figure in the second line of Column 6 from the figure in the third line of Column 5, and so on.

At this point it is interesting to repeat the trial-and-error work for the foregoing example worked out in Table 1, but using only 6 instantaneous movements of the gate instead of 24. The results are shown in Table 3, and the pressure-time curve in dotted lines in Fig. 1. From these it will be noted that the total rise of pressure is the same as that obtained by the calculations for 24 movements, and, moreover, the resulting pressure at the end of each interval is the same in both cases. Although six movements of the gate, or one movement to each interval of time, are sufficient to determine the pressure rise at the end of each interval, it requires the larger number of movements to obtain intermediate points on the pressure-time curve. If a still greater number of movements is taken, the increments in pressure rise become smaller, and, in the limit, the stepped diagrams similar to Fig. 1 would become a series of smooth curves from the beginning to the end of each interval. The diagram, however, would not necessarily form a smooth curve from the beginning to the end of the closing time, because cusps or changes of curvature at the end of each interval result from the action of the pressure waves in changing at that instant from super-normal to sub-normal or *vice versa*. When the duration of closure is short, the change of curvature in the diagram at the end of each interval is frequently very apparent; but, when the duration of closure is long, the changes of curvature in many cases cannot be detected by the eye. These changes of curvature at the end of the intervals make it difficult to formulate the integration which can so easily be performed by the trial-and-error work already explained.

It is possible, however, to obtain a series of equations, one for each interval of the closing time, that constitute a direct mathematical solution of the problem, without recourse to trial-and-error methods. The foregoing example has been explained in order that the analytical work may be more easily understood, and in order that the method of tracing the course of the pressure waves and keeping track of their periodic changes may be kept clearly in mind. More particularly, it should be borne in mind that though a formula may be written for the pressure rise in the first interval, using only the known quantities existing before the shut-down, the formulas for the pressure rise in any succeeding interval will involve, as one of the known quantities, the value of the pressure rise at the end of the preceding interval. It thus becomes necessary, when calculating the pressure rise at any time during, or at the end of, the closing of the gate, to obtain first the amount of the pressure rise at the end of each preceding interval. Moreover, if it is desired to determine the pressure rise at any time between the beginning and end of any interval—that is, at any fractional part of an interval—not only is it necessary to determine the pressure rise at the end of each preceding interval, but also the pressure rise at the same fractional part of each preceding interval. This also applies in determining the excess pressure-time curve when the duration of closure is not exactly a whole number of intervals.

Nomenclature

L = length of penstock, in feet;
a = velocity of pressure wave, in feet per second;
g = acceleration due to gravity, in feet per second per second;
$2L/a$ = one interval of time;
T = governor time, in seconds, *i.e.*, total duration of gate closure;
$T_1, T_2, T_3, \ldots T_n$ = Time at the end of the 1st, 2nd, 3rd, ... nth interval;
$t_1, t_2, t_3, \ldots t_n$ = any time during the 1st, 2nd, 3rd, ... nth interval;
n = any number of intervals; the final interval in the time, T, need not be complete;
H_0 = normal net head, in feet;
$h_1, h_2, h_3, \ldots h_n$ = excess pressure above normal, in feet, existing at the end of the 1st, 2nd, 3rd, ... nth interval, *i.e.*, at the times, $T_1, T_2, T_3, \ldots T_n$;
$h_{t_1}, h_{t_2}, h_{t_3}, \ldots h_{t_n}$ = excess pressure above normal, in feet, at any time during the 1st, 2nd, 3rd, ...nth interval, *i.e.*, at the times, $t_1, t_2, t_3, \ldots t_n$;
V_0 = initial velocity, in feet per second, of the water in the penstock before shutdown.
$V_1, V_2, V_3, \ldots V_n$ = velocity, in feet per second, of the water in the penstock at the end of the 1st, 2nd, 3rd, ... nth interval;
$V_{t_1}, V_{t_2}, V_{t_3}, \ldots V_{t_n}$ = velocity, in feet per second, of the water in the penstock at any time, $t_1, t_2, t_3, \ldots t_n$, during the 1st, 2nd, 3rd, ... nth interval;
$B_0 = V_0/(H_0)^{1/2}$ = a number representing the gate opening;
$S_{t_1} = (a/g)^2(1-t_1/T)^2B_0^2$
$S_{t_2} = (a/g)^2(1-t_2/T)^2B_0^2$
$S_{t_n} = (a/g)^2(1-t_n/T)^2B_0^2$
$C_{t_1} = (2a/g)(V_0-V_{t_1})$
$C_{t_2} = (2a/g)(V_1-V_{t_2})-C_{t_1}$
$C_{t_n} = (2a/g)(V_{n-1}-V_{t_n})-C_{t(n-1)}$
F = a friction factor such that FV^2 = total loss, in feet of head, for velocity, V
$R_0 = (a/g)V_0$
$R_{t_1} = h_1+(a/g)V_1-C_{t_1}$
$R_{t_2} = h_2+(a/g)V_2-C_{t_2}$
$R_{t(n-1)} = h_{n-1}+(a/g)V_{n-1}-C_{t(n-1)}$
$Z_1 = (a/g)^2S_{t_1}/[(a/g)^2+S_{t_1}F]$
$Z_2 = (a/g)^2S_{t_2}/[(a/g)^2+S_{t_2}F]$
$Z_n = (a/g)^2S_{t_n}/[(a/g)^2+S_{t_n}F]$.

Time is always to be measured from the beginning of the gate movement. Thus, the time, t_2, is the time from the beginning of the stroke to some time between the first and third intervals. The successive values of t_1, t_2, etc., must always be one interval apart.

First: Derivation of Formulas with Friction Neglected.—Joukovsky's formula for water-hammer, as already stated in Equation (1), is:

$$h = aV/g.$$

During slow closing of the gate, $dh = (a/g)dV$.

At the beginning of the closing time, as already stated in Equation (3),

$$V_0 = B_0(H_0)^{1/2}$$

and, in general,

$$V = B(H_0+h)^{1/2}.$$

For the first interval,

$$\int_0^{h_{t_1}} dh = (a/g)\int_{V_{t_1}}^{V_0} dV$$

where h_{t_1} = pressure rise at any time, t_1, during the first interval, and V_{t_1} = velocity at the time, t_1, during the first interval.

Integrating, then:—

$$h_{t_1} = (a/g)(V_0-V_{t_1}) \quad \ldots\ldots\ldots\ldots\ldots\ldots(5)$$

Since V_{t_1} must be proportional to the gate opening multiplied by the square root of the head, then, for uniform gate motion:—

$$V_{t_1} = (1-t_1/T)B_0(H_0+h_{t_1})^{1/2} \quad \ldots\ldots\ldots\ldots(6)$$

Substituting this value of V_{t_1} in the equation for h_{t_1}, the latter becomes:—

$$h_{t_1} = (a/g)V_0-(a/g)(1-t_1/T)B_0(H_0+h_{t_1})^{1/2}$$

For simplicity, substitute the symbol, R_0, in place of $(a/g)V_0$, and the symbol, $(S_{t_1})^{1/2}$, for $(a/g)(1-t_1/T)B_0$. Thus:—

$$h_{t_1} = R_0-[S_{t_1}(H_0+h_{t_1})]^{1/2}$$

Squaring:—

$$(h_{t_1}-R_0)^2 = S_{t_1}(H_0+h_{t_1})$$

Expanding:—

$$h_{t_1}^2-2h_{t_1}R_0+R_0^2 = S_{t_1}H_0+S_{t_1}h_{t_1}$$

Collecting:—

$$h_{t_1}^2-h_{t_1}(S_{t_1}+2R_0)+R_0^2-S_{t_1}H_0 = 0$$

Solving:—

$$h_{t_1} = \tfrac{1}{2}\{(S_{t_1}+2R_0)\pm[(S_{t_1}+2R_0)^2-4R_0^2+4S_{t_1}H_0]^{1/2}\}$$

Simplifying:

$$h_{t_1} = \tfrac{1}{2}\{(S_{t_1}+2R_0)\pm[S_{t_1}(S_{t_1}+4R_0+4H_0)]^{1/2}\} \ldots\ldots(7)$$

For the second interval, an examination of Table 1 will show that—

$$\int_0^{h_{t_2}} dh = (a/g)\int_{V_{t_2}}^{V_1} dV+h_1-2(a/g)\int_{V_{t_1}}^{V_0} dV$$

Where h_{t_2} = pressure rise at any time, t_2, during the second interval;
V_{t_2} = velocity at the time, t_2;
V_1 = velocity at the end of the first interval;
h_1 = pressure rise at the end of the first interval;
V_{t_1} = velocity at the time, t_1, which must be exactly one interval before the time, t_2.

Integrating, then:—

$$h_{t_2} = (a/g)(V_1-V_{t_2})+h_1-2(a/g)(V_0-V_{t_1}) \quad \ldots(8)$$

Substituting C_{t_1} for $2(a/g)(V_0-V_{t_1})$,

$$h_{t_2} = (a/g)(V_1-V_{t_2})+h_1-C_{t_1}$$

Again, since V_{t_2} must be proportional to the gate opening multiplied by the square root of the head, then, for uniform gate motion:—

$$V_{t_2} = (1-t_2/T)B_0(H_0+h_{t_2})^{1/2} \quad \ldots\ldots\ldots\ldots\ldots\ldots(9)$$

Substituting this value of V_{t_2} in the equation for h_{t_2}, the latter becomes

$$h_{t_2} = (a/g)V_1-(a/g)(1-t_2/T)B_0(H_0+h_{t_2})^{1/2}+h_1-C_{t_1}.$$

Substituting the symbol, R_{t_1}, in place of $(a/g)V_1+h_1-C_{t_1}$, and the symbol, $(S_{t_2})^{1/2}$, for $(a/g)(1-t_2/T)B_0$,

$$h_{t_2} = R_{t_1}-[S_{t_2}(H_0+h_{t_2})]^{1/2}$$

Squaring:—

$$(h_{t_2}-R_{t_1})^2 = S_{t_2}(H_0+h_{t_2})$$

Expanding:—

$$h_{t_2}^2-2h_{t_2}R_{t_1}+R_{t_1}^2 = S_{t_2}H_0+S_{t_2}h_{t_2}.$$

Collecting:—

$$h_{t_2}^2-h_{t_2}(S_{t_2}+2R_{t_1})+R_{t_1}^2-S_{t_2}H_0 = 0.$$

Solving:—

$$h_{t_2} = \tfrac{1}{2}\{(S_{t_2}+2R_{t_1})\pm[(S_{t_2}+2R_{t_1})^2-4R_{t_1}^2+4S_{t_2}H_0]^{1/2}\}$$

Simplifying:—

$$h_{t_2} = \tfrac{1}{2}\{(S_{t_2}+2R_{t_1})\pm[S_{t_2}(S_{t_2}+4R_{t_1}+4H_0)]^{1/2}\} \ldots(10)$$

In a similar manner, the value of h, at any time in any interval, may be found.

(Concluded in the next issue)

Hon. A. L. Sifton, who has been Minister of Customs and Inland Revenue in the Dominion Cabinet, is relinquishing that portfolio to accept the one recently surrendered by Hon. F. B. Carvell; in other words, Mr. Sifton will be Minister of Public Works. He is a lawyer, and was formerly premier of Alberta.

LARGE PORTABLE ROAD CRUSHERS

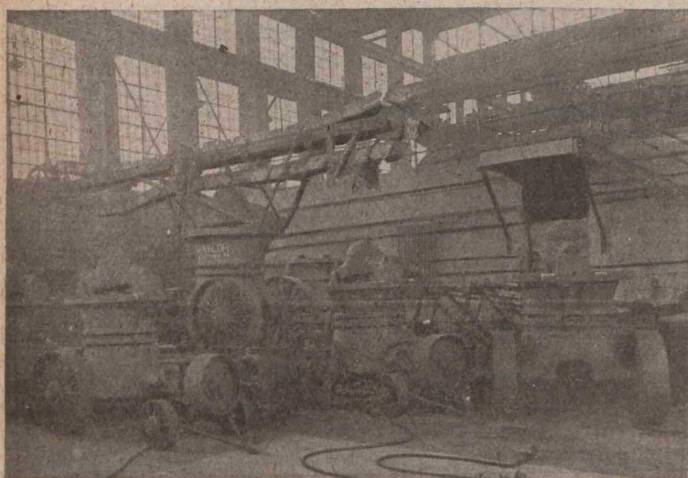
By R. R. Shafter

Engineer, Traylor Engineering & Mfg. Co., Allentown, Pa.

EIGHT portable gyratory crushers, believed to be the largest of their kind ever constructed, were built last year in the shops of the Traylor Engineering & Manufacturing Co., of Allentown, Pa., for the use of the American Expeditionary Force in road construction work in France.

The accompanying illustration shows some of these crushers in process of assembly in the Traylor shops. Each of the crushers weighs about 8 tons. They are made of cast steel practically throughout, in order to reduce the weight and increase the strength. They are capable of handling stone of "one man size" or up to 11 ins., and each crusher has a capacity of 25 tons of 2-in. stone per hour, with a power consumption of only 18 k.w.

The machines are of the "Bulldog" design, wherein the crusher-shaft is decidedly shorter than in the old type of gyratory crusher, thus decreasing the likelihood of bending or breaking the shafts.



Large Portable Crushers Partly Assembled

Each crusher is mounted on a heavy set of road wheels, with a pair of front wheels under the support or outboard bearing of the countershaft of the machine. On the end of the countershaft is supplied a pulley for driving a folding elevator, which equipment was furnished with each crusher.

This type of machine proved to be a very durable, compact and economical crusher for road and general work, and on account of the extensive road building programs now under way, the Traylor Co. is preparing to add a line of these large portable crushers to the other machines which the company carries in stock.

PROPOSES DRAINAGE CANAL FOR NIAGARA

THE problem of freeing the Niagara river from sewage pollution, which still remains unsolved, although exhaustive investigation by the International Joint Commission resulted two years ago in a plan which, by reason of its heavy cost on the cities of Buffalo, the Tonawandas and Niagara Falls, as well as La Salle village, is apparently being "side-stepped" by those municipalities, was again discussed by City Engineer T. W. Barrelly, of Tonawanda, at the National City Planning Conference, held a couple of months ago in Niagara Falls.

Mr. Barrally recited the conditions affecting the situation, and found two methods of relief. They were: First, preliminary treatment of the sewage previous to its discharge into the river; second, removal of sewage by diversion to Lake Ontario.

Discussing diversion project, Mr. Barrally dismissed the proposition of an open canal along the margin of the river on account of prohibitive cost unless it were possible to take advantage of the difference in elevation of the lakes for developing water-power. A plan to construct a marginal sewer in a deep tunnel extending from the Tonawandas to Lake Ontario was advocated by the speaker.

"In making a preliminary study of the sewage disposal problem of the Niagara frontier for the pure water committee of the Tonawanda Chamber of Commerce," he said, "I have developed a plan for a marginal sewer in a deep tunnel extending from Tonawanda to Lake Ontario. There exists at the present time the old Erie canal running along the margin of the Niagara river from Buffalo to Tonawanda, and now substantially abandoned as a canal. The new barge canal route utilizes the river from Buffalo to the mouth of the Tonawanda creek at Tonawanda. At present a part of the sewage of the city of Buffalo enters the canal, including the Hertel avenue trunk sewer.

"This canal would be utilized as a drainage canal from Buffalo to Tonawanda, where it would drop about 275 ft. into the tunnel and develop water power. A similar development may be carried out at La Salle at Cayuga creek outlet. The tunnel would be about 21 miles in length and of sufficient capacity to dilute the sewage in accordance with the standards required.

"Increased dilution is secured at intervals along the route by this project and thus ample provision made to avoid the creation of nuisance along the route or at the lake. Accurate figures of cost can be made only after extensive surveys and borings and detail designs. Assuming that the tunnel is in rock, a tunnel 20 ft. in diameter could probably be constructed for $125 per ft., or a total cost of about $13,000,000 for the tunnel. Changes at the cities to make connections with the canal and tunnel for the existing sewerage systems, and power houses, machinery, etc., would cost about $7,000,000 additional, or a total of $20,000,000 for the entire project.

Water-power Development

"Assuming a diversion of 4,000 c.f.s., representing a dilution of 4 c.f.s. for each 1,000 of population, and based on a total population of 1,000,000, a head of 275 ft., and a turbine efficiency of 80%, we get a total of 100,000 h.p.

"Distributing this over the entire cost of the project, which may be as high as $20,000,000, would give a cost of $200 per horsepower.

"Since this power may be ultimately sold under a 40% load factor and to the extent of about 200,000 h.p. on this basis, we would have $100 per horsepower delivered to consumers, for the cost of the entire project.

"Probable yearly cost for power development:—

Interest on $2,000,000 at 4½%	$ 900,000
Depreciation	200,000
Other expenditures	250,000
Sinking fund @ 4%	132,000
Total	$1,482,000

"Cost per horsepower reckoned as 24-hour, seven-day power, $14.82 per horsepower per year, or if reckoned on 11 hours per week day, or under a 40% load factor, the cost would be about $7.50.

"The full income would not, of course, be attained for several years. These figures are approximate and are only given because they indicate the financial advantages possible in comparison with a sewage treatment project.

"A large part of the profit on the investment would be indirect, resulting from the more rapid growth of the cities due to power development, and consequent employment of more men and building up of industrial communities.

"This solution is attractive because it would accomplish two most desirable things, the diversion of sewage from the river and income to carry the financial burden of the project.

"Whatever method is adopted should be undertaken under state or federal regulation. It would be possible, however, to form all the municipalities and towns within the area to be served into a sanitary district, in the same manner as was adopted at Chicago in carrying out the Chicago drainage canal project."

Objections to Arthur Young Co.'s Classification

Report to Dominion Government Fails to Group Engineering Service Along Orderly Lines and Provides Too Narrow Limits for Promotion and Inadequate Compensation—Open Letter from the Chairman of U.S. Engineering Council's Committee on Classification and Compensation

SERIOUS objections are being raised by many engineers in the employ of the Dominion government to the classification and schedule of compensation recommended to the government by Arthur Young & Co., of Chicago, Toronto and New York. These objections have been well summarized in the following open letter addressed to Alfred D. Flinn, secretary of the U.S. Engineering Council, by Arthur S. Tuttle, chairman of the Engineering Council's committee on classification and compensation of engineers:—

"From time to time within the last few weeks, you have forwarded to me various letters addressed to you concerning the proposed 'Classification of the Civil Service of Canada' as recommended by Arthur Young & Co., of Chicago, Toronto and New York. The copy of this classification, which was also received, indicates that its preparation was authorized by the Canadian parliament and that the work was done under the direction of the Civil Service Commission of Canada.

"Your correspondents offer objections to the classification, particularly on the ground that the compensations proposed for higher grades of service are inadequate. In view of the investigation now being made on behalf of Engineering Council as to the classification and compensation of engineers in federal, state, municipal and railroad service, this report is of more than usual interest, and especially so since council's committee is informed that Arthur Young & Co. are performing a similar service for the U.S. congressional committee on reclassification and compensation of government employees, including engineers.

Recommend Seven Professional Divisions

"Engineering Council's committee on classification and compensation for the state and municipal services has tentatively proposed that all positions in these services be limited to 13 in number, of which 7 are distinctly professional, while the remaining 6 are in a class directly leading to professional work, but not necessarily of a professional character.

"In the questionnaire recently issued by the committee, the views of the responsible heads of the services affected are being sought, and in the responses which have been received up to the present writing, there has been practically unanimous agreement on the classification. The inquiry has not progressed far enough to warrant any expression as to the views concerning compensation other than to say that there is an unquestionably strong belief that if the engineering service is to be maintained on a proper plane, there must be a very substantial increase in pay.

No Attempt to Standardize Titles

"The Canadian report appears to cover every position in the civil service. It is arranged alphabetically, and in the absence of grouping, a complete analysis of the engineering service involves a task of magnitude greater than I have found time for. I have attempted, however, to make such examination as time permitted, and am impressed with a belief that the objections raised are well found.

"No attempt seems to have been made (by the Canadian report) to standardize titles. Consequently there are in the engineering service at least 157 independent titles as compared with the 13 titles proposed by our committee. It is recognized that qualification of a general title to show the nature of the service rendered is quite proper, but in the judgment of the writer there is no reason for treating similar positions as entirely unrelated and as warranting entirely independent specifications.

"The report states that the compensations proposed are intended for 'normal times,' and the pending restoration of such times, the rates recommended should be 'supplemented by a bonus,' but no information appears as to the magnitude of the bonus.

"From my study of the report it would appear that the groups and ranges of compensation, tabulated as far as practicable under the classification tentatively proposed by Engineering Council's committee are about as follows:—

TABULATION OF TITLES AND SALARIES FOR ENGINEERS IN CANADIAN CIVIL SERVICE REPORT UNDER CLASSIFICATION PROPOSED BY COMMITTEE OF THE U.S. ENGINEERING COUNCIL

Tentative Classification of Positions in State and Municipal Service Proposed by Engineering Council's Committee on State and Municipal Service.	No. of Titles Provided in Proposed Canadian Classification.	Salary Range Proposed for Canadian Service. Usual. Min.	Usual. Max.	Extreme. Min.	Extreme. Max.	Qualifications Proposed for Canadian Service.
Consulting Engineer	1	$6,000	......	......	......	Professional Engineer, 12 years' experience (7 in charge).
Chief Engineer (major work)	5	6,000	......	$4,800	......	Professional Engineer, 7-12 years' experience (3 to 7 in charge).
Chief Engineer (minor work)	7	3,900	$4,800	3,600	6,000	Professional Engineer, 7-12 years' experience (3 to 7 in charge).
Chief Engineer—Deputy	8	3,900	4,800	3,600	5,700	Professional Engineer, 7-12 years' experience (3 to 7 in charge).
Engineer	37	3,300	4,020	3,000	4,500	Professional Engineer, 5-10 years' experience (2 to 5 in charge).
Senior Assistant Engineer	40	2,640	3,000	2,400	3,480	Professional Engineer, 3 years' experience (2 to 3 in charge)
Assistant Engineer	23	2,100	2,580	2,040	3,120	Professional Engineer, 3 years' experience.
Junior Assistant	15	1,680	2,040	1,680	2,160	Professional Engineer, 2 years' experience.
Senior Draftsman	..	.....	.....	Included in Professional Service.		
Draftsman	8	1,260	1,560	.....	.....	3 years' experience.
Junior Draftsman	4	900	1,200	.....	.....	2 years' experience.
Chief Instrumentman	..	.....	.....	Included in Professional Service.		
Instrumentman	5	1,260	1,560	.....	.....	3 years' experience.
Rodman	4	900	1,200	.....	.....	2 years' experience.

"In general, promotion through most of the grades is by increments of about $120, the minimum and maximum rates of each being respectively higher and lower than the rates fixed for the grades below and above, this resulting in a comparatively small salary range for each position, and in this respect corresponding with what seems to have been the general practice heretofore. This treatment is one which it would seem desirable to modify to the end that the relative ability and experience of men performing similar work may be given adequate recognition.

"Exceptions are noted in the case of 'Topographical Engineer,' where a salary range of from $2,160 to $3,120 is proposed, and in the case of promotion from 'Junior Electrical Engineer,' at a maximum salary of $1,980 to 'Electrical Engineer,' with a minimum salary of $2,640, each of the two latter grades having an extreme salary range of only $360. In the case of 'Chief Draftsman,' 'Structural Engineer,' and 'Chief Topographical Engineer' maximum salaries are proposed of $3,000, $3,240, and $3,840, with no provision for promotion to other engineering grades, although for each position the qualifications required are such as to indicate ability to progress to high positions in the service.

"The table also shows that only 6 engineering positions are open to compensation at a rate of more than $6,000 per annum.

"It would seem to the writer that this report is open to serious criticism on the grounds that it fails to group engineering service along orderly lines, that it provides too narrow limits for promotions within a grade, and that the compensation proposed for all grades, is inadequate for the service rendered. The latter criticism seems particularly pertinent in comparison with the rates now being demanded by organized labor. The practicability of properly meeting present-day conditions by the addition of a 'special war bonus' to the proposed rates in order to meet the present high cost of living is also to be questioned on the ground that, and as set forth in the circular letter issued by Council's committee on classification and compensation of state and municipal engineers, the 'revolutionary change in the cost of living' is one which 'unless modified by further economic disturbance is likely to be permanent or to continue for a long time to come.'"

MUNICIPAL BUREAU'S APPROVAL OF PLANS

Legislation Requiring Same is Recommended by the Ontario Municipal Association at Annual Meeting Held Last Week in Toronto—Other Resolutions Adopted

AT the annual meeting of the Ontario Municipal Association, held last week in Toronto, a number of resolutions were adopted, and the executive committee was requested to prepare bills, embodying the spirit of the resolutions, for presentation to the Ontario legislature. Among the resolutions were the following:—

(1)—Whereas municipalities are, from time to time, called upon to undertake municipal works which demand high-priced expert skill and experience; and whereas the financial standing of many municipalities require careful and conservative consideration when large expenditures are involved; therefore resolved,—that all by-laws, plans and specifications providing for the construction of permanent improvements and the issue of debentures therefor, should be approved by the municipal bureau.

(2)—That the legislature of Ontario, and the department of highways, be respectfully requested to enact such legislation as will provide for the standardizing and erection of danger signals on roads and highways throughout the province.

(3)—That the Dominion Railway Board provide that at points where gongs are used, or are necessary as warning at railway crossings, these said gongs be placed at both sides of the said railway crossings, on the highway, at a distance of not less than 50 ft. from the railway.

(4)—That rural municipalities be granted the power now enjoyed by urban municipalities of regulating the opening of sand and gravel pits and the removal of sand and gravel from pits already in operation.

(5)—Whereas dissatisfaction has been expressed by citizens with the present form of municipal government; and whereas more centralized control of all civic activities by one governing body is desired, either by what is commonly called commission government or by some method of co-ordinating the existing councils, boards and commissions; be it resolved that the provincial legislature be petitioned to secure a report on improvement of the present municipal government system which will best conform to Ontario ideals of government and satisfy modern demands.

EDUCATION OF HIGHWAY ENGINEERS

By Arthur H. Blanchard
Professor of Highway Engineering, University of Michigan

HIGHWAY officials, progressive educators and many prominent business men realize that a serious condition will confront the United States and Canada if graduates of our technical schools are not properly trained in highway engineering. The phenominal development of highway transport has created a demand for efficient highway improvement which can only be satisfied by placing highway work in the hands of competent engineers.

Thoroughly trained and experienced highway engineers are needed to occupy the innumerable positions connected with the administration, financing, design, construction and maintenance of the 2,500,000 miles of rural highways and the thousands of miles of streets in the municipalities of the United States and Canada in order that highways may efficiently serve economic, social, transportation, agricultural, industrial, commercial and military requirements. Highway appropriations will increase rapidly during the next five years, as is indicated by the 1919 appropriations of $500,-000,000 in the United States and a relatively large amount in Canada, for highway improvements, and a wide-spread demand for the construction of a system of 50,000 miles of national highways by the United States government under the direction of a national highway commission.

Estimates made this year by the United States Bureau of Public Roads disclosed a remarkable field of opportunity for highway engineers, as investigation showed that for federal and state highway work alone, exclusive of cities, counties and towns, there are required 122 chief executives and administrators; 360 division engineers of the federal government, division chiefs of bureaus, division chiefs of highway departments, district engineers of highway departments, etc.; 3,630 supervising engineers and chiefs of party; and 6,350 junior engineers, rodmen, chainmen, draftsmen and others.

The consensus of opinion of eminent highway engineers and educators is to the effect that highway engineers should have the broad foundation which the four-year course in civil engineering gives. The Asphalt Association takes the definite stand that as much time should be given to the essentials of highway engineers as is given to sanitary, hydraulic or railroad engineering. The association will devote its educational campaign especially to institutions where either no courses or very short courses in highway engineering are given. The Asphalt Association has found that only 25 of the 93 colleges investigated give a satisfactory fundamental training in highway engineering as a part of the civil engineering course.

The waste of millions of dollars annually in the United States will continue until the profession of highway engineering is placed on the same basis as structural, hydraulic, sanitary and other branches of civil engineering. England and France have seen the light. As a result, efficient highway engineers are retained in office, methods of construction and maintenance suitable for traffic requirements are employed, and as a consequence the public funds are wisely and economically expended.

CONCRETE RAILWAY TRACK SUPPORT

VARIOUS types of concrete track construction that have been installed on United States railways were described by A. C. Irwin, engineer of the Structural Bureau of the Portland Cement Association, in a paper recently presented before the American Concrete Institute. The following excerpts are from Mr. Irwin's paper:—

Street Car Track Construction at Anderson, S.C.—A type of track construction designed by E. R. Horton, Jr., and used in Anderson and Greenville, S.C., for street car track construction is shown in Fig. 1. This is in reality the longitudinal girder principle. The rails are embedded in the concrete and rest on a continuous plate. Rail clips and hook bolt anchors are used.

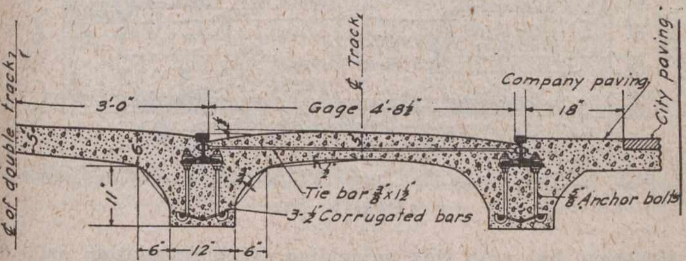


FIG. 1—CONCRETE STREET RAILWAY TRACK CONSTRUCTION AT ANDERSON, N.C.

Recent inquiry in regard to the condition of this track after four years' service indicated that the construction has been found satisfactory in every particular, that vibration has not caused deterioration of the concrete and that even the paving between the tracks is in good condition. To adapt this design to steam railroad requirements, states Mr. Irwin, it would only be necessary to deepen the girders and widen them out at the base for additional bearing area and to change the paving in between tracks to diaphragms at intervals below the base of rails.

Installation on Long Island R.R. at Jamaica, N.Y.—Examples of the type involving a concrete slab carrying ballast in which ordinary track ties are embedded is shown by Fig. 2. This construction was placed under 49 crossings, switches and slips on the Long Island R.R. at Jamaica, N.Y. The work was put in during the winter of 1912-13 on embankments composed of sand averaging 20 ft. high. Portions of the slabs were placed without allowing time for the embankment to settle and the traffic over these slabs has been extremely heavy from the day they were put in, running as high as 1,300 train movements per day. After 3½ years the general manager of the Long Island R.R., J. A. McCrea, reported that there had been practically no maintenance on the track. Mr. McCrea goes on to say that the great advantage of the slab is that the bearing surface on the natural ground is increased about three times over the usual method without taking into consideration its continuity and that examination of these experimental slabs showed that there

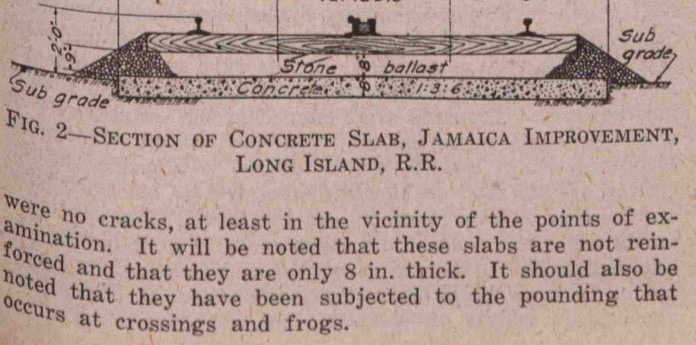


FIG. 2—SECTION OF CONCRETE SLAB, JAMAICA IMPROVEMENT, LONG ISLAND, R.R.

were no cracks, at least in the vicinity of the points of examination. It will be noted that these slabs are not reinforced and that they are only 8 in. thick. It should also be noted that they have been subjected to the pounding that occurs at crossings and frogs.

It has become very common practice to use reinforced concrete slabs to form the decks of deck girder railroad bridges. These slabs are usually about 1 ft. thick, 5 ft. long and span the distance between girders. The ballast is retained by curbs at the ends of the slabs. The testimony of railroad officials in regard to this construction is that when

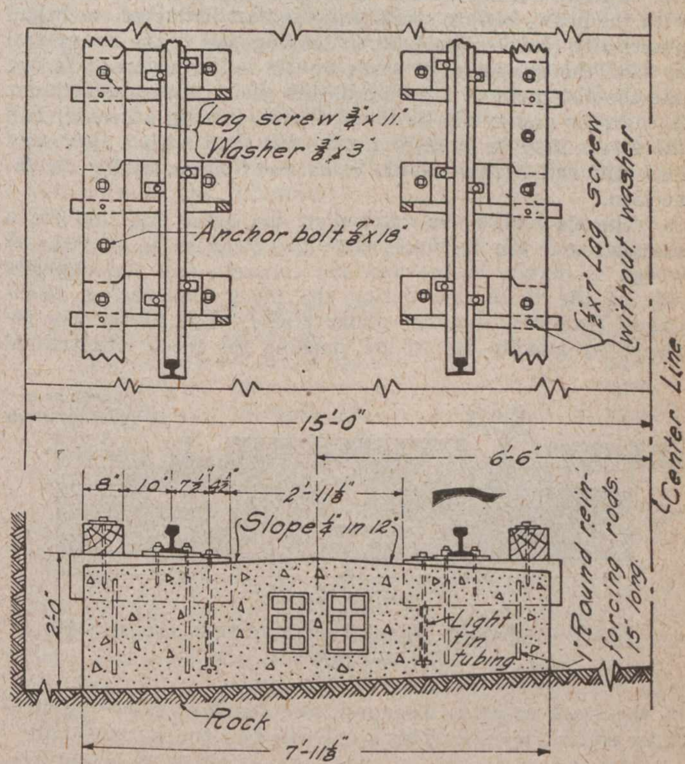


FIG. 3—CONCRETE TRACK CONSTRUCTION USED IN BERGEN HILL TUNNEL OF D.L. & W. RY.

the ties are once embedded they stay in place and that maintenance is very greatly reduced.

Bergen Hill Tunnel Tracks, Delaware, Lackawanna & Western R.R.—The new Bergen Hill Tunnel of the D., L. & W.R.R. was completed in 1909. The tracks in this tunnel are carried on reinforced concrete slabs, details of which are shown in Fig. 3. This construction was designed by Lincoln Bush, who was then chief engineer of the railroad.

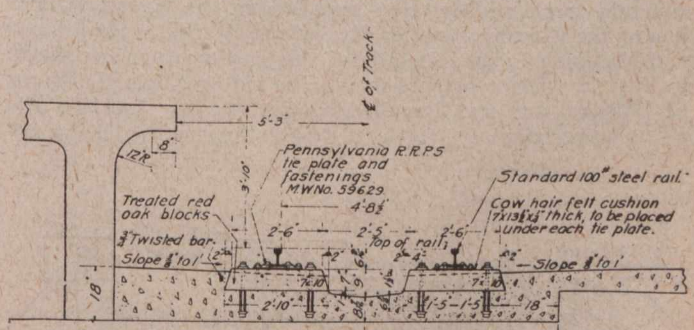


FIG. 4—CONCRETE TRACK CONSTRUCTION AT PENNSYLVANIA TERMINAL, NEW YORK

Under date of October 3, 1916, Mr. Bush reported as follows in regard to this construction:—

"It was completed and turned over for service in February, 1909. The roadbed in the new tunnel has stood up exceedingly well and none of the creosoted tie blocks have been renewed so far as I have learned on recent inquiry.

"My idea in getting out this design was that if railroad track could be made perfectly rigid and unyielding, there would be no pounding or unusual stress in rail. The roadbed in the new tunnel referred to has been in service under the heaviest kind of traffic since February, 1909, and has demonstrated fully that if track is made perfectly rigid that it will stand up against the heaviest kind of traffic.

"I am convinced that with a perfectly rigid surface there will be no pounding and serious damage in railroad track unless some defect existed such as flat wheels. Such conditions, however, are corrected when they do arise with the railroad rolling stock. I have felt for some time that with the heavy rolling stock that the best ballasted track had practically reached the limit of loading and if the heavy rail is used the supports of same on tie ballasted track is not like the abutment of a bridge as ties yield causing deflections in the rails and it will be found that even with a heavier rail the stress may be greater in the rail than with a light and less stiff rail section which lends itself more readily to deflection."

The tie blocks are notched at the outer end to form a shoulder and are in place when the concrete is poured. A wedge is driven in between the concrete and the opposite side of the block, preventing the block from being disengaged from the shoulder under traffic. The blocks are replaced by moving the wedge, pushing the block longitudinal

Fig. 5—Concrete Track Construction on Chicago Junction Ry.

of the track so as to disengage the shoulder and slipping it from under the rail. This work can be done by one man.

Track Construction in Pennsylvania R.R. Terminal Station, New York.—Fig. 4 shows the concrete track construction in use in the Pennsylvania R.R. terminal station, New York. A single track length of 14,600 ft. of this type was laid adjacent to platforms. In general the concrete was laid on the rock of the subgrade, but where the subgrade consisted of loose rock backfilling the concrete slab was reinforced. A length of 720 ft. of similar construction is in use in two of the East River tunnels (Nos. 1 and 2) immediately east of the Long Island shafts. These sections of track are subjected to high-speed traffic.

The Chicago Junction Ry. Track.—In 1911, 500 ft. of concrete track support was installed on the Campbell Ave. line of the Chicago Junction Ry., where it crosses the Illinois and Michigan Canal. Details of this construction are shown by Fig. 5. This construction is patented by Louis H. Evans, of Chicago, and was installed on the Chicago Junction Ry. as an experimental stretch of track, the location being se-

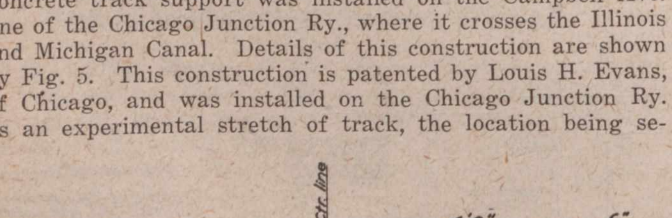


Fig. 6—Type 1 of Northern Pacific Ry. Concrete Foundation

lected with a view to subjecting it to very heavy and continuous traffic. A majority of the stock trains going to the Chicago Stock Yards pass over this concrete track. These trains are usually drawn by heavy locomotives and make more than usual freight train speed. A thorough examination of the track indicates that although transverse cracks appear in the portion of the concrete above the base of rails, these cracks do not extend down into the supporting slab. In fact, the construction seems to have suffered practically not at all from the heavy traffic which it has carried. G. W. Hegel, chief engineer, the Chicago Junction Ry., advises that there has been no maintenance on this stretch of track excepting to renew a few of the tie blocks. The tie blocks are spaced 34 in. centres. So great a spacing would not be allowed with the usual ballast and tie type of con-

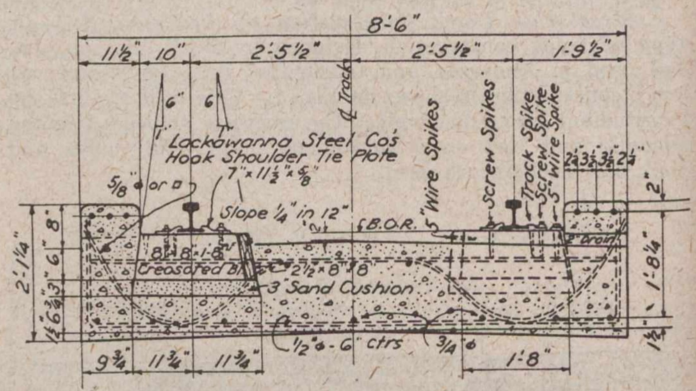


Fig. 7—Type 2 of Concrete Foundation on Northern Pacific Ry.

struction, but with this unyielding track foundation such a spacing has been found to be practicable, since the majority of the deflection in railroad track is due not to the lack of rail stiffness but rather to the lack of any sort of rigid support. Mr. Evans sums up the comparison of this construction with the usual type as follows: Weight of train distributed over 3 times the surface saves 9/10 of the ties. The cost for 20 years is one-fourth of rock ballasted track.

Northern Pacific Ry. Track.—On the Point Defiance Line of the Northern Pacific Ry., in the State of Washington, there was constructed about five years ago, 2,000 ft. of track with a concrete slab foundation. Details of the three types used are shown by Figs. 6, 7 and 8. In general, these types consist of a reinforced concrete slab provided with recesses or troughs for the reception of wood blocks or stringers to carry the rails. Details of Type No. 1 are shown by Fig. 6.

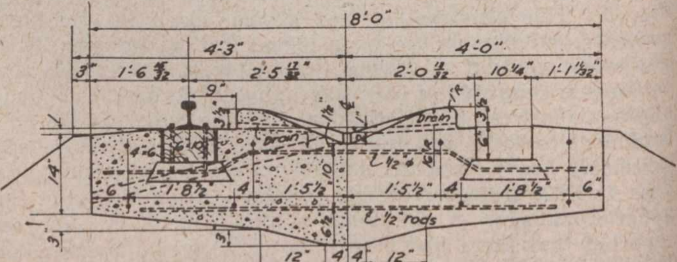


Fig. 8—Type 3 of Concrete Foundation Used on Northern Pacific Ry.

The short tie blocks rest on two longitudinal 3 by 6 pieces in the bottom of a trough at each side of the slab. The space in between tie blocks is filled with ballast. Drainage of the troughs is provided at intervals. There is a total of 594 ft. of Type 1 construction. The slabs are cast in lengths 16 ft. 5½ ins.

Type No. 2, Fig 7, is 6 ins. wider than Type No. 1 or No. 3, and is distinguished by a curb practically equal to height of rail along each side. There is also 594 ft. of single track of this type in service. In this type recesses are cast into the slab into which the tie blocks are placed and wedged into position. The rails are fastened in the usual way with tie plates and screw spikes. In the bottoms of the tie block recesses 3 ins. of sand is placed to afford a cushion. On top of this sand cushion the creosoted tie block is placed and wedged at the inner end of the block. L-shaped malleable shims are used at the other end of the tie blocks with one leg of the L resting on top of and fastened to the tie block. This allows lining and gauging of track. These slabs are cast in widths of 32 ft. 11 ins.

Type No. 3 is shown in detail on Fig. 8. The distinguishing features of this type are that the concrete is carried up 3½ ins. near the inside of each rail and sloped to centre of track for drainage, and that the rail rests directly on a continuous longitudinal stringer of 6 by 10 ins. creosoted fir. These stringers are fastened at intervals by long lag screws driven into wood anchor blocks embedded in the slab. The slabs have a depth of 18 ins. at the centre and were moulded in lengths of 16 ft. 5½ ins. There is a total of 810 ft. single track of Type 3.

While neither the first cost of the concrete track foundation on the Northern Pacific R.R nor the annual maintenance cost of it are available, yet the railroad company's officials say that the maintenance has been far below that of track of the ordinary type of construction on the same line. The greater part of this maintenance concerns the wooden blocks to which the rails are fastened, especially with Type 3. In

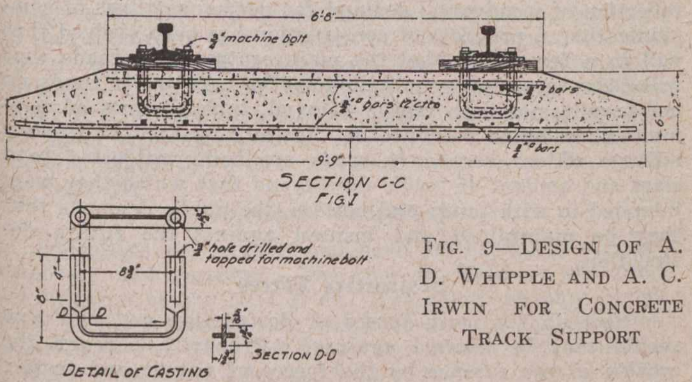


FIG. 9—DESIGN OF A. D. WHIPPLE AND A. C. IRWIN FOR CONCRETE TRACK SUPPORT

this type the key blocks out in spite of the fact that they are spiked to the tie blocks.

New Design for Concrete Track Support.—Fig. 9 shows a suggested design for concrete track support prepared by A. D. Whipple and A. C. Irwin. The form work required for this slab is of the simplest sort. The design of the slab is based on Cooper's E-60 loading with 100 per cent. impact. This design does not require any radical departure from the usual type of rail fastenings, that is, a rail clip is used similar to those now standard. There is, however, a very great difference between this rail fastening and the usual cut or screw-spike used with wooden ties. In this concrete design a U-shaped casting is embedded in the concrete and the upstanding legs of the U are tapped to receive the threaded end of holding down bolts which pass through the rail clips, tie plate and tie block. A positive fastening which has great strength against lifting the rail is thus secured. The use of a block of wood under the rail in this design is at once a concession to the prevalent idea that some elastic medium must always intervene between a track rail and a solid foundation and a means for easy adjustments of the rail both vertically and horizontally to provide for whatever inequalities may exist in the top of the slab either at the time of placing or subsequent thereto. The latter is the only sufficient reason for using this tie block, and where the slab is placed on a well compacted subgrade the rail may be anchored directly to the concrete, with possibly the intervention of a longitudinal steel plate between the rail and the concrete surface, thus affording the rail a continuous support. In the latter case drainage would be taken care of by finishing the slab to a slight pitch between the rails and furnishing openings beneath the rails at intervals.

City Commissioner Mackie, of Moose Jaw, Sask., has prepared a statement showing the operation of the Light and Power Department and the Water Works Department for the first six months of this year. The Light and Power deficit was $200.70 and the Water Works deficit, $1,444.94. At the beginning of the year Mr. Mackie had estimated that the Light and Power Department would just about pay its own way for the ensuing six months and that the Water Works deficit would be over $9,000.

FINE-GRAINED CONCRETE SANDS

By F. E. Giesecke
Professor of Architectural Engineering, University of Texas

THE engineering division of the University of Texas is planning a systematic study of sands with reference to their value in concrete construction, because we believe that there are many deposits of fine-grained sands which are generally considered too poor to be used in concrete construction and which have to be rejected under most specifications in force at the present time, but which, with proper care, might possibly be used to advantage, thereby saving considerable sums of money. We were led to this conclusion by a consideration of the following:—

We have a considerable quantity of an extremely fine-grained sand to be tested; the sand has the following sieve analysis:—

Retained on 200-mesh sieve	78.0%
Retained on 100-mesh sieve	43.0%
Retained on 65-mesh sieve	4.8%
Retained on 48-mesh sieve	3.0%
Retained on 35-mesh sieve	None

Among the current specifications for concrete sand are the following:—

(A)—Sand shall grade from fine to coarse; all shall pass the ¼-in. sieve; not more than 28% shall pass the 50-mesh sieve, and not more than 10% the 100-mesh sieve.

(B)—All sand shall pass the ¼-in. sieve; not more than 75% and not less than 40% shall pass the 20-mesh sieve; not more than 30% and not less than 2% shall pass the 50-mesh sieve; not more than 6% shall pass the 100-mesh sieve.

(C)—At seven days a 1:3 mortar should have a strength at least equal to that of Ottawa sand mortar; the sand shall be rejected if the strength is less than 70% of that of the Ottawa sand mortar.

The sand referred to would therefore have to be rejected under specifications A and B; it would also have to be rejected under specification C, because when tested in mortar it developed a tensile strength of 200 lbs. per sq. in. at seven days in a 1:3 mortar as against a strength of 293 lbs. for Ottawa sand mortar.

It may be of interest to note that this sand has a "fineness modulus" of 0.46 according to the system proposed by the Lewis Institute of Chicago, and that Bulletin No. 1, issued by the Lewis Institute in April, 1919, suggests on page 12 that "sand with a fineness modulus lower than 1.50 is undesirable as a fine aggregate in ordinary concrete mixes. Natural sands of such fineness are seldom found." So the sand also fails to meet the requirements proposed by the Lewis Institute.

In spite of the fact that the sand failed to pass any of the current specifications, concrete made with the same was fairly good, as will be seen from the following:—

The concrete was made up with a blend cement and with Colorado river gravel carefully screened and rescreened so as to contain no material finer than ¼-in., and in the following proportions:—

Blend cement	14.3%
Fine grained sand	14.3%
Gravel, ¼ to ¾ in.	35.7%
Gravel, ¾ to 1¼ ins.	35.7%
	100.0%
Water	11%

The resulting mix had a thick, flowing consistency. The following unit strengths were found at an age of 28 days in 6 by 12-in. cylinders:—

Rodded eight times, 30-minute intervals	3,420
Rodded eight times, 30-minute intervals	3,240
Rodded eight times, 30-minute intervals	3,110
Rodded only slightly just after moulds were filled	2,530
Rodded only slightly just after moulds were filled	2,500
Rodded only slightly just after moulds were filled	2,440

(By "rodding" concrete we mean pushing a pointed iron rod into the concrete to allow the excess water and the entrapped air to escape upward and to compact the aggregate. See article in the August 14th, 1919, issue of *The Canadian Engineer*, page 217.)

The above-mentioned strengths compare favorably with those of other concretes; for example:—

Compared with the Lewis Institute expression for the strength of concrete ($14,000 \div 7^{R}$), this concrete should have a strength of about 1,500; it is apparent that the three rodded specimens were about 117% stronger and the three plain specimens about 65% stronger.

Compared with the best concrete prepared in our laboratory with carefully graded Colorado river sand and gravel and with the same percentage of cement (about six sacks per cu. yd.) and thoroughly rodded, which developed a unit strength of about 4,700 lbs. per sq. in., this concrete was about 69% as strong.

Compared with concrete recently used in a reinforced concrete building, and prepared of good materials under specifications calling for a 1: 1½: 3 and a 1: 2: 4 mix, and developing the following strengths in 28 days: Plain concrete, 1,568 and 1,208 lbs. respectively; thoroughly rodded concrete, 2,293 and 2,215 lbs. respectively, this concrete is about 50% stronger.

We wish it understood in this connection that we are not advocating the use of such extremely fine sand in concrete construction, but we believe that there are many deposits of sands which are too fine to pass current specifications and yet sufficiently coarse to produce good concrete if used in the best possible manner, thereby saving considerable sums of money in concrete construction near such deposits, and that this subject deserves careful investigation.

Your attention is invited to the fact that the mix described above was about a 1: 1: 5 mix and it may not be amiss here to call attention to the common but erroneous belief that a 1: 2: 4 mix will always produce good concrete.

According to Fuller's maximum density curve, a 1: 2: 4 mix is good when the fine aggregate grades from very fine to ¼-in., and when the coarse aggregate grades from ¼-in. to 1¼ ins.; when either the fine or the coarse aggregate grades differently, a mix other than 1: 2: 4 should be used for 1: 6 concrete.

INCREASE OF RAILWAY MILEAGE SINCE 1835

THE history of railway mileage in Canada, less trackage rights, is brought to the year 1918 in the following table, taken from the report of Railway Statistics for the year ended June 30th, 1918, issued by the Department of Railways and Canals:—

Year.	Miles in operation.	Year.	Miles in operation.
1835	0	1868	2,270
1836	16	1873	3,832
1846	16	1878	6,226
1847	54	1883	9,577
1850	66	1888	12,163
1851	159	1893	15,005
1852	205	1898	16,870
1852	506	1903	18,988
1854	764	1908	22,966
1855	877	1914	30,795
1856	1,414	1915	35,578
1858	1,863	1916	37,434
1859	1,994	1917	38,604
1860	2,065	1918	38,879
1865	2,240		

T. Kennard Thomson, of New York City, who is a well-known consulting engineer and a graduate of the University of Toronto, has planned a six-track belt line railway to run around Manhattan Island, at a cost of $250,000,000. Mr. Thomson states that 200 business men are willing to finance the work at no cost to the city.

NEW STONE AND GRAVEL ROADS INSURED BY SURFACE TREATMENT

By F. H. Gilpin
Engineer, Asphalt Sales Department, The Texas Co.

EVERY form of construction dedicated to public use and comfort bears some type of insurance against its own particular agent of destruction, except those means of communication which are open to the free and unlimited use of all—our highways and by-ways. Whether it be a main artery of travel between large centres of industry, or a minor capillary sufficient for the needs of a small community, some insurance should be created to ensure to all a longer, useful life of these means of communication upon whose very existence is dependent the life, health and happiness of the inhabitants.

Particularly the minor arteries are of interest, as, in reflection of a universal demand for permanent lines of communication, a program of construction has been evolved that will in a few years bind the main centres with roads that will carry practically unlimited traffic. Available funds do not permit, nor does reason demand, that all lines of communication be so established. Already by far the greater mileage of our secondary roads are being subjected to a class and amount of traffic far beyond that which they were intended to withstand; and besides, the public demands that they be maintained and insured against the future destruction.

Destructive Forces

How do the main forces of destruction act, and how should they be insured against? Primarily, through the erosion of the surface by the forces of nature and traffic; secondarily, by the destruction of the wearing course, and finally, the destruction of the base through the same agencies aided in increasing ratio as the avenues of attack are opened. How can these agencies of destruction best be insured against? By the creation of a greater bond in the surface that at the same time renders it more tenacious, adherent, resilient and waterproof.

This is attempted in many ways: By the use of water, solutions of various chemicals, deliquescent salts, paraffine base oils, tar distillates and asphalt base oils.

What are the merits of the various means? Water obviously is temporary in character and requires repeated applications, in some cases many times daily. Deliquescent salts are dry weather remedies, and their very nature tends to wash them out in heavy rains. The same argument applies to chemical solutions. Paraffine base oils are more or less odorless and colorless but their lack of binding qualities and tendency to run off the road and be washed off by heavy rains, place them in a class useful only as temporary dust layers requiring duplication of seasonal routine.

Tar distillates are the first that come within the class that in addition to dust laying, form a waterproofing adhesive mat on the surface of the road, and, being marketed in various grades, permit of several degrees of intensity of application, both with or without prior heating.

Asphaltic Oils

Asphaltic oils permit of a wider range of surface treatment than any other type of material for this purpose. Having a minimum susceptibility to temperature change, the protective coating formed does not become brittle in cold weather nor too soft in hot, thus ensuring a waterproof, resilient surface throughout the year. Available in all grades from a light dust-laying material to the heaviest which requires both heat and pressure for application, practically any type of road from earth to new macadam can be protected against erosion and made to render a longer serviceable life to the property owner and the user.

The more open the surface of the road, the more recent the construction, the greater is the ability of the road to take a heavier surface treatment with consequent increased length of time between applications and satisfactory results. Oiling a road will not restore an eroded surface, nor will it re-establish a destroyed crown, but where the surface is not badly worn, a treatment with a hot application and clean stone screenings or slag grit will re-establish a wearing surface which will withstand moderate traffic for several years.

Don't Wait Too Long

The fact that a road is newly constructed and needs no repairs should be only an added incentive to protect the surface before the forces of destruction have full sway and put the road into such a condition that oiling of the surface preserves only the portions that remain intact, and permits the impact of heavy moving vehicles to enlarge any potholes or depressions, so that the effect of the oiling becomes nullified. The success will be no greater than that of trying to stop holes in a roof caused by dry rot or physical damage, by painting the remaining surface. The time to oil is now, before destruction starts, and repeat the treatment, according to the intensity desired, as required, successive treatments decreasing in intensity.

As in any material application, the best material applied to the purpose at hand in the most skilful and careful manner, gives the best appearance and the most lasting qualities. Oil that requires a small amount of heat to permit the most efficient operation of a pressure distributor, applied to a thoroughly clean, swept road, and covered with sufficient gravel or screenings to completely cover the surface immediately after application, has given complete protection against excessive rainfall by which untreated roads have been partially destroyed.

Objections Temporary

Objections as to odor and color of asphaltic oils are temporary and personal. The odor is slight at any time, and vanishes as the road dries. The color can only be objected to when tracked into the residences of the property-owners, and any oil (if of value as a binder), if permitted to adhere to other objects, will form a nucleous around which the objectionable particles of dirt will collect, whether the oil possesses a color or not.

At seashore or other resorts where unpleasant, personal contact with the new surface is an obvious objection, treatment early in the year would permit a finished surface to be presented during the season and would meet with the approval of all.

Where the road surface is of a material that is finely divided and does not permit of sweeping, oil containing a minimum of asphalt, lightly applied, will allay the dust for a season, though the protection against such traffic as a road so constructed should be called upon to stand is more nominal than real. The small degree of porosity and close formation of the surface prevents the absorption of any binder except such as can be carried by the lighter carrier in the oil.

As the character of the surface of the road changes so that a heavier oil can be applied, two light applications in a season permit a rapid drying of the surface and a penetration of the asphalt sufficient to reduce, to a negligible amount, the ability of traffic to pick up the oil.

HIGHWAY TRAFFIC REGULATIONS

SUGGESTED general highway traffic regulaions, accompanied by an interpretative bulletin, are now being sent out by the tens of thousands as a part of the campaign inaugurated by the U.S. Council of National Defense through its Highways Transport Committee, to the end that the number of accidents on the highways be decreased.

Police records, it is said, especially in recent months, emphasize the vital need for concerted action looking to the safety of life and limb, and intelligent study along the lines of simple and easily understood highway regulations.

The view of experts who have given the subject of traffic regulations extended study is that uniformity, especially as to the fundamentals in traffic regulation, is necessary if success in combatting this evil is to be in proportion to the need for the same.

The Council of National Defense believes it is possible, through the adoption very generally by municipalities of the suggested regulations which it is distributing to the public, to reduce to a most gratifying extent the number of accidents growing out of the rapidly increasing number of motor vehicles on the highways.

The key to the solution of the problem of how best to protect those travelling on the highways, especially in the cities and towns, both pedestrians and drivers of vehicles, says the council, is through education of the public. Once the standardization of highway traffic regulations is brought about through co-operation by authorities in the principal cities of the country, this education of the public as to the need for observation of rules laid down in these regulations, it is believed, may fairly quickly be brought about.

The regulations being distributed by the Council through its Highways Transport Committee stress the necessity for caution being exercised at crossings, roadway intersections and junctions, where most accidents occur. This caution implies extreme care on the part of drivers and constant watchfulness upon the part of both drivers and pedestrians.

MONTREAL AQUEDUCT ARBITRATION

City Must Pay $308,000 to the Cook Construction Co., Who Claimed $1,775,000—Company Is Held Responsible for the Break in the Concrete Conduit

CLAIMS aggregating $438,000 have been allowed against the city of Montreal by the award of the Board of Arbitration in the suit for $1,775,000 brought against the city by the Cook Construction Co. as damages for the cancellation of the aqueduct contract. Counter-claims to the amount of $130,000 were conceded by the board, leaving a balance of $308,000 to be paid by the city to the construction company.

The arbitrators were W. F. Tye, consulting engineer, Montreal; J. M. R. Fairbairn, chief engineer of the C.P.R.; and Aimé Geoffrion, K.C., Montreal.

The company originally claimed $1,900,000 and the city claimed $50,000, but these amounts were later reduced respectively to $1,775,000 and $412,000.

A feature of the arbitrators' judgment is that the Cook Construction Co. is held responsible for the break in the conduit, December 25th, 1913, when most of the people of Montreal were deprived of water for several days. On this account the city was awarded $81,889 as compensation for lack of precaution by the company.

In this portion of the award Mr. Tye dissented, but Messrs. Fairbairn and Geoffrion were of the opinion that the company is liable for the reason that it had been emphasized in the contract that the conduit was the sole source of water supply for the greater portion of the city of Montreal, and that extreme precaution would be required in connection with it, and that the contractor would be held responsible if he were to damage it.

Mr. Tye dissented on the ground that the city engineers had misled the company in regard to the reinforcement of the conduit, the tamping of the backfill, and the underdrain, and because the city had not informed the company of a washout that had occurred before the signing of the contract.

The largest individual item of damages awarded to the company was on account of delays. The amount claimed under this head was $600,000; the amount awarded was $215,881.

The agreement to arbitrate the differences between the company and the city was made nearly two years ago, and since then witnesses and experts galore have been called to enlighten the arbitrators regarding the responsibility for one of the biggest municipal tangles in which Montreal has ever become involved.

According to the terms of the arbitration, each party pays its own costs for legal advice and witnesses, while all other costs are equally divided.

PROBLEMS CONFRONTING MUNICIPAL ENGINEERS*

By Charles Brownridge
Borough Engineer, Birkenhead, Eng.

WITH the conclusion of the war there is much leeway to be made up, and arrears to be made good, and it is very desirable that—having regard to the altered conditions which now exist—we should closely consider how we can in future best plan and carry out our work, and what improvements in our methods we can with advantage adopt.

In work connected with the war, all branches of science were organized for one common aim, and I would express a hope that this prinicple should not be altogether abandoned, but that the system should, at least in part, be retained and continued, with its energies directed now to investigation and research for the improvement of the health and welfare of the community, and that the State should, either by direct action or generous subsidy to the laboratories of the various universities, foster and encourage experiment and research in order to ascertain the best methods and appliances to adopt to prevent and stamp out disease, and to discover new, and improve existing, materials and methods used in construction work.

The Supply of Materials

With reference to materials, we have in the past, while endeavoring to do our best with those to hand, been too content to accept the materials available. I feel sure that if the energy and ability of our chemists were directed in the right channels, they would be able to give us many improved and alternative materials suitable for our work, and devise methods to increase production and cheapen the cost of manufacturing or producing existing materials.

As engineers we would welcome the discovery of a cement having the combined merits of portland cement and bitumen, and satisfactory substitutes for wood, stone and bricks. I feel sure that, although the bricks at present manufactured are excellent, cheaper methods of manufacturing and burning could be devised.

Any and all efforts to ensure good buildings being erected and new work carried out at a reasonable cost will be to the material advantage of the State, and enable us to carry out more quickly the many and various works that are so urgently required, and so necessary in connection with our municipal work, to make our people healthy, and to keep them healthy and happy in the future.

The past has taught us many lessons from which we should now profit, and we should now, by taking a wide and generous view, so shape and design our work as to look well ahead and not only provide for the present, but have due regard to the changing conditions now existing and the consequent probable requirements of the future.

Labor Difficulties

The wave of industrial unrest now passing over the country is seriously affecting the work of our municipalities, and it will be necessary that we should carefully consider and review the position with a view to best overcoming the serious labor shortage existing, and adapting our conditions to meet the higher wages now ruling.

It is to be regretted that workmen, whilst justly and properly taking all means to assert their rights, do not in very many instances appreciate that they have in addition also their duties to themselves, their families, their work and to the State.

Good wages can always be justified if supported by good labor, but the present irregular time-keeping of many of our workmen is causing serious unnecessary difficulties and waste to arise. In my own case, I regret to say that since armistice day there has been amongst the men employed under my direction an average daily absenteeism exceeding 10 per cent., often causing necessary sanitary duties to be seriously prejudiced and affected. Unfortunately, this irregularity not only affects the work which should be done by those absenting themselves, but in many instances disorganizes and interferes with the arrangements necessary to be made in connection with all work, and causes serious loss and waste of time. If any steps can be taken to stabilize labor and make its service dependable—subject, of course, to justifiable absence owing to sickness—it would, I am sure, be welcomed by all having the charge and direction of work.

Use of Machinery Necessary

It will be necessary on financial grounds for the engineer carefully to consider what machinery and appliances can be installed to cheapen and expedite work, and to foster and further the employment of mechanical appliances for all work in which it is possible for it to be suitably and beneficially used, especially that which will tend to reduce the employment of unskilled labor, as, with the universal advance in education and learning, this branch of labor should be reduced to a minimum and its present members transferred to and trained in some branch of the arts and crafts.

The extent and character of the use of machinery in our work in future will no doubt be considerable, and its form and design offer a wide field to the ingenuity of the inventor, and, as progressive engineers, we should do all we possibly can to further its application and foster its invention. Most municipalities have already found it both economical and advisable to adopt mechanical haulage, and are considering the introduction of machines for the combined sweeping and collecting of refuse from the streets, and for excavating, filling and ramming trenches; a more extended use of mechanical mixers for concrete and tar-macadam; a more general adoption of mechanical means for lighting and extinguishing lamps and other numerous mechanical devices will be found necessary and desirable.

Institution Sparing no Efforts

The work of the municipal engineer is most wide in its scope, of a most varied character, and its duties onerous, calling for unremitting attention, care and thought, and it is therefore fitting that the Institution of Municipal and County Engineers are sparing no efforts to ensure that its younger members shall be properly educated and trained for their work, and have every facility for this purpose, and further to ensure that local authorities should only appoint properly trained engineers and surveyors at a proper and adequate salary; and, having regard to the great effect the work of the engineer and his assistants has on the prevention of disease and the comfort and health of the community, this excellent work will no doubt bear good and valuable fruit and enable the members of our profession to direct their endeavors in the most effective and productive way to carry on their duties.

*Excerpts from presidential address delivered before a Conference of Engineers and Surveyors held in connection with the Royal Sanitary Institute Congress at Newcastle-on-Tyne, Eng.

For five hours last evening, Toronto was without street car service, as 250 electrical workers of the Toronto Power Co. went on strike and stayed out until Manager R. J. Fleming wrote a letter to Mayor Church accepting, in its entirety, the report that had been made by a Board of Conciliation. The strike was unexpected and many street cars were stalled, unlighted, at street intersections.

The "Review of the Foreign Press," which has been published fortnightly for the past 2½ years by the General Staff of the War Office, London, Eng., has been discontinued, the last number appearing August 19th, 1919. Major Simnett, the editor, says: "Having regard to the cessation of war, it is obviously inappropriate that this work should be conducted under the auspices of the General Staff."

The Consolidated Iron and Steel Corporation, Ltd., has been incorporated with offices in Toronto. The company's officials state that the company owns two large deposits of iron ore lands, one of which is at mileage 182 of the Algoma Central Railway, and the other consists of 1,500 acres in the county of Leeds, Ontario, 25 miles north of Brockville. It is stated that the city of Brockville has offered inducements to the company to build a smelter there.

HIGH CONTRACT PRICES SHOULD LEAD NEITHER TO POSTPONEMENT NOR TO DAY LABOR*

IT is difficult to realize that the cost of road and street construction has doubled in five years. Consequently, when contractors bid twcie as high as in 1914, there is a strong inclination to reject all bids. In some cases this leads to postponement of the work till next year. In other cases it leads to construction by day labor. Whichever of these two courses is adopted there will be regret. Wages are rising and prices of materials show no sign of falling. Hence, contract prices are apt to be higher next year than now.

Work done by day labor is rarely done as cheaply as by contract. Usually, day labor work on roads costs fully 25% more than if done by contract; and not infrequently the cost is double. Men working for a city, county or state simply will not exert themselves as when working for an individual. The editor travels extensively, and wherever he on a day labor job. It is sophistical reasoning, but you can from a "contract gang" at sight. The typical "contract gang" shows far more energy than the typical "day labor gang."

It is frequently said that "day labor work" would always be as efficient as contract work if good managers were in charge, but this is not true. Whoever has been superintendent or foreman over construction forces, both day labor and contract gangs, knows that it is usually impracticable to get a day labor gang to work as vigorously as a contract gang.

"The State is rich. Don't break your back saving a few cents for the State." "Who put the governor in his soft job? Your votes and mine. Well, the governor appointed the commission; the commission appointed the engineers, and they appointed the foremen. So every last Jack of them owes his job to our votes. Why should we sweat more than the men who owe their jobs to us?" Such is the reasoning of the man that wields the shovel or runs the engine on a day labor job. It is sophistical reasoning, but you can no more convince him of his error than you can persuade a Hindoo that the system of caste is grossly uneconomic.

*From "Engineering and Contracting," Chicago.

ELECTRICITY AND CIVILIZATION

IN connection with the value of water powers, the "Electrical World," of New York, commenting on remarks by Dr. George Otis Smith, Director of the United States Geological Survey, states that, in the long run, the utilization of water power means the saving of human energy for purposes to which power-driven machinery is not yet adapted. The mere change from steam power to water power is not only significant of lower costs in manufacturing and of the saving of the earth's stored fuel for its more important uses, but it relieves the labor necessary in mining the coal and the still greater burden of transporting it.

Every water power harnessed and displacing steam power implies, therefore, a great band of laborers in the mine and on the railways freed from this particular necessity of toil, for other and more useful work. Now that the price of labor has risen beyond the wildest dreams of a few years ago, we are approaching an era when, wherever possible, human energy will be replaced by mechanical or electrical power.

If we are to attain a condition of production that will give us a chance of successful competition in the world's market, it must be through the most determined efforts at cheap power production and all possible saving in the field of human labor. The great power enterprises of the present day give opportunities such as have not yet been realized.—By Leo G. Denis, writing in "Conservation," published by the Commission of Conservation, Ottawa.

ADVISORY BOARD TO DOMINION HIGHWAYS BRANCH CONFERS WITH PROVINCIAL OFFICIALS

OFFICIALS from various provinces met the Advisory Board of the Highways Branch, Department of Railways and Canals, last week at Ottawa, and discussed how the $20,000,000 federal aid should be spent.

Copies of the form to be used in applying for aid, which had been prepared by A. W. Campbell, the head of the Highways Branch, were submitted to and approved by the provincial representatives, and other regulations were also discussed.

Those present from the various provinces were: Nova Scotia, Hon. H. H. Wickwire and Chief Engineer J. W. Roland; New Brunswick, Chief Engineer B. M. Hill; Ontario, W. A. McLean, Deputy Minister of Highways; Quebec, B. Michaud, Deputy Minister, and G. Henry, Chief Engineer; Manitoba, Alex. McGillivray, Chief of the Good Roads Branch; Saskatchewan, Hon. S. J. Latta, Minister of Roads, and his deputy, H. S. Carpenter; British Columbia, A. E. Forman, Chief Engineer, Public Works Department.

The advisory board, of which Hon. J. D. Reid, Minister of Railways and Canals, is chairman, is composed of C. A. Magrath, Ottawa; J. P. Mullarkey, Montreal; and R. Home Smith, Toronto.

RESULTS OF TESTS OF WIRE ROPE

IN "Technologic Paper No. 121," published by the U. S. Bureau of Standards, J. H. Griffith and J. G. Bragg present the results of tests on 275 wire ropes submitted by United States manufacturers to fulfill the specifications framed by the Isthmian Canal Commission in 1912. The samples were selected by government inspectors for acceptance tests of material to be used at the Canal Zone. The following review of the paper appears in "Mechanical Engineering," of New York:—

The ropes ranged in diameter from ¼ to 1½ in., a few being of larger diameters up to 3¼ in. Over half the specimens were plow and crucible cast-steel hoisting rope of 6 and 8 strands, 19 wires each. The remainder were galvanized steel guy rope and iron tiller ropes of 6 strands 7 wires, and 6 strands 42 wires, respectively.

The investigation was made primarily to determine the tensile strengths of the ropes. Much of the experimentation was of a supplementary character—to determine the general laws of construction of the rope as the basis of the interpretation of their physical behavior under stress. A comparative analysis was made of the chemical constituents of steel, rope fibers and lubricants of plow ropes submitted by different manufacturers.

The wires at the ends of specimens were "frayed out" to form a "broom." These were inserted into molds, into which molten zinc was poured so as to form conical sockets for connection to the testing machines. Most of the tensile tests were made on a 600,000-lbs. Olsen testing machine, the ropes of large diameters being tested on the 1,200,000-lbs. Emery machine. Stress-strain measurements were made on over half the specimens. Numerous tests of individual wires were conducted in tensile, bending and torsion machines. The strengths of the cables were studied in connection with their modes of construction, the strengths of their component wires and the types of fractures which were presented.

The homologous linear dimensions of the strands, wires and fiber cores were found to vary in direct proportion to the diameters of the ropes. The diameters of the strands and fiber cores were generally ⅓ the diameter of the rope. The mean pitch or lay of the strands was 7½ diameters. The mean lay of the wire was 2¾ diameters. The mean diameter of the wires was expressed by the equation:—

$$d = KD/(N+3)$$

where d = diameter of wires
D = diameter of rope

N = number of wires in outer ring of wires of a strand

$$K = \begin{cases} 1.0 \text{ for hoisting and guy rope} \\ 0.8 \text{ for extra flexible } 8 \times 19 \text{ hoisting rope} \\ 0.33 \text{ for tiller rope.} \end{cases}$$

The aggregate cross-sectional areas of the wires was expressed approximately by the equation:—

$$A = CD^2$$

where C = 0.41 for 6 x 19 plow steel hoisting rope
= 0.38 for 6 x 19 crucible steel hoisting rope
= 0.38 for 6 x 7 guy rope
= 0.35 for 6 x 17 plow-steel rope
= 0.26 for 6 x42 iron tiller rope.

It was found when the maximum loads determined from tensile tests were platted as functions of the diameters of the ropes that the curves bounding the lower frontiers of each zone comprising the observed values were in close agreement with similar curves platted from the minimum strength stipulated in the specifications of the Isthmian Canal Commission of 1912. These strengths were also in approximate agreement with the standard strengths recommended in 1910 by the manufacturers from the results of their tests of cables similarly classified. The minimum strengths found from the present investigation are given by the following empirical equation:—

$$\text{Load} = C \times 75{,}000 D^2$$

where D = diameter of wire rope in inches

$$C = \begin{cases} 0.9 \text{ to } 1.1 \text{ (mean about 1.0) for } 6 \times 19 \text{ plow-steel cables} \\ 0.8 \text{ to } 0.95 \text{ (mean, about 0.9) for } 8 \times 10 \text{ plow-steel and } 6 \times 19 \text{ crucible cast-steel cables.} \\ 0.3 \text{ to } 0.4 \text{ (mean, about 0.35) for iron tiller and steel guy rope} \end{cases}$$

The modulus of the rope calculated from stress-strain measurement was found to vary from 3,000,000 to 9,000,000 lbs. per sq. in., depending upon the diameter and class of cable.

Plow-steel ropes were selected for comparative analyses of the constituent materials. In the chemical analyses the carbon content ranged from 64 to 96 per cent., with a mean of about 75 per cent. The manganese ranged from 25 to 68 per cent., the silicon from 11 to 24 per cent. The percentage of phosphorus and sulphur was relatively low. In certain cases the steel of the filler wires was softer than the main wires.

The fibers used in making the core of the rope were estimated as manila, jute, istle, mauritius, manila fiber alone being employed by certain manufacturers. The preservative and lubricants on the cores were composed of wood and vegetable tars, petroleum products, and fish oil, the practice varying somewhat.

There was a reasonable uniformity in the strengths and elongations of the wires from a particular cable, but a larger variation in the strengths of the wires from cables of different manufacturers. This was probably due to the fact that different grades of plow steel were used by the several manufacturers in meeting the provisions of the specifications.

The cables developed from 72 to 90 per cent. of the aggregate strengths of the wires. The upper limit of the ratio of the strength of a rope to the strengths of its wires was found from theoretical considerations to be 89.2 per cent. for 6 x 19 plow-steel cables. The differences between the results of the theoretical analysis and the practical tests were largely attributed to different strengths and degrees of ductility of the wires, this causing an unequal distribution of the load among the strands, with over-stressing of certain strands near the point of failure.

The Civil Service Commission of Canada will receive applications not later than September 6th for the following positions at the Royal Military College, Kingston, Ont.: Professor of engineering, salary $3,480; instructor in physics, $1,800; instructor in civil engineering, $1,800. W. Foran, Ottawa, is the secretary of the commission.

TOWN PLANNING IN EASTERN CANADA*

THE Nova Scotia Town Planning Act has been amended in accordance with suggestions made by the Town Planning Branch of the Commission of Conservation. The Act formerly required that town planning schemes or by-laws had to be prepared before 1918, but the war prevented this being done. Under the amendments made the period for compulsory preparation is extended to 1921. The Act has also been widened in scope to deal with rural as with urban development. The model town planning by-laws of the province have been prepared for recommendation to the municipalities.

Nova Scotia has also passed a Housing Act to enable the province to take advantage of the federal loan. A draft housing scheme is under consideration. In the investigations made into the housing shortage in Canada and the costs of building, it has been found that conditions are worse in Halifax than in any other part of the Dominion, owing to the combined effects of exceptional prosperity and the destruction caused by the disaster of 1917.

The Halifax city and county schemes, covering large areas, are well advanced in preparation.

New Brunswick

The St. John Town Planning Scheme, dealing with over 20,000 acres, has been approved by the councils of the city and the county municipalities. This is an important achievement having regard to the novelty of many of the provisions of the scheme and the somewhat drastic changes which they introduced in local procedure. The scheme has been prepared by the City Planning Commission in consultation with the Town Planning Branch of the Commission of Conservation. The Housing Act of New Brunswick is now on the statute books and a housing scheme has been prepared by the province and approved by the federal government.

Quebec

In Quebec a Housing Act has been passed, a provincial housing scheme has been prepared and a director of housing has been appointed. The Quebec scheme conforms more strictly to the federal scheme than the schemes in any other provinces. Practically all the recommendations of the federal government have been introduced into the Quebec scheme in a mandatory form. The appointment of Dr. Nadeau as director of housing is significant of the importance which the province attaches to the promotion of housing schemes in the form of garden suburbs and with proper town planning provisions. For many years Dr. Nadeau has been an active worker for town planning and housing reform in Quebec.

Although Quebec is the only eastern province without a Town Planning Act, it has introduced town planning provisions in its housing scheme and the intention is to pass a Town Planning Act at the next session of the legislature.

Ontario

The fact that Ontario was responsible for initiating the movement for government housing in Canada and that the province has appropriated $2,000,000 of its own money to be spent in housing, has given it a start in advance of the other provinces in the matter of carrying out housing schemes. The Housing Act and scheme of the province was approved by the Federal government on February 20th last.

J. A. Ellis, an ex-mayor of Ottawa and a member of the Ontario Railway and Municipal Board, has been appointed director of housing, and is giving able leadership to the movement in the province. The director reports that 47 municipalities have already appointed housing commissions and applied for loans, and that the whole of the $10,000,000 available is already spoken for. Actual building operations have begun in Toronto. Two sites of about 40 acres in area have been acquired in the city of Ottawa and are being planned with a view to building operations being started in the immediate future.

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*From "Conservation of Life," published by the Commission of Conservation, Ottawa.

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PRINCIPAL CONTENTS

PRESSURE RISE IN PENSTOCKS

PRESSURE rise in penstocks, due to gradual gate closure, forms an important problem in hydro-electric developments, as it not only affects the design of penstocks, but also the regulation of the plant, which is of prime importance.

The article which starts on page 269 of this issue opens a new field for the investigation of this problem in regard to its effect upon regulation. Mr. Gibson has applied to slow gate closures Prof. Joukovsky's theory of maximum water-hammer, which had been proven experimentally by Prof. Joukovsky himself in regard to instantaneous gate closures. Mr. Gibson also shows the limitation of several formulas that have been in common use, such as Allievi's, Warren's and Vensano's. The accuracy of these formulas has been a source of contention among hydraulic engineers for several years, due to the assumptions upon which these formulas were based.

The solution presented by Mr. Gibson is entirely general in its application, giving correct results for any time or condition of gate closure. The method of arithmetic integration which he first uses for the solution of the problem, is worthy of special note, as many hydraulic problems that do not lend themselves to analytical solution, can be solved by this method.

Water works engineers will also be interested in this article, as frequently the cause of serious breaks in water mains can be traced to excessive pressure rise due to the sudden shut-down of a pump. It is not likely, however, that the broad application of Mr. Gibson's paper will be universally appreciated at first glance. Indeed, one of the country's leading hydraulic engineers states that it will be fifteen years before its full use is realized to the maximum. This can be readily believed when one considers that Prof. Allievi dealt analytically with this same subject fully 12 years ago in Italy, and that his paper to this day has never been translated into English in its entirety. It may be mentioned that those who are familiar with the original text of Prof. Allievi's work, state that his results coincide with those that have been secured by Mr. Gibson by an entirely different method.

AEROPLANES IN BUSINESS LIFE

PRESENT standards of business efficiency are rapidly undergoing readjustment on account of the introduction of the aeroplane to everyday business activities.

Previously, when an engineer requested samples, he thought that the firms with whom he was dealing were very prompt and efficient if his letters were answered by return post and samples mailed at once by parcels post or express. To-day, the samples are likely to arrive by aeroplane.

A few years ago, when an engineer offered plant for sale, machinery firms sent representatives by train to inspect it, and if they arrived within several days after their presence had been requested, their firms were said to be "right on their job." The modern machinery man is likely to land at your factory door in an aeroplane within a few hours after he gets your letter or telegram.

This will certainly influence the rapidity with which business will be transacted in the future. The example set by a few enterprising firms will extend, and soon hundreds of business men will learn aviation or employ aviators in order to prevent their more venturesome rivals from stealing a march in important deals. Or should we say, stealing a flight?

One alert young business man in Toronto, A. R. Roberts, a dealer in contractors' equipment, declares that he intends to use an aeroplane for business trips to all parts of Ontario, whenever the weather is suitable and the business urgent. A fortnight ago he flew from Toronto to Owen Sound to inspect a boiler in order to be able to effect its immediate purchase for a client. He left Toronto at 2 p.m., stayed in Owen Sound for 2½ hours, and was home in time for dinner at 7 p.m. The scheduled time for trains from Toronto to Owen Sound (one way) is more than five hours. Mr. Roberts began the study of aviation only a couple months ago and purely for business purposes. If he finds it worth while to go to that trouble, are not scores of returned officers, who have had extensive experience in flying at the front, likely to find that their knowledge of aviation is a real asset in peaceful pursuits?

In the United States a large manufacturer of contractors' equipment is now using an aeroplane for advertising purposes. Lt. George M. Comey, late of the A.E.F. air service, and a Curtiss biplane are engaged in distributing free copies of the "Lakewood Aerial Bulletin," a clever house organ published by the Lakewood Engineering Co., of Cleveland. The first issue contains numerous illustrations of Lakewood equipment and also a number of witty remarks, including the following:—

"These bulletins are dropped in an attempt to reach a height equal to that of the quality of the Lakewood line.

"Circulation, highest in the world. No copies delivered by mail or newsboys.

"After decreasing the weight of his plane by dropping these bulletins, Lt. Comey was still unable to reach an elevation equal to the Lakewood standard.

"Frank A. Michell, general purchasing agent of the Lakewood Engineering Co., is accompanying Lt. Comey on this trip. Mr. Michell does not intend to place any orders on the way, but, as he says, just to find out if he can see the top of the high prices."

In the last issue of "Engineering News-Record," of New York, there appeared the following interesting editorial on aeroplane passenger traffic:—

"Speculation has naturally been rife among laymen as to the probability of the early introduction of the aeroplane into regular passenger service. Its possibilities appear to be so great that one is eager to see the predicted development begin. For some time there has been regular passenger service between Paris and Brussels, while this week's cables tell of the inauguration of service between London and Paris. Those who have studied the situation account for the slowness of development on two grounds—the natural conservatism of capital in venturing into a new and untried field beset, apparently, by peculiar hazards, and the lack of suitable, centrally located landing fields. They do not believe that the dangers of aeroplane travel, when calmly considered, are a deterrent from the standpoint of the operating company, though the risks may tend to discourage prospective passengers. Aeroplane travel, of course, is not attended with the degree of safety of rail or even water travel, but the constant use of aeroplanes for transporting British diplomats between London and Paris, from the very beginning of the peace conference, shows the confidence of the British air service and British officials in this mode of travel. Safety measures are receiving careful study—parachute experiments, for example—and these will go far to remove the fears that the public now entertains. As to landing fields, a new civic and civil engineering problem enters here. The landing of passengers far out in the suburbs is naturally a handicap, even though automobiles are in waiting. In this respect, too, advances are to be looked for. Landing and starting in smaller areas than are now felt necessary will surely come. Incidentally, the success of the New York-Washington aeroplane mail service should not be forgotten. It gives warrant for the optimism of those who contend that there is no physical reason why a New York-Chicago passenger aeroplane service should not be in operation."

PERSONALS

CAPT. BRUCE ALDRICH, who has been appointed as the Asphalt Association's district engineer for Canada, was born in London, Eng. He was brought to Canada at an early age and received his primary education in the public schools of Ottawa, returning later to England for further study. Again leaving England, Capt. Aldrich went to the United States and served as a volunteer in the United States army in the Spanish-American and Phillipine wars. In 1901, he joined the staff of the inspector of asphalts and cements, engineer department, District of Columbia, where he served until February, 1912, in various capacities, testing paving materials under Prof. A. W. Dow, of New York City. In March, 1912, he went to Baltimore, Md., which was then undertaking the biggest paving program in the history of that city, with expenditures aggregating nearly $15,000,000. Capt. Aldrich organized and equipped the municipal laboratory, in which were tested all the materials entering into the new paving. As inspector of asphalts he supervised the laying of more than 3,000,000 sq. yds. of sheet asphalt and bituminous concrete, having at times as many as seven asphalt plants working simultaneously. He assisted also in the inspection and construction of all vitrified brick and concrete block pavements laid in Baltimore. When the United States declared war upon Germany, Capt. Aldrich volunteered in an infantry battalion and served at the front for one year with the rank of captain. He returned to the United States last June and resumed his Baltimore position, which he has now resigned in order to accept the appointment with the Asphalt Association. The head office of the Asphalt Association is at 15 Maiden Lane, New York City. With the staff at that office, Capt. Aldrich will be in close touch, but his personal headquarters will be in Toronto. On account of the present crowded condition of office space in Toronto, he will make his headquarters at the office of the H. K. McCann Co., 56 Church St., until he can find suitable offices. It is his intention to co-operate gratuitously in every way possible with municipal officials, consulting engineers and others in obtaining the best results in the construction of asphaltic pavements of all types. His work will be impartially in the interests of all asphalt producers and his services will be equally available whatever kind or brand of asphalt may be used in the construction.

C. A. LOUNT, superintendent of water works at Cornwall, Ont., has placed his resignation in the hands of the town council.

IVAN WALKER has been appointed chief engineer of the Kitchener Water Commission to succeed his father, who has resigned.

WILLIS CHIPMAN, who designed the William Head Quarantine Station's water works system, at Victoria, B.C., recently visited that city for the purpose of testing the plant.

J. I. NEWELL, electrical superintendent, British Columbia Electric Railway, Vancouver, B.C., has taken over the hydroelectric engineer's duties, succeeding F. S. Easton, who resigned to join the Mexican Light & Power Co.

MAJOR CECIL EWART, formerly of the 8th Battalion, Canadian Railway Troops, is now engaged in locating a line from the Pacific Great Eastern Railway at Clinton, B.C., to Ashcroft, B.C., for the Department of Railways of British Columbia, of which department F. C. Gamble is chief engineer.

GEO. H. BRYSON, city engineer of Brockville, Ont., intends to resign in order to become manager of the Brockville Highway Construction Co. Mr. Bryson is financially interested in this company, which has just secured a large contract for penetration bituminous road construction for the province of Ontario.

CAPT. LUCIUS A. FRITZE has become associated with the technical staff of Wallace & Tiernan Co., Inc., of New York City, manufacturers of chlorine control apparatus. Capt. Fritze, who was sanitary officer of the Rainbow Division, U.S. Army, after the armistice, was assigned to the office of the Surgeon-General in Washington, and while there prepared a history of the Sanitary Corps of the A.E.F. Capt. Fritze will be the manager of a new office which Wallace & Tiernan Co. are opening at Kansas City, Mo.

OBITUARY

THEODORE COOPER, one of the continent's leading bridge engineers, died August 24th, in New York City, at the age of 80 years. He began private practice in 1879. His name became universally familiar through his system of locomotive and train loadings for bridge design. Composed of a wheel system representing the heaviest locomotives of that time, followed by a uniform load whose amount in pounds per foot bore a simple relation to the driving-axle load, this system proved so convenient, and was so excellently adapted to modification for increasing weight of trains and engines by simple multiplication, that it quickly won a commanding position, and for many years has been the almost universal standard for railway-bridge design. Mr. Cooper was born at Cooper Plains, N.Y., and was a graduate of Rensselaer Polytechnic Institute.