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HOW THE STRENGTH OF WOOD IS TESTED IN CONSTRUCTION

A STUDY OF THE PROPERTIES OF THE VARIOUS KINDS IN USE—EFFECT OF MOISTURE CONTENT UPON STRENGTH—CONDITIONS AND NATURE OF TESTS — STRENGTH OF CANADIAN SPECIES

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FROM time immemorial, wood has been used for construction purposes more than any other material, yet it is a curious fact that our information regarding its strength is not nearly so complete as in the case of steel, cement and other materials which have come into use in comparatively recent times. For a few kinds of wood our knowledge of their strength is fairly satisfactory, for a number of others it is still rather vague, whilst for the great majority of them it is almost a negligible quantity.

Selection of Material.—Every wood-worker knows that great variations occur in the appearance, weight, hardness and strength of any given kind of wood. For example, heartwood differs from sapwood, body-wood from limb-wood, butt logs from top logs, etc., etc., and it is therefore a matter of great importance to know the origin of the material being tested and the conditions under which it was grown. A piece of wood is not simply a material but a *structure*, just as much as a railroad bridge or a balloon frame, and as such varies greatly even in wood from different parts of the same tree. The fact of the matter is that it is almost impossible to understand the behavior of the material being tested without a somewhat intimate knowledge of its internal structure, because the size, character and arrangement of the tiny fibres composing it have a very important bearing upon its behavior when subjected to external forces. This is well illustrated in the case of weight, strength and hardness, which are closely related to the thickness of the cell walls. Unlike metals and artificial products with a homogeneous structure, such as steel and cement, wood is an exceedingly complex and heterogeneous structure, and it is therefore necessary to consider separately the stresses applied to it and the resultant strains.

Methods of Testing.—The strength of a piece of wood may be tested for: Elasticity; cross-breaking strength; endwise crushing strength; crushing strength across the grain; shearing strength; hardness; tension along the grain; or, torsional strength.

So far, most of the studies conducted have been for the determination of elasticity, cross-breaking strength, and endwise compression strength, whilst crushing strength across the grain, shearing strength, hardness, etc., have received comparatively little attention.

Whilst the various tests are made separately, it is, of course, evident that the fitness of wood for a given purpose depends upon a combination of several qualities. For example, railroad ties must be hard enough to resist mechanical abrasion, strong enough not to break and tough enough to prevent splitting and to hold spikes; a wagon spoke must be stiff, strong, hard, resilient and tough; furniture wood should be hard enough to resist indention, take a good polish, etc., etc.

Importance of Knowing Moisture Content.—One reason for dry wood being so much stronger than green material is due to the increased number of woody fibres to the square inch as the material seasons, and it is worthy of note that this increase in strength does not become apparent until the percentage of moisture falls below 40% of its kiln dry weight. The explanation of this lies in the fact that for more than 40% of moisture the water fills not only the cell walls but also the cell cavities themselves. As the weakening effect comes only from the wetting of the cell walls, it therefore follows that after they are fully saturated, any excess of water which occupies the cell cavity would be inoperative. Consequently, no increase in strength is noticeable until the cell walls themselves begin to dry out—after which the increase in strength takes place very rapidly, and becomes approximately two and one-half times that of the wood as it comes from the tree, as shown by the following figures (Table I.) by Tiemann:—

It should be clearly understood that the percentage of moisture is always calculated upon the weight of the wood when absolutely dry.

TABLE I.

	Bending Strength,		Endwise Crushing Strength,	
	12% Moisture.	3½% Moisture.	12% Moisture.	3½% Moisture.
Long leaf pine	1.5	2.5	1.7	2.9
Red spruce	1.9	2.8	2.4	3.7
Chestnut	1.6	2.1	1.8	2.8

Much of the pioneer work in testing the strength of wood is unreliable because sufficient care was not exercised in determining either the percentage of moisture present in the test pieces or their physical structure, both of which have a most important bearing upon the strength of wood. In fact it is only recently that these sources of weakness or strength have been studied exhaustively, and even yet an enormous amount of work remains to be done before our knowledge of the subject has been placed upon a satisfactory basis.

Previous to 1896 Johnson's figures for the strength of timber were based upon the assumption that it contained 15% moisture, but since then they are given for wood containing 12% moisture; as representing the condition of well-seasoned wood. In a dry-heated building the moisture content often falls as low as 8% or 10%.

Testing Laboratories.—In Europe many tests have been made by Bauschinger, Laslett, Tetmayer, Julius, Barlow, Tredgold, Warren, H. D. Smith and C. Graham Smith; whilst in the United States of North America the strength of several commercial species has been investigated by Johnson, Sharpels, Lanza, Tiemann, Thurston, Trautwine, Unwin and others. Unfortunately, however, the methods of testing and the varying percentages of moisture present in the specimens used have varied so much that it is impossible to reduce the results obtained by a number of these investigators to a satisfactory basis for comparison.

This whole subject of the strength of wood is of such importance to engineers and builders that in recent years the United States Forest Service has established wood-testing laboratories at Washington, D.C.; New Haven, Conn.; Madison, Wis.; Seattle, Wash., and a number of other places where the leading commercial species of the region are being investigated according to a uniform plan. From time to time, the results obtained are published in bulletins and circulars which may be obtained from the Superintendent of Documents, Washington, D.C., for a merely nominal charge.

Elasticity.—Elasticity refers to the ability of a horizontal beam of given dimensions to recover from a given amount of deflection, or "sag," when the force which has produced the deflection is removed, and is therefore closely related to stiffness. Obviously, pressure applied transversely to a beam of wood has a tendency to break the fibres across, and in modern testing machines is applied gradually to a system of levers by means of small weights or hydraulic pressure, and the force exerted upon the specimen is indicated by a delicately adjusted steel-yard. To avoid shearing along the grain the length of the beam should be ten to twenty times its depth, and to minimize the amount of crushing across the grain-bearing plates of the same width as the beam are used. The distance to which the middle point of the beam is forced down is termed its "deflection," and may be indicated by means of the letter d; the readings being taken to hundredths of an inch for large beams and to thousandths of an inch for smaller ones. For solid rectangular beams repeated tests have shown that the "modulus" or measure of elasticity varies directly as the pressure applied at their centre and the cube of the distance between the points of support, and inversely as their breadth and the cube of their depth. This explains the common practice of setting flooring joists on edge, which enormously stiffens the whole structure. For example, if the joists consist of 2 x 10-inch material, then setting them on edge and placing diagonal braces between them to keep them in position gives a floor $\frac{2}{10}$ of $\left(\frac{10}{2}\right)^3 = 25$ times as stiff as if they were laid flatwise. In practical engineering the load acts continuously and it has been found that the deflection for wooden beams should not exceed $\frac{1}{480}$ of their length; which would amount to only half an inch for a 20-foot beam.

Stress Diagrams.—When the deflections, in inches, are plotted on the horizontal axis of a sheet of cross-section paper and the number of pounds pressure required to produce these deflections are plotted on the vertical axis, it is found that the series of points obtained gives us a curve which is practically a straight line up to a point known as the "elastic limit"; beyond which it still continues to rise but soon curves away from the straight line to another point known as the "maximum load." After this it descends gradually because of the failure of the piece being tested, as is well shown in the accompanying diagram (Fig. 1) for a piece of fairly straight-grained red spruce having a span of 14 feet between the roller bearings and measuring 6 inches in width and 8 inches in height. From the diagram it will be noticed that the

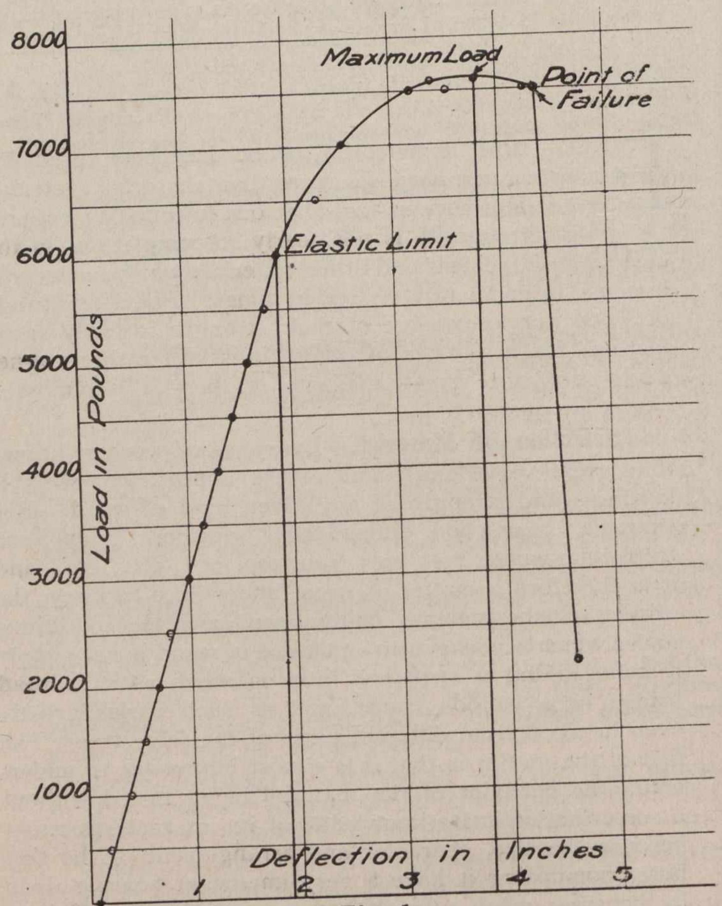

Fig. 1.

elastic limit was reached under a strain of 6,000 pounds and the maximum load at 7,580 pounds. Disks cut from the beam near the point of failure and dried in a steam-heated copper kiln showed moisture content of 25%, 33% and 42; according to the distance they were taken from the surface.

Modulus of Elasticity.—From the reading obtained at the elastic limit, the deflection observed at that pressure and the dimensions of the piece tested we may calculate what is known as the "modulus of elasticity" by means of the formula

$$E = \frac{w\,l^3}{4\,d\,b\,h^3}$$

where w represents the pressure in pounds midway between supports, d the deflection or "sag" in inches, l the number of inches between the horizontal supports, and b and h the breadth and height of the beam, in inches. Any five of these quantities being known it is an easy matter to calculate the sixth. For example, in the case of our red spruce beam, 6,000 pounds pressure produced a deflection of 1.9 inches, whence we have

$$E = \frac{6{,}000 \times 168 \times 168 \times 168}{4 \times 1.9 \times 6 \times 8 \times 8 \times 8}, = 1{,}244{,}842.$$

Conversely, if we know the value of E and wish to calculate what weight will produce a sag of 2 inches in a red spruce beam similar to the one tested, but six inches square and having a span of ten feet, then we have the equation

$$1{,}244{,}842 = \frac{w \times 120 \times 120 \times 120}{4 \times 2 \times 6 \times 6 \times 6 \times 6}, \text{ whence } w = 7{,}469 \text{ lbs.}$$

Cross-breaking Strength.—When forced beyond the elastic limit the piece being tested acquires a permanent set and finally breaks at what is known as the "point of failure," or "maximum load." When this occurs the "modulus of rupture" is calculated by means of the formula $R = \frac{3\,W\,l}{2\,b\,h^2}$, which in the case of our red spruce beam gives us $R = \frac{3 \times 7{,}580{,}168}{2 \times 6 \times 8 \times 8} = 4{,}974.$

For bending tests of this kind the early experimenters used small pieces because of the difficulty in holding and bringing strains to bear upon larger ones. Bauschinger used beams 20 inches square and nine feet long with 98.4 inches between their supports. At the Massachussetts Institute of Technology, Lanza used beams varying from four to twenty feet long, from 2 to 6 inches in width and from 2 to 12 inches in depth. In Johnson's work on large beams, smaller pieces (measuring 4 inches square) were cut from the large ones as soon as they failed and were then tested to see whether the same *moduli* would apply, and this was found to be the case *whenever similar conditions existed.*

Many Tests Required.—On account of the great variations that occur in the weight of any kind of wood, the proportion of heartwood to sapwood, differences in minute structure due to different conditions of growth or of wood taken from different parts of the same tree, and the enormous variations that may occur in the moisture content of the test pieces, it is evident that reliable figures on the strength of wood must be based upon the average of a large number of tests. The following figures (Table II), for the cross-breaking strength of woods containing 12 per cent. moisture, show a wide range.

TABLE II.

Species.	No. of tests.	Highest single test.	Lowest single test.	Average of all tests.
Pignut hickory ...	30	25,000	11,000	18,700
Shagbark hickory .	187	23,300	5,700	16,000
White oak	218	20,300	5,700	13,100
Red oak	57	16,500	5,700	11,400
Red pine	95	12,900	3,100	9,100
White pine	120	11,800	4,600	7,900
White cedar	87	9,100	3,500	6,300

Effect of Permanent Loads.—Thurston experimented on small wooden beams one inch square and four feet long for the purpose of determining the effect of permanent loads on their strength as compared with the results obtained with testing machines, and found that 60 per cent. of the breaking load in the machine would break the beams if the load was left on them for nine months time. Later on Johnson experimented with well-seasoned wooden columns and came to the conclusion that "The ultimate strength of wooden columns is only about one-half the utilimate strength of those same columns as determined by a testing machine."

Endwise Compression.—The failure of a piece of wood under pressure along the grain is a very complex phenomenon. At first the fibres act like a number of hollow columns firmly bound together, but as the load becomes too great they tear apart and act as a number of independent pieces and finally bend over when the piece fails. In all test pieces it is advisable to have the length less than 15 times the least diameter, else they are liable to fail by bending sideways before the full load they are capable of sustaining is reached. A number of tests of West Australian timber showed that 60 per cent. of the columns having a ratio of 18 to 1 failed in this way, and every builder is familiar with the common practice of bracing the studding in a wall to prevent the failure of the upright pieces by sidewise flexure. The endwise compression strength of wood is given in pounds per square inch, and is read directly from the testing machine. Johnson says that the result of over 40,000 tests shows that 55 per cent. of the results fall within 10 per cent. of the general average and that 90 per cent. of them fall within 25 per cent. of the general average. This is a greater range of variation in strength than is usually found in other kinds of building material, and is partly due to variations in the structure of the wood itself. The following figures (Table III), illustrates some of the variations that occur.

TABLE III.

Endwise Compression, in Pounds Per Square Inch.

(For 12% moisture).

Kind of wood.	No. of tests.	Highest single test.	Lowest single test.	Average of all tests.
Pignut hickory ..	30	13,000	8,700	10,900
Shagbark hickory .	137	13,700	5,800	9,500
White oak	218	12,500	5,100	8,500
Red oak	57	9,700	5,400	7,200
Red pine	100	8,200	4,300	6,700
White pine	130	8,500	3,200	5,400

In spite of the complex nature of woody structures it is rather a surprise to learn that properly designed wooden columns will support a greater load than an equal weight of cast-iron or steel of similar proportions.

Crushing Strength Across the Grain.—A timber column is frequently designed for its maximum load and is then set on a sill of the same wood without knowing that the crushing strength across the grain is very much less than it is in the endwise direction. Many failures of timber structures are due to this cause alone. For very heavy loads, it is therefore, advisable to use caps and sill pieces to distribute the load and thus prevent crushing across the grain as much as possible. The crushing takes place layer by layer and woods with thin-walled fibres, like pine and spruce, give way sooner than those with thicker walls, such as oak and hickory. Furthermore, in woods containing large pith rays, like oak and sycamore, the crushing strength in the radial or "edge-grain" direction is greater than in the tangential or "slash-grain" direction. Naturally the greater the percentage of moisture present the more easily the wood crushes, as is well illustrated in Table IV.

TABLE IV.

Kind of wood.	Percentage moisture.	Pounds per square inch.	Percentage moisture.	Pounds per square inch.
Shagbark hickory	58	1,080	9.8	2,717
Sugar maple	56	870	12.5	1,755
White oak	78	1,004	11.4	1,685
Rock elm	46	696	11.2	1,603
Yellow birch	72	439	10.5	1,340
Black oak	80	802	11.4	1,246
White ash	47	801	11.2	1,292
Beech	61	605	13.0	1,185
Red oak	80	807	11.9	1,100
Tamarack	52	480	11.0	1,080
Red pine	54	358	12.5	833
Western yellow pine ..	125	326	9.7	805
Lodgepole pine	46	364	11.0	779
Douglas fir	32	427	12.0	744
White pine	75	314	9.9	757
Eastern hemlock	129	420	9.5	726
Red spruce	31	322	12.9	531
White spruce	41	262	12.6	455
White cedar	55	288	11.2	389

Shearing With the Grain.—Shearing strength refers to the force required to push a piece of wood in the direction in which its fibres run, and has its practical application in the strains exerted on mortise and tenon structures. The lighter conifers and hard woods shear more easily than the heavier kinds, and the best of pine from one-third to one-half as easily as hickory or oak. Surfaces parallel to the annual rings shear more easily than those parallel to the pith rays and green wood about one-third as easily as dry wood. Table V. shows the shearing strength of ten well known woods which have been kiln dried and contain specified percetages of moisture.

TABLE V.

Kind of wood.	Percentage of moisture.	Shearing force (pounds per square inch).
Shagbark hickory	9.6	2,290
Bitternut hickory	9.7	2,048
White oak	12.1	2,165
Black oak	11.6	2,005
Red oak	11.2	1,845
White ash	10.8	1,522
White elm	10.8	1,447
Red pine	12.5	1,262
White pine	9.9	1,072
White cedar	11.2	902

Hardness.—From the carpenter's point of view, hardness refers to the resistance of the fibre of wood to axe, saw, chisel or plane, and will depend upon such factors as density, moisture content, etc. Wide rings in oak and narrow rings in pine increase the hardness; heartwood is harder than sapwood; and, dry wood is harder than green wood—excepting willow and poplar. The static test for hardness used to be to note the number of pounds pressure per square inch required to force a square die into the wood to a depth of one-twentieth of an inch, but as this included shearing across the grain for two edges of the die and shearing along the grain for the other two edges the method now adopted is to record the number of pounds pressure required to force a steel ball .444 inches in diameter into the wood a distance equal to half its own diameter. Such tests show that wood is harder in an endwise direction than it is across the grain. Partly for this reason, but mainly because the endwise crushing strength of wood is much greater than its crushing strength across the grain, it is customary to set paving blocks on end.

Table VI., for the hardness of 16 well-known woods, exhibits, in a rather striking manner, how very much harder any kind of well-seasoned wood is than the same material as it came from the tree.

TABLE VI.

Kind of wood.	Percentage moisture.	Pounds pressure required to imbed a .444 inch ball to ½ its own diameter. Endwise.	Sidewise.
White oak	62	1,087	1,048
	12.8	1,520	1,487
Sugar maple	57	992	910
	10.3	1,942	1,346
Yellow birch	72	827	754
	10.3	1,542	1,280
Rock elm	46	954	888
	11.2	1,593	1,257
Beech	61	1,012	908
	13.1	1,463	1,217
Black oak	80	847	795
	11.4	1,598	1,208
Black ash	77	566	544
	11.6	1,101	792
Tamarack	52	401	375
	11	725	636
Douglas fir	32	415	406
	12	723	616
Red pine	54	355	342
	12.5	696	596
Red spruce	12.9	648	510
White spruce	12.6	526	494
Lodgepole pine	44	288	312
	11	503	533
White pine	74	304	296
	9.9	611	469
Western yellow pine	98	310	314
	11.6	546	408
White cedar	55	321	226
	11.2	466	338

Tension Along the Grain.—The tensile strength of straight-grained wood is very high and hard to measure because of the difficulty of preventing the ends of the test pieces from slipping in the shackles of the testing machine. However, it is not often that a wooden beam is used for a tie bar. For rock elm the tensile strength along the grain is approximately 28,000 pounds, or 3.8 times its endwise crushing strength; for shagbark hickory 32,000 pounds, a ratio of 3.4; for tamarack 19,400, or 2.5; and for long-leaf pine 17,300, or a ratio of 2.2 to 1. Hence, in a general way, we may say the tensile strength of the tougher woods is approximately three times their endwise compression strength.

The tests of most interest to the architect and the engineer are those for cross-bending, crushing and shearing. Long before the timber would give way in tensile strength the bolts or connections would shear through the ends of the timber, and for this reason it is customary to place them at least three or four inches from the ends of the beam required to bear tensile stress.

Torsional Strength.—The torsional strength of wood refers to the ability of its fibres to withstand twisting and is measured by securely fastening one end of the rod at one end of a lathe and clamping the other end in a wheel which can be rotated until the fibres of the wood are completely twisted and torn asunder. Hickory, rock elm, blue beech and willow possess this property in a marked degree.

Flexibility.—This property depends upon the toughness and cohesive force of the woody fibres, the percentage of moisture present, the temperature and the amount of natural or artificial impregnation. Wood from the base of the tree is more flexible than that obtained higher up, and hardwoods are generally more flexible than conifers. For all kinds of wood, moisture and heat soften it and increase its flexibility, as is well illustrated in the manufacture of bent-wood furniture, barrel staves and hoops, the bending of wooden rims for wheels, veneer peeling, etc.

Toughness.—This is a more or less general term applied to woods which are both pliable and rather difficult to split. When the dry wood permits of an aggregate distortion in compression and tension of at least 3% and resists a longitudinal shearing force of 1,000 pounds per square inch it may be pronounced "tough," as for example, hickory, ironwood, oak, elm, ash.

Resilience.—This term is often confused with toughness and may be defined as ability to withstand impact, and explains the use of oak and hickory for wagon spokes, where each spoke is dealt hundreds of terrific blows in a mile journey over a rough road. Maple, beech, hawthorn and dogwood also have a high resilience.

Weight and Strength.—Broadly speaking, the strength of well-seasoned wood increases with its weight per cubic foot, the exceptions being confined mainly to the oaks which have an exceedingly complicated structure. To state the case more accurately, we may say, the higher the density of the wood the greater is its crushing strength, although density is no criterion of tensile strength.

Effect of Long Immersion in Water.—Sixty-five tests on alternate sections of the same sticks tested in the regular way indicate that soaking in water for six months produces no apparent loss of strength. Whilst soaking in cold water does not diminish the strength of wood, it is a well-known fact that heating the water weakens it considerably and boiling the water causes a still greater dimunition in strength, as noted already under the heading of flexibility. Timber which is first kiln dried and then soaked in water is found to be weaker than air dry timber containing an equal percentage of moisture, and fails much more suddenly because kiln drying increases the permanent brittleness of wood.

Effect of Hot Air Drying.—Apart from the checking action which results from a too rapid drying of the exterior portions of the test pieces, the result of over 200 tests shows that with the temperatures commonly used for drying lumber no detrimental effect was observed on the strength of the material.

Effect of Creosoting.—The following figures (Table VII.) for compression tests made on pieces of loblolly pine which had been soaked in water and in creosote for six days are interesting:

TABLE VII.

	Length of soaking (days).	Moisture %	Relative load.
Air dry wood	0	9.1	1.00
Soaked in water	6	71.5	.42
Soaked in creosote	6	70	.80

These figures show that creosote diminished the strength of the wood approximately one-half as much as soaking in water. It should be remembered, however, that these tests were made on very small pieces, and the results should be received with caution. More recent experiments show that whilst the strength decreases immediately after being creosoted this decrease is only temporary. Apparently the presence of creosote does not of itself weaken the wood but only retards the seasoning process, so that after a time it should become as strong as the original seasoned wood.

Safety Factors.—On account of such defects as knots, season checks, star-shake, etc., present in most structural timber and the great variation constantly occurring in its moisture content, it is customary to design timber structures so that they will carry several times the load ordinarily required—this multiplier being known as a safety factor. In the case of ordinary timber structures a safety factor of four is generally sufficient, provided the modulus of rupture has been determined from a large number of tests on fairly large-sized pieces, but in the case of structures carrying moving or jarring loads (bridges and foundations for machinery) a safety factor of five or six should be allowed.

In 1896 a committee of the American International Association of Railway Superintendents of Bridges and Buildings recommended the following factors: For timber in shearing and compression across the grain, 4; for columns under 15 diameters high and for end bearing, 5; for extreme fibre stress in transverse rupture, 6; in tension with and across the grain, 10.

Testing of Canadian Woods.—Because of the importance of this subject to all classes of wood users, the Forestry Branch of the Department of the Interior is about to undertake an exhaustive series of tests at McGill University. Beginning with a few of the more important of the commercial species, every kind of wood in the country will be tested for its strength in various ways, and for different conditions of growth and moisture content. At present the only information we have on this subject is based upon tests of wood grown in the United States; many of which were grown under entirely different conditions to what we find in our own country.

Provisional Table.—In the absence of more satisfactory information, the writer has therefore compiled the following table (Table VIII.) for 84 species of wood found growing in Canada. The necessary information has been gleaned from numerous sources and will be of considerable assistance to the designers of timber structures until such time as the Forestry Branch has completed its investigations along this line and furnishes fuller information regarding the strength of our native woods.

(Continued on following page.)

CANADIAN FOREST FIRES IN 1913.

The Forestry Branch, Department of the Interior, announces that the loss of timber by fire in Western Canada was smaller during last season than ever before. On several of the reserves in Manitoba and Saskatchewan fire occasioned no damage whatever, and on the Dominion reserves in the Railway Belt, B.C., the only green timber injured by fire was four acres of young lodgepole pine. Even on the Rocky Mountains reserve in Alberta, with the immense area of 13,373,856 acres, most of which is remote from settlement, fire destroyed only 1,150 acres of young timber, whose present value was small, and mature timber to the value of $150. The total area burnt on this reserve was but two one-hundredths of one per cent. of the above acreage, and it is likely, when the reports are complete from the other reserves, which are smaller and usually better protected, that the aggregate area burnt over by fire will be no greater than one one-hundredth of one per cent. of the total reserved area. The significance of this figure is apparent by comparison with the corresponding figure for the National Forests in the United States, where the area burnt over by fire in 1913, although admittedly the smallest in recent years, was about 0.03 per cent. of the total area.

TABLE VIII.

Kind of Wood	Kiln Dry Weight (Pounds per Cubic Foot)	Percentage Moisture, (Based on Dry Weight)	Number of Tests Made	Modulus of Elasticity $B = \frac{wl^3}{4dbh^3}$	Modulus of Rupture $R = \frac{3wl}{2bh^2}$	Endwise Compression Strength (Pounds per Square Inch)
Ash, Black	33	91	6	1,107,000	6,000	2,340
	..	11.6	6	1,395,000	11,620	5,590
	39	12	..	1,230,000	11,400	.....
“ Blue	38	39	5	1,241,000	9,650	4,180
	45	12	8	1,108,000	11,500	7,070
“ Green	39	48	5	1,480,000	10,040	4,360
	44	12	10	2,050,000	11,600	8,000
“ Oregon	36	12	8	1,200,000	9,400	7,360
“ Red	39	12	3	1,154,000	12,300	6,160
“ White	44	40	5	1,635,000	10,760	4,630
	39	12	87	1,640,000	10,800	7,200
Basswood	23	110	5	842,000	4,450	1,820
	..	9.2	5	1,674,000	7,310	4,770
	28	12	..	1,190,000	8,300	.....
Beech	42	61	5	1,353,000	8,610	3,480
	..	13.1	5	1,830,000	14,830	6,450
	43	12	10	1,720,000	16,300	6,765
Blue Beech	45	12	4	1,160,000	16,300	7,075
Birch, Cherry	44	61	5	1,490,000	8,590	3,560
Paper (Canoe)	37	12	12	1,185,000	15,000	6,885
Birch, White (Gray)	35	12	..	1,036,000	11,000	.....
“ Yellow	41	72	5	1,597,000	8,390	3,400
	..	10.3	5	2,396,000	19,400	9,560
	41	12	..	2,290,000	17,700	.....
Butternut	25	102	5	1,008,000	5,870	2,580
	25	12	9	1,150,000	8,400	5,545
Cedar, Red (Pencil)	31	12	13	950,000	10,500	5,805
“ Western, Red	23	12	..	1,460,000	10,600	.....
(Shingle)	20	55	5	643,000	4,250	1,990
“ White	19	12	87	750,000	6,300	5,200
“ Yellow	29	..	..	1,460,000	11,000	.....
Cherry, Black	33	55	5	1,308,000	8,030	3,540
	36	12	.	1,200,000	11,700	.....
“ Wild Red	..	46	5	1,042,000	5,040	2,170
Chestnut	28	12	..	1,260,000	9,500	5,550
Cucumber	29	80	5	1,535,000	7,420	3,140
	..	12	8	1,310,000	9,500	7,570
Dogwood, Flowering	50	62	5	1,175,000	8,770	3,640
	51	12	..	1,160,000	12,800	.....
Elm, Rock	45	46	5	1,222,000	9,430	3,740
	..	11.2	5	1,755,000	16,350	7,570
	..	12	7	2,550,000	15,100	8,380
	40	57	5	1,314,000	9,510	3,990
	..	11.6	5	1,622,000	13,950	7,080
Elm, Slippery	43	12	..	1,300,000	12,300	.....
“ White	34	66	5	1,052,000	6,940	2,700
	..	10.8	5	1,504,000	12,140	5,840
	..	12	18	1,540,000	10,300	6,500
Fir, Alpine	20	47	5	861,000	4,450	2,050
	..	15.9	5	887,000	5,960	3,400
“ Balsam	24	12	1	1,160,000	7,300	5,175
“ Douglas	29	32	5	1,242,000	6,340	2,920
	..	12	5	1,392,000	9,320	6,050
	32	..	..	1,680,000	7,900	.....
“ Lovely	24	117	14	1,323,000	6,570	3,040
“ Lowland	22	12	..	1,360,000	7,000	.....
Gum, Black	39	..	11	1,160,000	11,800	6,630
Hackberry	35	50	1	1,170,000	7,800	3,320
	..	11.4	..	1,426,000	14,070	7,250
	45	..	10	1,149,000	11,700	5,960
Hawthorn, Pear	..	64	2	964,000	7,650	3,110
Hazel, Witch	45	70	5	1,112,000	8,280	3,400
Hemlock, Eastern	25	129	5	917,000	5,770	2,750
	..	9.5	5	1,048,000	7,510	5,740
	26	..	20	1,270,000	10,400	5,565
“ Western	32	52	..	1,428,000	7,290	3,390
	..	12	..	1,666,000	10,370	5,400
	32	12	3	1,746,000	12,800	7,740
Hickory, Bitternut	..	65	11	1,399,000	10,280	4,570
	..	9.7	11	1,880,000	18,850	10,600
	..	12.0	25	....	15,000	9,600
“ Nockernut	41	57	11	1,508,000	11,110	4,320
	..	9.2	11	2,555,000	21,950	10,400
	..	12.0	75	....	15,200	10,100
“ Pignut	..	55	5	1,605,000	4,820	11,450
	..	9.5	5	2,370,000	11,130	24,000
	56	12	30	2,730,000	18,700	10,900
“ Shagbark	..	58	9	1,346,000	4,360	10,990
	..	9.8	9	2,120,000	10,500	22,600

TABLE VIII. (*Continued.*)

Kind of Wood	Kiln Dry Weight (Pounds per Cubic Foot)	Percentage Moisture (Based on Dry Weight)	Number of Tests Made	Modulus of Elasticity $E = \frac{wl3}{4dbh3}$	Modulus of Rupture $R = \frac{3wl}{2bh^2}$	Endwise Compression Strength (Pounds per Square Inch)
Hickory, Shagbark	51	12	187	2,390,000	16,000	9,500
Hop, Hornbeam, (Ironwood)	51	12	6	1,950,000	16,000	7,660
Larch, American, (Tamarack)	35	52	5	1,236,000	7,170	3,480
	..	11	5	1,680,000	12,050	7,590
	38	12	14	1,790,000	12,800	7,470
" Western	..	46	..	1,310,000	7,250	3,700
	..	14.8	..	1,565,000	10,230	5,940
	46	..	6	2,300,000	17,400	9,755
Locust, Black	45	..	9	1,830,000	18,100	9,890
" Honey	47	53	3	1,732,000	12,360	4,970
Madrone (Arbutus)	43	..	4	1,190,000	12,000	8,835
Maple, Ash-leaved, (Box Elder)	27	..	4	820,000	7,500	4,560
" Broad-leaved, (Oregon)	30	..	..	1,110,000	9,720	.....
" Red	..	69	..	1,445,000	8,310	3,680
	..	12.1	..	1,761,000	13,420	6,610
	38	..	9	1,340,000	15,000	6,550
Maple, Silver	32	66	5	943,000	5,820	2,490
	..	12	1	1,570,000	14,400	6,820
" Sugar	..	56	5	1,437,000	8,820	4,000
	..	12.5	5	1,930,000	14,830	7,370
	43	..	9	2,070,000	16,300	7,780
Mulberry, Red	36	..	..	1,700,000	11,000	.....
Oak, Black (Yellow)	..	80	5	1,121,000	7,650	3,080
	..	11.4	5	1,641,000	14,670	7,120
	45	12	40	1,740,000	10,800	7,300
" Burr	42	70	5	877,000	7,180	3,280
	46	12	13	1,320,000	13,900	6,950
" Chestnut	47	12	..	1,780,000	14,600	.....
" Pin	43	12	..	1,500,000	15,400	.....
" Red	..	89	6	1,248,000	8,100	3,440
	..	10.5	6	2,000,000	14,400	8,150
	45	12	57	1,970,000	11,400	7,200
" White	44	58	5	1,137,000	8,090	3,520
	..	10.5	5	1,595,000	13,900	7,580
	..	12.0	218	2,090,000	13,100	8,500
" Swamp, White	49	74	1	1,593,000	9,860	4,960
	..	19.2	..	2,020,000	19,210	8,030
" Western White, (Garry)	46	..	..	1,150,000	12,400	.....
Pine, Jack	30	..	6	1,332,000	9,100	5,600
" Limber	27	..	3	961,000	8,800	4,950
" Lodgepole	26	44	5	1,015,000	5,130	2,530
	..	11	5	1,270,000	8,740	5,520
	..	..	5	1,099,000	7,890	4,715
Pine, Red	32	54	5	1,384,000	6,430	3,080
	..	12.5	5	1,787,000	12,300	7,080
	31	12	95	1,620,000	9,100	6,700
" White	24	74	5	1,073,000	5,310	2,720
	..	9.9	5	1,417,000	9,620	6,360
	..	12	120	1,390,000	7,900	5,400
" Rocky Mountain White	27	12	..	937,000	8,700	.....
" White-barked	26	12	2	729,000	8,150	4,685
" Western White	24	12	..	1,356,000	8,700	.....
" Western Yellow, (Bull)	..	80	..	1,121,000	7,650	3,080
	..	11.4	..	1,641,000	14,670	7,120
	29	12	..	1,260,000	10,200	.....
Poplar, Asper	26	96	5	1,185,000	5,850	2,720
	..	12	4	....	......	4,670
" Large-toothed Asper	28	12	2	1,360,000	10,200	5,050
" Cottonwood	24	..	7	1,400,000	10,900	4,980
" Black Cottonwood	23	..	4	1,580,000	8,400	5,520
Sassafras	31	..	..	730,000	8,500	.....
Spruce, Black	28	12	170	1,560,000	8,400	5,770
" Engelmann	22	45	5	866,000	4,550	2,170
	..	12.8	5	1,074,000	7,740	4,560
	21	12	4	1,140,000	8,100	4,780
Spruce, Red	32	31	4	1,143,000	5,820	2,920
	..	12.9	4	1,574,000	10,340	5,720
	..	12	170	1,560,000	8,400	7,500
" White	..	41	2	968,000	5,200	1,940
	..	12.6	2	1,394,000	9,210	5,020
	25	12	10	1,450,000	10,000	5,800
Sumach, Staghorn	28	45	5	800,000	5,845	2,680
Sycamore, (Button-ball)	33	81	5	964,000	6,300	2,790
	..	11.5	5	1,365,000	9,350	5,340
	35	12	4	1,220,000	9,000	6,370
Tulip, (Yellow Poplar)	26	..	..	1,300,000	9,300	.....
Walnut, Black	38	..	5	1,550,000	12,100	.....
Willow, Black	26	148	5	480,000	3,340	1,220
	27	12	2	550,000	6,000	2,015

FACTORS GOVERNING THE SELECTION OF A ROAD SURFACE OR PAVEMENT.*

By L. R. Grabill,
Superintendent of Suburban Roads, Washington, D.C.

THE selection of a pavement or road surface is one of the most important of the duties of a highway engineer. The surface of the road or street, equally with the bridge truss or the retaining wall, should be neither over-designed nor under-designed as to the strength required to satisfy the conditions which it will be called upon to meet. In this particular the discrimination and care used must be similar to that of the architect in choosing the type of building suited to the case he has in hand, and to that of the bridge engineer in selecting the kind of bridge he will use. The roadbuilder or the pavement engineer must choose not only the type of surface which will be the easiest over which to pull a load, which will prove durable under the traffic that it will carry, and which will be adapted to the numerous local conditions; but he must, if his work is properly done, choose the surface that will produce these results with the minimum final cost both to the users of the road and to the community which pays for its construction and maintenance.

Nothing could be easier than to select a few types of road suitable to a few locations, and to adhere to these types, regardless of wide variations in the conditions; and this, it is feared, is too often done. It is very much on the safe side to assume that the character of pavement required for the most exacting purpose should be used for very different and lighter requirements; or to assume that the surface which costs the most will necessarily be the best; but it is not always possible to decide with such facility the question of what surface will prove the most satisfactory, under the special conditions involved, for the lowest total expenditure per ton carried over it. Yet this is the question to be solved in every new construction.

There is frequently the danger, too, that a lack of sufficient funds for the work proposed will cause the effort to be made to cheapen the first cost of construction beyond the limit necessary for durability; and it is not often that the road engineer finds enough funds available to build a better road than he wishes, if indeed he is able to build as well as his judgment dictates. In these cases, however, it is usually possible to limit the area covered, either in length or width, or both, so that a suitable character of surfacing may be employed.

It is assumed here that all of the necessary requirements for the sub-grade have been met, such as those that relate to grade, drainage, and the preparation of the earth foundation for the pavement. These being the necessary and most permanent part of the road, should always be well done, in the best and most enduring manner that is practicable with the funds available, even at a sacrifice of the character of the surfacing, which will in time require renewal under any circumstances.

In considering the question from a purely academic standpoint, the availability of the funds necessary for constructing the kind of surface required for any given case may be also assumed, so that the question of cost presents itself only as a factor of the problem, and not as a limiting feature of the selection. This assumption is necessary, because if sufficient money cannot be obtained, the question becomes one of the selection not of the proper surface, but of the best one that can be paid for; forming a somewhat different problem, with greater limitations. In fact, the entire question may be said to cover two classes of cases, namely, those which are not limited by some special consideration, such as cost, grade, etc., and those which are so limited. The latter class is more frequently met with.

The word pavement is used by the writer for any class of hard surfacing of the road or street.

Mr. A. T. Byrne, in his work on Highway Construction, names the following as the essential qualities of a good pavement: Imperviousness; durability; freedom from slipperiness, noise, dust and mud; adaption to every grade and to every class of traffic; ease of cleaning; minimum resistance to traction; cheapness.

Mr. G. W. Tillson, in the valuable chapter on "The Theory of Pavements" in his book on "Street Pavements and Paving Materials," appears to have originated the method of selection by assigning comparative values to the different qualities of surfaces upon a scale of 100, as follows:—

	Values.
Cheapness	14
Durability	21
Ease of cleaning	15
Light resistance to traffic	15
Non-slipperiness	7
Ease of maintenance	10
Favorableness to travel	5
Sanitariness	13

Mr. Tillson also gives, in his table number 51, a summary of the values of the various qualities which he assigns to different pavements, as compared with the full value in the ideal pavement. By combining the various values of the properties which are demanded to meet particular conditions this author shows how the selection of a pavement may be made. In speaking of the values as applied to various pavements, Mr. Tillson says: "It must be understood, of course, that the table is a general one; that much of it is based on the personal judgment of the author; and it will vary in different localities, even if the conclusions are agreed to."

Mr. Ira O. Baker in "Roads and Pavements," divides the qualities of pavements, and gives the relative values as follows, in percentages of the value of an ideal pavement:

	Values.
Economic Qualities:	
Low first cost	15
Low cost of maintenance	20
Ease of traction	10
Good foothold	5
Ease of cleaning	10—60
Sanitary Qualities:	
Noiselessness	15
Healthfulness	10—25
Acceptability:	
Freedom from dust and mud	10
Comfortable to use	3
Non-absorbent of heat	2—15

Mr. Baker states: "The assignment of these numbers is wholly a matter of judgment, and different individuals will differ greatly as to the relative values to be

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given to each quality. Different values should be assigned to the same quality according to the attendant conditions. The application of these principles is likely to be complicated by the personal interests of the residents or property holders."

An indication of the values of the qualities of different pavements is obtained from the average of the values as signed in ten replies by that number of paving engineers to an inquiry by the United States Forestry Service, which are tabulated as follows, using standard values which are apparently based on Mr. Tillson's but differ slightly, viz:—

sidered. A certain tonnage in heavy slow-moving vehicles with iron tires produces an entirely different effect from that produced by the same tonnage in lighter rapid-moving automobiles with rubber tires; and a still different effect will be produced by the same tonnage in heavier and slower motor trucks. It has been well suggested that a traffic unit should be adopted, which could be used to represent, as far as possible in the same denomination, the amount of wear caused by the passage of one ton over the road in each of the several ways. The width of space available for travelled way must be considered in connection with the amount of traffic.

Comparative Value of Different Pavements.

Qualities.	Standard percentage value.	Granite.	Sand stone.	Sheet asphalt.	Asphalt block.	Brick.	Macadam.	Treated wood block.
Cheapness	14	4.0	4.0	6.5	6.5	7.0	14.0	4.5
Durability	20	20.0	17.5	10.0	14.0	12.5	6.0	14.0
Ease of maintenance	10	9.5	10.0	7.5	8.0	8.5	4.5	9.5
Ease of cleaning	14	10.0	11.0	14.0	14.0	12.5	6.0	14.0
Low traction resistance	14	8.5	9.5	14.0	13.5	12.5	8.0	14.0
Non-slipperiness	7	5.5	7.0	3.5	4.5	5.5	6.5	4.0
Favorableness to travel	4	2.5	3.5	4.0	3.5	3.0	3.0	3.5
*Acceptability	4	2.0	2.5	3.5	3.5	2.5	2.5	4.0
Sanitary quality	13	9.0	8.5	13.0	12.0	10.5	4.5	12.5
	100	71.0	73.5	76.0	79.5	74.5	55.0	80.0

*Acceptability includes noise, reflection of light, radiation of heat and emission of odors, etc.

The prime factors which should determine the selection of a type of surface, when this selection is not limited by any necessity for giving undue preference to any factor, appears to be as follows:—

1. The volume and nature of the probable traffic over the pavement.

2. Conditions incident to the location of the pavement; including the character of the adjacent land and improvements; the character of the foundation; the kinds of adjoining pavements; the ruling gradients; the climatic conditions; and especially the availability and cost of different materials at the work.

3. The characteristics of the surface which will adequately meet physically, hygenically and esthetically the conditions expressed in the two factors first named. These characteristics are practically those named in the tables cited.

4. The quotient obtained by dividing the total estimated traffic to be carried per unit of width into the cost per unit of area of the pavement during its probable life; including first cost and interest on the same; special surface treatment for dust suppression or other purposes; and any necessary repair until replacement; but not including the cost of cleaning. For the best pavement this quotient will be the lowest. This ratio may be called the ultimate cost of the pavement per traffic unit carried.

(1) The volume and nature of the traffic—not the present traffic, if the road now exists, but the traffic after the improvement—is the most essential factor. This must necessarily be approximated, and due allowance should be made for increase during the life of the pavement. The effect of traffic upon the pavement should be expressed in units of a known value, to which all classes of traffic can be reduced.

The different effects produced on a surface by different kinds of traffic are elements which must be considered.

Traffic when confined to a single vehicle width is very damaging and widening a few feet only may easily double or triple the life of a pavement.

One solution of the character of the roadway, when pleasure traffic and commercial vehicles use the same highway, is to construct a surface adapted to each, separated by a short distance, making a double roadway. This is done to the great advantage of the road users of every class where the travel is sufficiently dense to require it. It is customary, for the reasons indicated, as well as from and esthetic standpoint, to prohibit heavy traffic on roads built especially for pleasure drives. This factor of traffic, which is one of the most essential, is sometimes given the least consideration, and we occasionally hear of a county or township bonding itself for a costly form of surface where a gravel road would answer the probable demands for some time. On the other hand, in the neighborhood of cities, where the travel is already heavy and sure to increase, roads or pavements are frequently laid which are inadequate for even present conditions.

The nature of the future traffic is quite as important as its volume; although owing to rapid changes in the weight and speed of freight-carrying trucks, and the increase of motor-driven vehicles, this is difficult to forsee. An estimate of traffic on a city street made for thirty years hence would probably almost ignore horse-drawn vehicles, and would provide for the heaviest class of motor-trucks instead. If the traffic is to be of one class only, such as motor vehicles driven for pleasure with a moderate limit of speed, the problem is much simplified, and it is the writer's experience that no class of traffic is more easily or cheaply provided for. If there is to be a mixed traffic of horse-drawn vehicles, motor trucks, and other automobiles, with a possibility of the steam-lorry and train of wagons in the future, this combination will require a very strong and durable pavement, and first cost should be given little consideration.

There is an approximate limit to the amount of tonnage which can pass over any width-unit of pavement in a given length of time; and any amount of traffic approaching this would demand the very highest type of surface practicable to be constructed. This limit is probably seldom reached for more than a few hours daily on the heaviest travelled streets.

(2) The nature of the surrounding conditions is a potent factor in determining the character of the surface. In a manufacturing or wholesale district where noiselessness is less essential a granite or brick block may well be used on account of its strength or durability; whereas in a residential section the less durable but more quiet asphalt or wood block is better. In a farming or country area, a macadam or gravel road harmonizes more perfectly with the surrounding fields and woods.

The value of the adjacent property has a large bearing in the case, for it is the basis of the revenue which usually must be raised to pay for the improvements. A closely built city block can fortunately afford a much higher priced pavement than a less closely built suburban section, on account of its larger taxable value.

The character of the foundation governs the construction in many cases. An especially soft sub-grade may require a base of cement concrete; while, with certain types of pavement, upon hard ground, this might be omitted at a considerable saving of cost. If the problem be that of surfacing an old waterbound macadam roadway, it may be solved by using a surface, for instance, of bituminous concrete, placed directly upon the old macadam; whereas, if no such foundation existed, an entirely different type of pavement might be required. A rigid surface, such as one of cement, should never be placed where there is danger of settlement.

The ruling gradients of the road must be considered, for the reason that some pavements do not afford sufficient foothold upon steep grades, and the climate must be taken into account, since pavements are differently adapted to warm or cold or wet or dry conditions. The character of adjoining pavements will have weight with the engineer, except in cases where the requirements are very exacting. Again, the practical consideration as to the availability of contractors and suitable construction plants in the vicinity must have weight as entering into the price to be paid.

Among local conditions, the availability of material, either local or foreign, the use of which latter largely depends upon the cost of transportation, is probably the deciding factor in more cases than any other. A city in an area producing excellent paving brick would be unwise to import granite block from a distance at a heavy cost for freight; or even to pay too heavily for the transportation of asphalt, and a western country could by no means afford to pay the cost of transporting the trap-rock used so largely on roads in the east, but must find the solution of its problem in the use of a surface of cement concrete or other material produced nearby. The very possibility of the construction of any roadway whatever, in many cases where the funds are limited, is dependent upon making the best possible use of the local materials available.

(3) The characteristics of the surface to be constructed, which must satisfy the requirements of the traffic, the environment, the foundation, the gradients, and the climate, may be divided into three classes, viz.:

(a) Those which are purely physical;

(b) Those which are required for health;

(c) Those meeting requirements of a more or less esthetic nature.

(a) The physical requirements are those previously stated, viz.: Strength; durability; ease of traction; sufficient roughness when either dry or wet to prevent slipperiness; imperviousness to a greater or less degree; sufficient smoothness to render the surface easily cleaned and to prevent excessive jarring of vehicles passing over it at high speed, and facility of repair, both as to openings and as to wear of the surface.

(b) The requirements as to health include noiselessness, freedom from dust produced by the wear of the wear of the pavement, and heat-absorbing and heat-radiating quality in a minimum amount.

(c) The esthetic requirements are such as appeal more directly to the senses. These are harmony with surroundings, a pleasing appearance, extreme noiselessness, and almost absolute smoothness. These qualities in their highest degree are usually demanded only in connection with streets of the highest class, or with pleasure drives.

Examining these characteristics further, but without going into details as to the qualities of materials, we find as follows:

Imperviousness is a very important feature, both from a sanitary standpoint, and as a matter of increasing the durability. No very permeable surface can be considered a good one.

Smoothness is particularly demanded by motor-vehicles, especially where speed can be used. Non-slipperiness is produced by slight irregularities in the surface. It is necessary for good foothold and to prevent skidding of rubber tires when the surface is wet.

Facility of repair is essential; and for this reason the pavement should not be constructed of materials and by methods which will be difficult to duplicate after the completion of the original pavement, without at least providing for its repair. Block pavements lend themselves most easily to repair, since they require no large plant for that purpose.

The sanitary requirements are mostly for the benefit of the public living or working on the streets, and less for the road-user. A noisy pavement with much travel seriously affects the nerves of those near it; a dusty pavement permits fine grit to be carried into eyes and lungs and becomes a muddy pavement in wet weather. A heat-absorbing and heat-radiating pavement, such as sheet asphalt, if exposed to the sun, adds much to the temperature of the street and the surroundings in the hot weather, to the discomfort of all in its vicinity.

The esthetic requirements are such as add a touch of good taste, and perhaps of luxury, to the road and are increasingly in demand.

All of these requirements will have somewhat different weights in different cases. Some of them can be omitted in considering nearly every case, and must be omitted often. In view of this it seems best not to assign special values to these requirements; but in each case to give preference to such characteristics as the situation demands, and to use the surface combining these characteristics in the greatest degree.

(4) This combination must produce a pavement, usually, which will give the lowest ratio of total cost to the total traffic units to be carried. The surface thus chosen should be that which is best adapted to the purpose.

In instances in which a high first cost might be prohibitive, the pavement showing the lowest cost-tonnage ratio could not always be selected; and a less costly surface with a higher rate of maintenance would be necessary.

The process of selection will usually be one of elimination, thus for a certain case of proposed construction several well-known classes of pavements, of nearly equal theoretical value, will be considered; say, granite block, vitrified brick, wood block, and sheet asphalt. If low cost is paramount, this element may eliminate the granite block and the wood block; and if noiselessness is desired, the vitrified brick will be eliminated; leaving the sheet asphalt, or a similar surface, to be adopted. If durability alone is considered, the granite block might be chosen where this material is convenient; whereas, if the case demanded noiselessness, smoothness and durability in a high degree, without especial reference to first cost, the wood block would probably receive the verdict.

A resident paving-engineer familiar with the local conditions and with pavements in general often need not tabulate or even assemble, otherwise than mentally, the reasons for his choice, and this mental way is very often the method of selection employed. In such cases, however, the same conditions should, and do, actually control as would be the case if the situation were being considered for the first time with the utmost pains.

In order to proceed with system in the matter of choice of a new pavement, or one in a new location, the engineer should have the necessary data as to traffic; as to cost of construction and maintenance of similar pavements in the vicinity, or under like conditions; as to the life of such pavements; as to climatic conditions, and, in fact, all available information on the subject. It is unfortunate that the supply of information on the subjects is not what it should be. This is a defect which every highway engineer can aid in correcting, by careful investigation and records in connection with his work. In the absence of the necessary data, the selection is merely an assumption based on judgment and experience, and sometimes on a desire to experiment, and this is the manner in which the choice is very often made.

On the whole, the selection of a pavement, like the tariff, is largely a local question, and in its final aspect, when under practical consideration, presents such a number of features, some of which are predominant at one time and some at another, that each case must usually be considered alone.

The matter is well summed up in this quotation from Mr. Tillson: "The official who decides on the material after the most careful investigation will often find that his decision is displeasing to many people. . . . . He must make his decision after taking all things into consideration, and stand by it although it will not always prove satisfactory to all. . . . . But if he meet the question successfully, and ultimately arrive at the true solution, his satisfaction is as great, perhaps, as in any other branch of his profession."

The reason why oil paint will not stand well on concrete surfaces is that the oil is saponified by the free lime of the cement. It is stated in a French architectural journal that this drawback can be obviated by first applying a wash of zinc sulphate in the form of a 1 : 5 solution, the result being to produce a film of plaster and zinc oxide which is quite harmless to oil.

THE SELECTION OF A ROAD SURFACE.

Discussion by W. A. McLean, Commissioner of Highways for Ontario.

THE paper by Mr. Grabill on "Factors Governing the Selection of a Road Surface or Pavement" is a most interesting and illuminating contribution. It expresses the complexity of the modern problem, which at times confronts road authorities.

Traffic.—Whatever other factor may enter into the problem, roads should be built to suit the traffic, using available materials to the best advantage. To do this, requires a thorough knowledge of (1) the traffic, and (2) the material. A paper read before this association last year by Col. Schier, of Massachusetts on "Traffic Census" is one of the most noteworthy statements on this phase of the subject yet produced, and is a type of analysis of which we have great need.

Knowledge of Material.—Traffic on the public highway within the past decade has so radically changed, that our knowledge of the characteristics of materials in meeting the new requirements is proportionately limited. A paving material should be in general use for at least its estimated lifetime before the facts regarding it are, to a reasonable extent, at our disposal. The mass of facts which we possess regarding any proposed material is an important factor in selection.

The elementary materials actually in use in road-building are comparatively few—such as broken stone, gravel, sand, clay, asphalt, tar, oils, vitrified brick, creosoted wood, stone setts, Portland cement—but their combinations and variations are almost innumerable. Unless some entirely new material comes above the horizon, the next five years will be a striking era, in leading to the more effective use of the materials now available, in confirming or setting aside our opinions of to-day and in standardizing construction. So far as roads of the open country are concerned, of which I am more especially speaking, there is a vast amount of theory still to be tested.

Division.—A road or pavement may be conveniently divided, for consideration, into four parts: (1) The system of drainage; (2) the earth sub-grade; (3) the foundation, and (4) the wearing surface.

As a rule, the wearing surface necessary will dictate the character of the substructure. But in other cases, one or more necessary or existing features of the substructure will influence our choice of wearing surface.

Foundations.—A secure foundation is an absolute necessity for permanent bituminous coatings. To this end a substantial depth of foundation should be used, a condition with which roads on this continent have not always complied. Very few conditions of heavy or constant traffic can be successfully met with a less foundation than 6 to 9 inches, or a less total depth of stone in the road crust than 10 to 12 inches. The price of good roads in one particular, at least, is a substantial depth of stone. The difficult part of our problem, the financial aspect, is not so much the selection of a wearing surface as our ability to pay for strong foundations. The existing foundation, or local materials available for a foundation will frequently dictate what the surface should be.

Heavy motor trucks and busses are placing a great and unexpected strain on road foundations. On main roads leading out of London, England, old 6-inch concrete foundations are being torn up and 9-inch foundations put in their place. This is necessitated by heavy and constant motor-bus and traction engine traffic.

New Bituminous Coatings.—In Great Britain, France and other countries of Europe, bituminous treatment has largely become the accepted practice in meeting the requirements of motor traffic in the open country: By carpet coats; by grouting or penetration; and by mixing methods, according to local conditions. It need not be said that asphalt and tar are now, on this continent, being used with marked success—a result that has been reached after many trials and not without tribulation.

That bituminous paving has been markedly successful in England is probably due, to a large extent, to the fact that it has been commonly applied only on old, solid and well-settled foundations, in re-surfacing their old macadam roads. Many of the failures on this continent, on the other hand, have plainly been due to weak, badly-drained foundations. To uneven settlement of new roads under traffic may be attributed much of the failure of bituminous surfaces, rather than to any inherent defect in bitumen itself for road purposes.

Settlement of New Roads.—Roads, as we now build them, are rolled in several layers with a ten- or twelve-ton roller, giving a compression of 500 lbs. per inch. Traffic follows with tire compression up to 700 and 800 lbs. per square inch. Under succeeding wet conditions of fall and spring, settlement must inevitably occur, leading to an uneven, wavy surface and consequent decay.

In the speaker's experience, a broken-stone road, commonly does not reach final settlement for two or three years after first construction; but within that period permanent subsidence may be taken for granted. French, German, and English road-builders laying bituminous surfaces over their old roadbeds, are manifestly not dealing with a condition which commonly exists here.

A reasonable course to pursue in many cases would be to build waterbound macadam roads on Telford or other suitable foundation. The surface could be maintained for two or three years by thin paint coats or oiling. At the end of that period perfect settlement and stability of the foundation having been attained, a heavy and durable bituminous surface could be applied where traffic demands it.

Concrete Roads.—The prejudice against concrete roads has within the past couple of years, been largely broken down, and a good deal has been done to demonstrate their value when built under favorable conditions; indicating more especially a one-course mixture; a high proportion of cement; a clean, tough aggregate; a flat undersurface; joint protection, and good drainage. A number of experimental sections have been built by the Ontario Highway Office, under varying conditions.

So much may be hoped, that there is a temptation to prophesy, but adhering to a strict basis of proven fact, and in the light of our knowledge of concrete in other structures, it is conservative to say that the next few years should be fruitful in determining the place of this important material, in the field of roadmaking; in putting the facts at our disposal to determine when and how it can be used with economy and certainty of results.

HIGHWAY IMPROVEMENT IN SASKATCHEWAN.

THAT the good roads movement is taking as firm hold in the west as in the east is evidenced by the very progressive manner in which their improvement has been undertaken by the various provincial governments of the western provinces.

The first annual report of the Board of Highway Commissioners of Saskatchewan for the year ending Feb. 28th, 1913, shows a very creditable advance in that province. The board derives its power from the Provincial Act respecting the construction and improvement of public highways, March 15th, 1912, and consists of three members appointed by the Lieutenant-Governor-in-Council, together with an advisory committee of two to be called upon when required by the chairman of the board.

Immediately following the passing of the Act, an appropriation of $1,500,000 was made by the assembly, and this amount, together with $100,000 with which the Public Works Department were to have carried on the erection and repairs of steel bridges was placed at the disposal of the Board of Highway Commissioners. This made a total of $1,600,000 available for roads and bridges, $1,300,000 of which it was decided to spend on the former.

Three main points, according to the report, were kept constantly in mind in determining the distribution over the province. First, a schedule was prepared whereby each municipality could receive $5,000, or each constituency $30,000. Then, main or trunk roads having the heaviest traffic, and feeding large areas were to have preference. Lastly, assistance would have to be given to many places in the province "where improvements were urgently required, which, although not on roads classed as main roads, were so far beyond the means of the local authorities" that government assistance would be imperative. This last applies to bridges and long side-hill roads across ravines and valleys, fills across large sloughs, marshes, etc. It was necessary, of course, to deviate considerably from the rule of only giving $5,000 to a municipality, but this rule was kept in view, and by it a fairly equitable distribution was obtained.

To thoroughly familiarize themselves with existing conditions, and to decide where improvements were most necessary, the board enlisted the help of inspectors, muni-

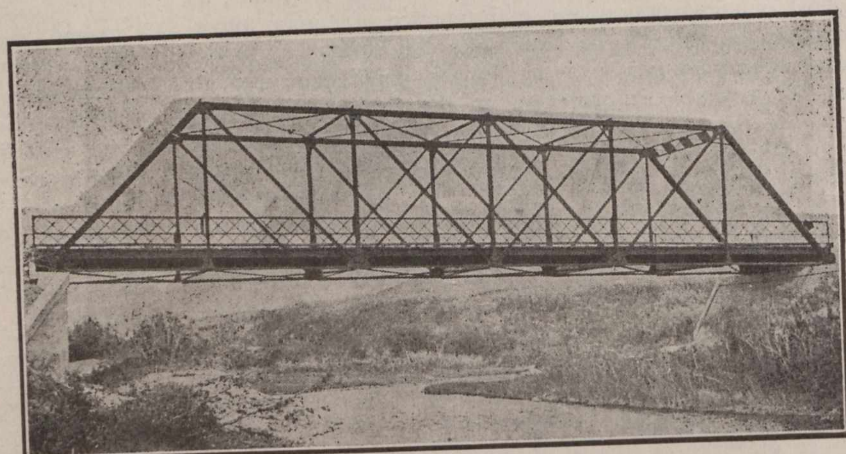

Fig. 1.—A 100-foot Steel Span on Concrete Abutments Over Eagle Creek, Sask.; Typical of the Steel Highway Bridges of the Province.

cipal councillors, and others; and thus succeeded in obtaining a great quantity of information by which they were enabled to start working out a main road system for each municipality in conjunction with adjoining systems. An effort was made to induce each municipal council to decide on what should be the main road system within their boundary, and in this they were assisted in every way possible by the board.

To hasten the commencement of the work so that the assembly's programme might be carried out in 1912,

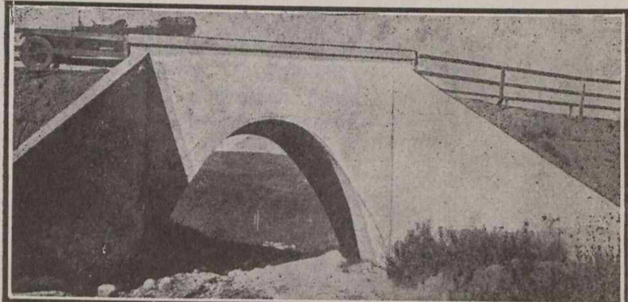

Fig. 2.—A 20-foot Concrete Span Over Gibson Creek, Sask.

a bulletin giving the board's aims, together with various methods of road construction, was widely disseminated throughout the province. To induce the municipalities to co-operate a set of regulations was adopted whereby each municipality could be assisted each year to the extent of 50 per cent. of the cost of any improvement they wished to make, subject to the restrictions in the regulations, some of which are noted below.

The assistance in any case is not to be more than the amount previously mentioned ($5,000). This applies to road construction, and not bridges. The improvements must be of a permanent nature, and such as may suitably be paid from capital account, and the construction must in every way be satisfactory to the board. A rather interesting clause is to the effect that the board have powei to valuate any work, in their opinion costing too much,

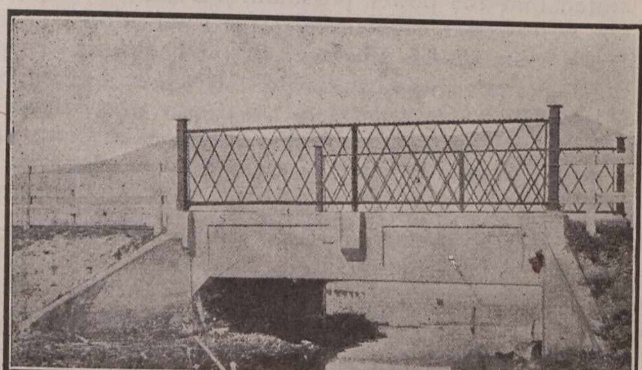

Fig. 3.—A 20-foot Concrete Span Over Rosthern Creek, Sask.

and pay the grant accordingly. To induce the local authorities to properly care for the roads when constructed their condition will be considered in giving further assistance.

Besides the distribution of bulletins of useful information on road making and actual help in construction, experiments have been made with the idea of overcoming special difficulties. So far nothing very definite has resulted from them, but they have served to indicate lines along which success may be possible, and it is probable that before long some method may be devised whereby the unfitness for earth road making of many of the gumbo clays throughout the province may be overcome.

By addition of the tabulated lists in all 363 roads were worked upon by government road gangs during the year, and 145 rural and urban municipalities received government assistance outside the regulations of the Board of Highway Commissioners. The amount expended directly on road improvements was $1,025,958.66. By direct grants to municipalities $100,935.54. By municipalities under the regulations, $138,325.87. Bridges departmental staff, inspection, printing, etc., cared for the balance of the appropriation.

Bridge Work.—The following summary of the bridge work is of interest. In all 19 steel and 2 concrete spans were constructed as follows:—

Construction.	Number of spans.	Length of span.
Steel	1	250 feet
Steel	2	150 feet
Steel	3	126 feet
Steel	4	100 feet
Steel	5	80 feet
Steel	3	60 feet
Steel	1	40 feet
Concrete	2	20 feet

The 250-foot span is over Battle River west of Battleford, and is a Pratt truss with curved top chord. The steel was supplied by the Canadian Bridge Company, of Walkerville, and erected by R. J. Lecky Company, of Regina, who erected the steel on twelve of the nineteen spans mentioned above. The departmental crews erected the steel for five, and Mr. E. Lenkin, contractor, the sixth. (There is one steel bridge to be erected.) The Hamilton Bridge Company supplied the superstructure for nine, the Western Steel and Supply Company for five, the Sarnia Bridge Company for four, and Wm. McNeil and Sons, Nova Scotia, for one of the 126-foot spans. The two 20-foot concrete spans were erected by

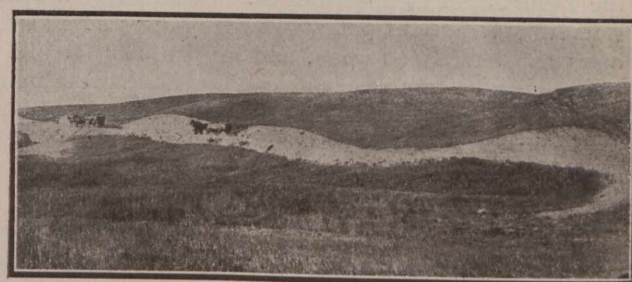

Fig. 4.—Typical Side Hill Grading, Saskatchewan.

J. J. McDonough, who also was the contractor for the abutments of two steel spans.

If the Saskatchewan board continues as it has begun a great future may be predicted for roads in that province, and if, as the chairman, Mr. A. J. McPherson, anticipates, it will be able to co-operate with the other provinces in a coast-to-coast highway and also highways to other points of importance in Canada, a great boon will not only be conferred on each province but the country as a whole.

WATER POWERS IN MANITOBA

IN January 1st issue of *The Canadian Engineer* a reference was made editorially to a report submitted recently by Hon. W. J. Roche, Minister of the Interior, to the Public Utilities Commission of Manitoba, respecting the physical features of the water powers within the province. The engineers of the Water Power Branch, under the direction of Mr. J. B. Challies, Superintendent, have been making a systematic study of water power and stream flow throughout Manitoba. The report shows, in result, the power possibilities of the various rivers. The following information is derived from Mr. Challies' letter of transmittal to Judge H. A. Robson, Chairman of the Commission.

As stated last week, the main sources of dependable power in commercial quantities are the Winnipeg River, the Grand Rapids on the Saskatchewan River, the Churchill, Nelson, Berens, and others of the larger rivers of the north.

The first of these, the Winnipeg River, with its tributary, the English River, lies within easy transmission distance of the present commercial centres of the province. It can furnish an adequate supply of hydro-electric power to satisfy all anticipated power requirements of the present settled communities.

Such a statement as this possesses a degree of attractiveness that will readily be embraced by the various power-using industries of the province. The development of an adequate supply of dependable water power, in the face of an alarming and constantly increasing price of coal for steam production, combined with the scientific progress that has been made in the manufacture of power generators, transmission apparatus, and equipment for economical consumption of electricity, unite to endorse unhesitatingly authoritative steps to increase the industries at present in operation or under contemplation. To this should be added the demand for hydro-electric energy for transportation and municipal enterprises, such as are springing up in and around the city of Winnipeg, and which have made the question of power development on the Winnipeg River one of the most important administrative matters that is occupying the attention of the Department of the Interior. Fortunately a well-considered and cautious policy of water power administration has been determined upon, and regulations put into force which afford every reasonable protection to the public in the way of limited grants, rentals and control of rates, both subject to periodic revision, and at the same time providing sufficiently attractive opportunities for investment to actively interest the capitalist.

Consistent with the policy of the Dominion Government, the Minister of the Interior has instructed that all vacant Dominion land contiguous to power sites on the Winnipeg River, or any other river in Manitoba, be reserved for disposition only under the water power regulations referred to.

It was early found necessary, in connection with the consideration of sundry applications for power privileges on the Winnipeg River in Manitoba, for the Water Power Branch to have extensive power and storage studies made of that portion of the Winnipeg River within the province of Manitoba. These investigations show that at eight distinct power sites, by means of storage easily and cheaply accomplished at the Lake of the Woods, at Lac Seul and at other lakes in the province of Ontario, it is possible and economically feasible to develop over 409,700 continuous 24-hour horse-power all within 80 miles of the city of Winnipeg and within feasible transmission distance of all commercial centres of the present settled portions of the province.

Of the eight possible power sites on the Winnipeg River there are three now under development, representing a total power capacity of 199,000 24-hour horse-power. One site is completely developed by the Winnipeg Electric Railway Company on the Pinawa Channel, and produces about 26,500 h.p. under most favorable conditions. Another site at Point du Bois Falls, developed by the city of Winnipeg, produces at the present time about 20,800 h.p., but is capable of extensions to a maximum of 77,000 24-hour horse-power. Development at the third power site at Great Falls, having a maximum possible development of 95,500 24-hour horse-power, is about to be commenced.

There is, therefore, at the present time about 47,300 h.p. produced on the Winnipeg River, and transmitted for use in and around the city of Winnipeg, which can with the two present plants be increased to 103,500 24-hour horse-power.

The five remaining power sites on the Winnipeg River are under the control of the Dominion Government, and can furnish a further amount of 24-hour power to a maximum extent of 210,700 h.p. In addition there are several important power sites on the Winnipeg and English rivers within the province of Ontario, which are within easy transmission distance of Winnipeg.

It is interesting to note that the Winnipeg River in its natural condition forms one of the most notable power rivers in the world, having a total drop in the province of Manitoba of 271 feet, and in average years its maximum flowage being only about four times its minimum—about 12,000 c.f.s. Full information regarding the enormous potential power resources of the river is set out in detail in the report by Mr. J. T. Johnston, Hydraulic Engineer of the Water Power Branch, under whose direction the surveys and investigations of the branch have been carried on.

With respect to the rivers in the far North, it is stated that the power possibilities associated with them will be of great importance to the future development of this portion of the province, although little is known of them at the present time, the only available data being from reconnaisance surveys. However, the data is sufficiently reliable to indicate that enormous amounts of dependable power, capable of economical development, are there.

With the exception of the information in the report relating to the Winnipeg River the preparation of the material was commenced by Mr. Douglas L. McLean, then chief engineer of the Manitoba Hydrographic and Power Surveys. Since his resignation in October, the work has been carried on by Mr. S. S. Scovil, assistant engineer, to whose energy and resourcefulness Mr. Challies, in his letter, pays tribute for the compilation of the material in the short time available.

The Fort William plant of the Canadian Car and Foundry Company will be in readiness to operate about May 1st. As to whether it will be started up immediately upon the completion depends, of course, upon the abundance of orders for cars, but it is altogether likely that the plant will not delay in getting into operation.

WOODEN STRUCTURES.

By J. A. Macdonald, Ottawa, Ont.

IN a great forest country like Canada, wood, as a material for the construction of viaducts, bridges, trestles, etc., can frequently be selected in preference to stone, cement or steel, on the score of economy; and also owing to the comparative rapidity with which such structures may be erected. Wood is, of course, very inferior to these other materials as regards strength and durability, and in construction work the inherent defects of wood must be counteracted as fully as possible. Experience has shown that the most simple combinations of timber are superior for strength to complicated systems, and the latter have become almost entirely abandoned. By calculation, a scientifically framed truss may be made, but the impracticability of making such a perfect assemblage of the timbers as the calculations would have been based upon, renders such complicated combinations unwise. Moreover, to obtain even that degree of perfection of which practice is capable, we must resort to an excess of strapping, bolting, keying, mortising, and jointing of every description, which becomes very expensive, and when we have done all this, the destructive effects of rain, sun and wind increase in the very proportion of complication embodied in the system of construction. Besides, also, an unavoidable quantity of moisture is wasted, which might have properlv been reserved for an increase of strength under a more simple mode of treatment. The intention of a truss, composed of a multitude of timbers, is not only an equable distribution of the superimposed weight, but also a dispersion of the shaking and vibration resultant from the motion of weight. Nothing but the very best workmanship must obtain, and we all know how extremely difficult this may be, however great the expense incurred.

The Mortise and Tenon.—A few words on details may be of some service to the reader. Timbers are connected by various types of joints, the most simple being generally the best. Fig. 1 shows a tenon and mortise. The thickness of the tenon, *T*, is made, according to the best engineering authorities, one-third the thickness of the timber on which it is cut, and the size of the mortise, *M*, corresponds to the dimensions of the tenon. The depth of a mortise should exceed that of the tenon by a small amount for a more perfect joint. The shoulders of the tenon should be exactly in line, and perpendicular to the axis of the timber. When acting by suspension, little depth is required if a strap be added; an oak treenail should be driven through the timbers, the holes being bored after the tenon is in the mortise. The diameter of the treenail should be, according to Colonel Emy, "one-quarter the thickness of the tenon, and the hole bored for its reception should be two-thirds from the end of the tenon," as shown in the figure; but the value as regards the strength of a tenon and mortise should be independent of the treenail. This is for a rectangular mortise and tenon. Fig. 2 shows an oblique joint of this description, and is self-explanatory. The above description of joint, though common, is not the best kind, the timber, T, being weak at the point, *a*, and liable to fly. Fig. 3 is a better system, where *T* is partly joggled into *M*, and *s x* is made of from about one-fifth to one-fourth of the thickness of *M*.

In setting out a joint of this kind, with a single joggle and no tenon and mortise, to find the direction of *s x* (Fig. 4) draw the central axis of the timbers, and *o s* will give the direction of *s x*. Or, divide the angle *a s b*, and the line *s v* will give the direction *s x*. Another method is to make *s x* perpendicular to *s b*; and another, from *c* as a centre with a radius *c s*, describe an arc, on which set off from one-fourth to one-fifth of the thickness of the timber *M*. It must not be forgotten that too sharp an angle at *x* is likely to make *M* fly at *x*.

Scarfing.—It is always expensive to obtain timbers of large scantlings and great length, and when a beam of 24 feet or more is required, we have generally recourse to scarfing which, it is unnecessary to add, is a joint in which the ends of the timbers are cut and overlapped so as to present a uniform appearance. Some are partial to complicated scarves, but there should be no greater faith in them than in complicated trusses, much for similar reasons, and because so much hacking of the timbers must weaken it. Moreover, they become very expensive.

In a scarf it is evident that the bearing surfaces have to support the strain, and therefore the greater the quan-

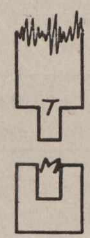

Fig. 1.

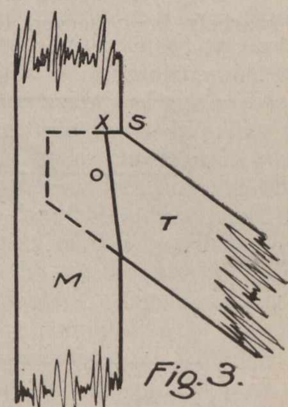

Fig. 3.

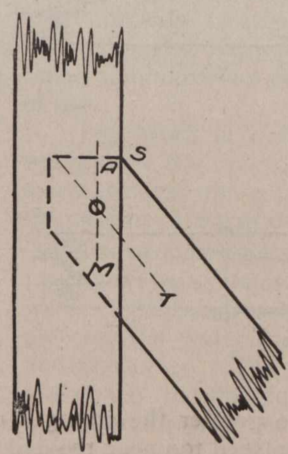

Fig. 2.

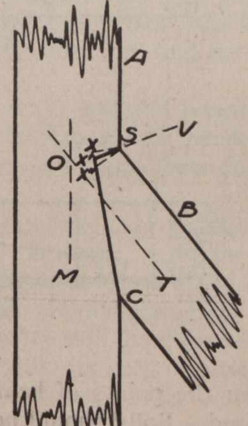

Fig. 4.

tity of surface the greater the strength, provided the best form be given. Therefore, a long scarf is stronger than a short one, for the same reason that any strength at all is gained by a scarf, but a great waste of timber and much workmanship involved. One important consideration, and which should never be lost sight of, is the strain to which a scarf will be exposed, compression or tension.

Scarves are greatly strengthened by iron bolts and oak keys. Where the surfaces of the scarfing are square, iron bolts are preferable to keys. The contrary is true where the jointing surfaces are oblique to the fibres of the wood. Let Fig. 5 represent a beam scarfed at *W*, where it is exposed to a strain from the weight at *W*. The upper portion of the beam is exposed to compression. The rectangular bearing, a, is therefore the most appropriate, as an acute angle formed by a line parallel to b, would, on the beam being compressed, act like a wedge, and tend to make the upper portion of one beam fly. But this is reversed at b, which point would tend to open by tension. Of the keys, c and d, the first would be under compression, and the latter would be loosened. Being near the neutral line, the tightening and loosening would be comparatively small, unless the beam were loaded beyond its safe bearing strength. Also c, under compression, would tighten the beam *a*, and though *d* would not do the same at *b*, the bevel joint must prevent any evil results. Whether we have one, two or more keys, the single or aggregate depth should not exceed the depth of the beam. Neither should they be too violently tightened when driven. This scarf is short and considerable strength may be added by a bolt at *W*. It would be better still to place a bolt at *c* and at *d*, with the key in the centre, as in Fig. 6.

Fig. 7 is strong enough for most purposes. It need scarcely be observed that the further the scarf may be

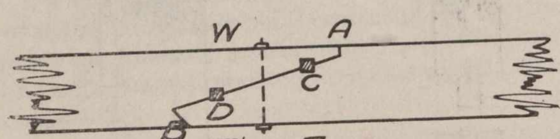

Fig. 5

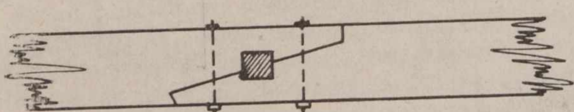
Fig. 6

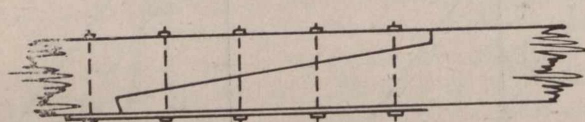
Fig. 7

from the points of bearing, the greater the strength required. Bolts should never be placed too near the end of a beam. Wrought iron straps are great auxiliaries of strength, and may be very advantageously used in connecting timbers, whatever may be the joint, provided always that tension be the strain to be resisted. It has been very cleverly remarked that a skilful workman never employs many straps, but however skilful a carpenter may be, he cannot prevent the effects of atmospheric influence; neither can he give to comparatively new wood the properties of well-seasoned timbers. No man who knows anything about designing in wood, would consider straps as factors of strength in his construction work, but simply as fastenings and auxiliaries. They are perfectly admissible, of course, in moderation, and are becoming daily more in use. Before use, straps, and indeed all iron work, should be heated to a blue heat, and struck over with raw linseed oil. This is much preferable to paint as preventative from rust. A strap 1 inch wide may be made ¼ inch thick; 1½ inches wide, ⅜ inch thick; 2 inches wide, 7/16 inch thick.

Cast iron plates and shoes are also very useful to receive or to equalize the thrust from the ends of butting timbers; the first particularly where employed as a connecting surface between the ends of timbers, which from shrinkage, defect of workmanship, or otherwise, may come to bear upon opposite angles, instead of the whole area of their intended connected surfaces.

Wooden Piers.—As regards piers, too much depends on circumstances connected with the nature of the natural foundation to recommend any particular plan. According to these circumstances, it may be advisable to build entirely of wood or of masonry and wood. It must not be forgotten that wood exposed alternately to wet and dry cannot last long, and this, therefore, is one reason for employing stone or concrete in water or marshy ground. On the other hand, in weak ground wooden piers are preferable, and sometimes it may be advisable to make a wooden pier occupy an area of considerable extent, in order to spread the effect of a superincumbent weight over a greater surface; and thereby, to a certain degree, neutralize this effect. Such may be the case in working over ground that is peaty to any considerable depth.

To Ascertain the Cohesive Strength of Timber.—The tension that timber will bear, when the force acts in the direction of the axis of the timber may be calculated by multiplying the area in inches by the proper "tabular number" from a table of specific gravities. For example, to find the force that will tear asunder a piece of 4-in. by 4-in. fir, we have an area of 16 square inches, and the tabular number is given as 9500; thus $9500 \times 16 =$ 152,000 lbs., one-fourth of which would be taken in practice for a perfectly safe load.

Given the load, the size of the scantling may be calculated by reversing the method.

Not long since the River Euphrates was diverted from its new course at Hindlieh, where the firm of Sir John Jackson (Limited) have recently completed the first great barrage in connection with their extensive Tigris-Euphrates irrigaton works. This is a part of Sir William Willcock's scheme upon which the Turkish Government originally proposed to expend some twenty millions sterling. The whole operation of turning the river into its new course passed off most successfully. The river was diverted by a dam, held up by a barrage, by means of which the water can be distributed through a regulator down the old Hilla branch past Babylon to ancient Hilla. The barrage was built to the east of the river bed. It is 800 feet long, and consists of thirty-five arches fitted with sluice-gates, each sixteen feet wide. The piers are nineteen feet high and four feet thick and the key-piers eleven feet. They rest upon a foundation of three feet of concrete and six feet of brickwork. The barrage will raise the level of the water twenty-two feet. Another barrage has been built immediately below the upper Hindlieh barrier. This was a perfectly straightforward bit of work, consisting of a lock and a huge shelf of masonry. By these means a dam of 130 feet thick has been flung across the river, which is 520 feet wide at this point, and the water turned into the new bed. When all these works at Habbania and Hindlieh are complete, with the smaller irrigation canals, some 600,000 acres of land will receive a plentiful and constant supply of water; and the ancient problem of the Babylonians will have been solved by British engineers.

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WATER MUNICIPALITIES IN BRITISH COLUMBIA.

Legislation is being planned in British Columbia for the establishment of municipal organizations to control the conservation and distribution of water for irrigation purposes. If the bill which will shortly come before the provincial legislature becomes law, farmers in the dry belts will be in a position to co-operate in the operation of irrigation systems. It will make possible the joint ownership and control of irrigation enterprises in any locality where the lands are so situated that they can be irrigated from a common source and through a common system. Such a bill will affect considerably the Okanagan, Kamloops, Southeastern Kootenay, and Ashcroft districts.

This bill for the formation of water municipalities is the logical sequence of the revision and consolidation of the Provincial Water Act, which revision was completed last November. The complicated subject of water legislation, although established in British Columbia to a degree that has drawn praise and compliment from prominent irrigation authorities, has experienced a severe handicap in the loose methods of administration that naturally prevailed in the earlier history of the province. The efforts to bring water records up-to-date has uncovered numerous vagaries and clauses uncertain in meaning. Dissatisfaction among water holders brought about the passing of the Act in 1909, and the appointment of a board of investigation. The duty of this board has been to determine existing rights to the use of water in various streams. The making of satisfactory adjucations has required careful surveys and the compilation of accurate hydraulic data. Points for investigation included the minimum and maximum supply and consumption at different periods of the year; the capacity and safety of storage works, the points of water diversion, the lines of canal, the individual points of distribution, and the nature of use.

This work is well under way, and the board of investigation has already held numerous final hearings on many streams where conflicting rights have been for years the subject of warm dispute.

The proposed bill contemplates the expropriation of all private water systems. It will, however, leave the actual water rights on streams standing in favor of the individual owners, the water municipality simply acting as carrier and conserver. The municipality will have government assistance in the formation of its organization and in its preliminary survey and hydrographic work. Its boundaries are to be fixed by the government upon the advice of the investigating board, each district to take care of all the agricultural land within those boundaries that is adaptable to irrigation.

MONTREAL'S INEVITABLE WATER INVESTIGATION.

The catastrophe which befell Montreal toward the close of 1913 will long be regarded by its citizens as unparalleled in the history of any Canadian city. Regretably the civic finger of censure is levelled at its engineering department, and public indignation is running high. The loss of millions, due to forced industrial inactivity, is lightly considered in comparison with the exposure to fire, cold and pestilence, to which the city found itself a helpless victim.

As a result, it is a subject of open comment that the department responsible for the conditions which culminated in such a disaster should be "cleaned up" forthwith; and that no board of investigation can rightly do otherwise than recommend the immediate removal of certain officials.

Montreal, for some reason or other, has allowed to be associated with its administration a reputation for municipal inertness, deep and of long-standing. Efforts to institute improvements in government have, as a general rule, come to naught. We recollect the city's procrastination in the matter of raising the tracks of the Grand Trunk Railway, the elevation of which would now cost the city many times the amount it would have cost when the question first arose. Again, the case of the Montreal's Tramways Company has dragged on through a number of years without apparent attempt at satisfactory solution. The proposal to purchase the Montreal Water and Power Company has had no unsurmountable obstacles in its way, according to prominent authorities. We do not mention these instances except to authorize a deduction that Montreal does not differ from the average city in the matter of putting off the undertaking of large municipal improvements.

These and similar features of the civic situation in Montreal create an impression that it would be unjust to lay all blame of the failure in the water supply to the fact that the City Engineering Department did not have a duplicate service main to throw into commission when it was so badly needed. In a November issue, *The Canadian Engineer* urged the City of Ottawa to consider, again, the inadvisability of depending entirely upon a single pipe line in connection with its proposed water scheme. The Montreal disaster is an instance in which a duplicate conduit would have saved its citizens its cost of construction times over, apart from the existing dangers to life and property.

But the engineering department of the average city does not entertain the blessed privilege of being immune from such contingencies as the above. It operates in accordance with the dictates of the administration, which is representative of the citizens, and in control of all civic expenditure.

Montreal's water situation has been a problem for fully half a century. It has been undergoing solution. The question is: has the progress been hampered by municipal inertness? The board of investigation will necessarily look beyond the past few weeks in its endeavor to provide the citizens of Montreal with an adequate reply to their query—What is the matter?

SPECIALIZATION AND REMUNERATION.

In addressing the Manchester section of the Institution of Electrical Engineers of Great Britain, Prof. E. W. Marchant recently drew attention to the fields of employment open to the electrical engineer. He dwelt to some length upon his opportunities and the financial prospects which they afforded him. He gave it as his opinion that the great majority of engineers engaged in the electrical industry are much underpaid, with the result that many men who have undoubted ability are leaving the profession, to its great detriment.

The Financial News (London), in commenting upon the remarks of Prof. Marchant, hazards the opinion that his statement might apply with equal appropriateness to men of the civil, mining, mechanical, or other branches of engineering.

"In engineering," it states, "as in everything else, there are plenty of opportunities for men to come to the fore. The trouble is that there are so few, comparatively speaking, who possess any initiative; so few who have the ability to see an opening and avail themselves of it at once, before it is closed forever. There is a certain allurement in setting up for oneself as a consulting engineer, or taking up one or more promising agencies. These are, however, stereotyped—the sort of thing that every engineer thinks about at some time of his life. But years of leanness have to be gone through before success comes to the consulting engineer, and even the most promising of agencies require a good deal of hard work before they bring in adequate remuneration. It must be in other and less hackneyed directions that the engineer must look who wishes to widen his scope. Yesterday was for the general engineer; to-day is a day of transition; but there is no possible doubt that to-morrow will be the day of the specialist, and unless an engineer specializes he will remain one of the rank and file, and never be able to get out of his field into one which will offer better prospects."

The specialization that is spoken of is everywhere regarded as commendable within certain limits, as the range of engineering work has become so extended that it is now necessary to specialize in practice. Still, it has an objection in that, rather than bringing about much "widening of scope," the engineer's mind is largely closed against other specialties. There are men of talent who have devoted their labors to the design, for example, of an electrical device, or to the stress diagrams for a truss bridge, until they seem impressed with the idea that their special work is the sum and substance of engineering. There is a tendency here for the young engineer to overlook the opportunities. He lacks, not the ability to see an opportunity, but contact with the opportunity itself. He possesses a remote idea that some day he will be chief engineer or head of a consulting engineering firm, that great works will be done under his direction, that he will plan immense structures and solve gigantic problems. But, as to how these attainments may best be reached, his mind does not go much farther than to think that they will come to him when he is older. This is often the result of narrowness of vision, produced by over-specialization.

It devolves, therefore, that with "specialization for the engineer," one must associate the danger of over-specialization for the young engineer. To it is to be added an admonition to keep well before his mind those things which he hopes to attain, and to work towards them. The specialization necessary, and the remuneration, too, will each strike new levels as he advances.

EDITORIAL COMMENT.

The Canadian Northern Railway has taken a decidedly commendable and progressive step in organizing a special department to devote its energies to the prevention of fire along the company's lines. This new department will have charge of right-of-way clearance, fire patrols through timbered country, and the construction of fire guards through the prairie sections. The prosecution of protective work along these lines is following out the mandate of the Railway Act and of the Dominion Board of Railway Commissioners.

MONTREAL'S WATER SUPPLY SYSTEM AND ITS RECENT FAILURE

HISTORICAL OUTLINE OF THE DEVELOPMENT OF THE $7,000,000 WATER SCHEME—ITS PRESENT SITUATION—THE RECENT BREAK, ITS SERIOUSNESS AND ITS REPAIR

THE City of Montreal has experienced one of the most serious occurrences that could befall any city with respect to the carrying on of business and the safety of its citizens from fire and disease. On December 25th, the reinforced concrete conduit, which provides the water supply for the city, failed by bursting at a place on the line where adjacent engineering work had excavated to the extent of five feet, or so, below the invert level of the pipe and a minimum distance of 17 feet to one side of it. Several opinions have been advanced as to the cause of the break, but it is generally conceded that it has been the withdrawal of that portion of the support, as mentioned. A full inquiry, to be proceeded with immediately, will no doubt determine whether or not this is correct.

A brief description of the construction of the conduit, together with the circumstances connected with it, may be of particular interest at this time. Originally, an aqueduct built by Mr. T. C. Keefer, of Ottawa, provided the water supply for the city. It was an excavation with a depth of eight feet, a main width of thirty feet, and a fall of approximately five inches per mile. This aqueduct conducted the water from a point in the St. Lawrence River about one and a half miles above the Lachine Rapids and distant approximately nine miles from the centre of the city. This point is thirty-eight feet above the level of the water in Montreal harbor.

In 1877, improvements were undertaken, but they were discontinued owing to a change of plan after about 4,000 feet of the entrance end had been widened to 140 feet, and to a depth of 14 feet. A general profile of the aqueduct before enlarging, together with the proposed enlargement, is shown in Fig 1. Since that time, several schemes have been advanced for a greater and better supply. That suggested by Mr. George Janin early in 1904 included a proposed concrete conduit with a daily capacity of 50,000,000 gallons. The object was to prevent contamination, to which the water supply had for many years been subjected. It may be stated that the danger from pollution hailed from two sources. The Ottawa River brought an impure supply into the St. Lawrence above Lake St. Louis at the western end of the Island of Montreal; and there existed a further liability of contamination of water en route through the open aqueduct. Mr. Janin's recommendation provided for the extension of the intake out into the river some 1,400 feet to clear the Ottawa water which kept well to the northerly shore at that point; and also for immunity from infection after leaving the river, by an enclosed supply line. Another feature of his scheme was that, as this conduit would supply water for drinking purposes, the aqueduct would be used as a canal for power and industrial purposes. When this supply line was established the aqueduct would be emptied and extended in width and depth to make it conform in cross-section with the enlargement begun in 1877.

The Construction of the Conduit.—The recommendations of Mr. Janin, then chief engineer and superintendent of the Montreal waterworks, were approved by a board of engineers acting for the municipal council, and the contract was let to Mr. Patrick McGovern, of Boston, on September 6th, 1907, for the sum of $785,000, the chief engineer's estimate prepared in 1905 being $660,000.

Work was commenced on the conduit in October, 1907, and the job was to have been finished before the end of 1908. Owing to infiltrations from the adjacent aqueduct, however, serious delays were experienced on several occasions, and the conduit was not fully completed within the specified time.

The conduit, the general direction of which is shown in Fig. 2, lies in earth of widely varying composition, from stratified limestone rock to clay which is hard when dry but very unstable when wet. The depth of cutting also varies from 10 to 35 feet. A section of the pipe is shown in Fig. 3. It is of horseshoe shape. The radius of the invert is 13 feet, with a thickness of 8 inches. The inner face of the sides and arch constitute a segment of a circle of 4½ feet radius. The thickness of the crown and lower portion of the sides is 8 inches, while on the horizontal diameter, that of the sides is 12 inches. This section gives a clear inside height of 7 feet 3½ inches, and a width of 9 feet. The walls are of concrete reinforced with No. 7 and No. 12 B. W. G. mesh, the larger strands being 4 inches and the smaller 12 inches apart. This reinforcing was used around the whole perimeter, where soft soil was encountered. Where the foundation was firm the steel went to about 1 foot below the springing line. Specifications called for a 1:2:5 mix of concrete throughout. For the invert and lower side the broken stone ranged up to 1½ inches in size and for the crown and upper part to ¾ inch. In no case was the reinforcing to come within 3 inches of the inner walls.

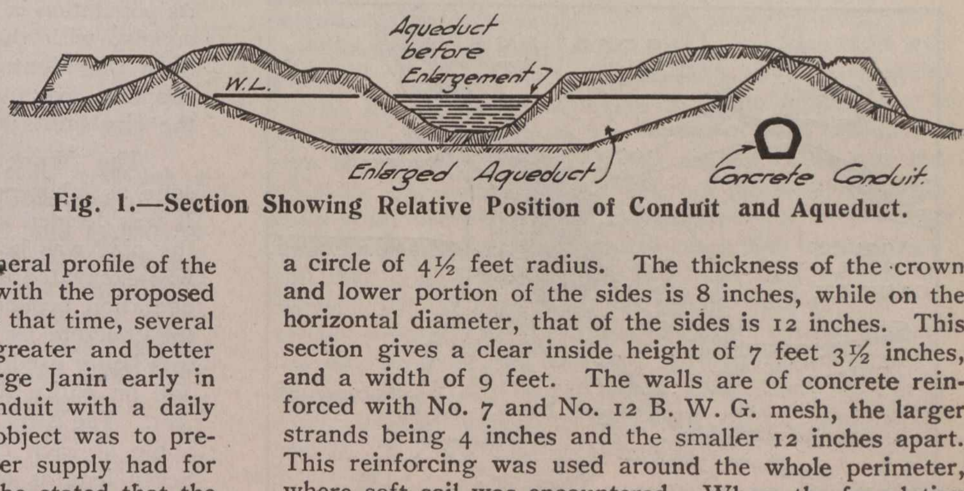

Fig. 1.—Section Showing Relative Position of Conduit and Aqueduct.

The conduit has a grade of 1 in 5,000. Under normal flow the water has a hydraulic gradient of 5 to 10 feet above the top of the pipe.

Other Improvements.—The construction of the concrete conduit was a part of the general scheme of development. A pier about 1,000 feet long had been built at the mouth of the aqueduct to reduce the current in the river. Sluice gates and movable gates in dams, of which there were two, regulated the level of the water. In 1910, Le Moyne, Fils and L. A. Dery were awarded the contract for the intake, the price being $124,000. The widening of the aqueduct was also proceeded with, and the work was scarcely completed when it was decided to enlarge again with a view to supplying more water for power purposes. Along the enlarged aqueduct there were to be long stretches of boulevarding.

The filters that are being built are also a part of the scheme. Their general design, including the excavation and the construction of the pre-filters and final filters, together with a filtered water reservoir, have been described in previous issues of *The Canadian Engineer*. It will be remembered that in October, 1912, contracts, which had been awarded to the F. H. McGuigan Construction Company in 1911, were transferred to Mr. Norman McLeod. Owing to lack of protection during the winter of 1912, these filtration works suffered considerable damage from the action of frost on the partially completed structures, no provision for protection of the foundation having been made by the contractor. The disturbance by frost resulted in raising and badly cracking the main collectors and floor slabs. The pier bases were raised and tipped. The wall bases were generally raised and some of them severed completely through. Tipping of dividing walls and opening of expansion joints, together with the displacement of the roof groins, were much in evidence. With the warmth of spring, the floor slabs settled, and parts of the structure returned toward their original elevation leaving cracks at expansion joints, and causing considerable spalling.

Failure of the Reinforced Concrete Conduit.—The widening and deepening of the aqueduct has been in progress during the past several years, the present enlargement being carried on by the Cook Construction Company. It constitutes a water-line width of 174 feet and a depth of 18 feet. As may be imagined from Fig. 1, widening to this extent approaches the conduit closely. It appears that about the middle of December, the conduit showed signs of considerable leakage at a point opposite the Verdun Insane Asylum, where the conduit makes a slight bend concave to the Canal, and where the ground consists of loose material. Upon discovery of this the section of the conduit was laid bare and an attempt was made to prevent the leakage by caulking. The canal excavation work was discontinued forthwith. Stone and sand filling were put in behind an outer tier of sheet piling, and on December 23rd the repair work, which had been rushed night and day, was presumed to be efficient and satisfactory.

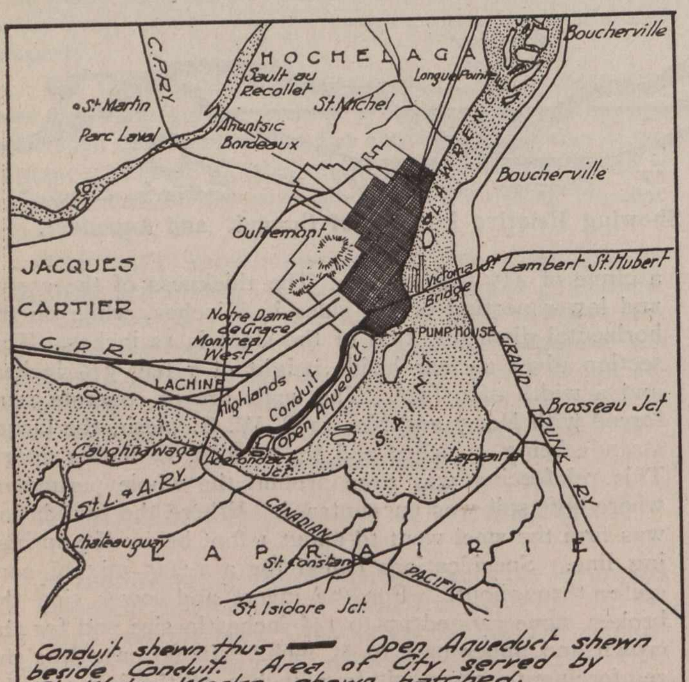

Fig. 2.—General View of Conduit and Aqueduct Location.

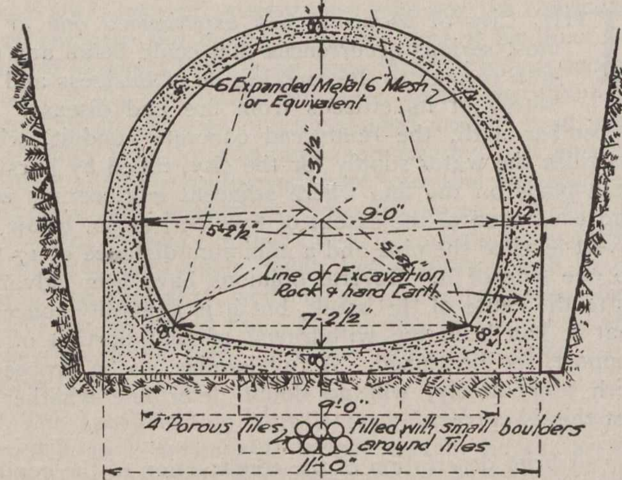

Fig. 3.—Cross-Section of Concrete Conduit.

About 5 p.m. December 25th, a section of the conduit about 60 feet in length broke from the lower portion of the southerly conduit wall at the point mentioned above, and quickly emptied the pipe. Evidently wash and undermining of the pipe had gone on practically unabated. This mishap deprived the City of Montreal, with its population in the neighborhood of 600,000, of its water supply, with the exception of a small domestic supply from the Montreal Water and Power Company, which supplies several suburbs and a few small districts within the city limits; and the distribution of water by carts.

The Work of Repair.—Operations commenced, as soon as laborers could be obtained, to mend the break. It was decided to insert steel pipe into the fissure. While the pipe was being constructed and delivered the break was excavated and the broken portion withdrawn, which operation occupied almost two days. Failing to break the concrete by mudcapping the drag-line bucket which was being used in the aqueduct was utilized as a sledge, and an entire section was removed to the extent of 62 feet. The steel pipe, in lengths of 18 feet, with a ring angle at each end as a bolting flange, was inserted. Seven lengths of it gave a lap of 32 feet at each end. The ends when in position were sealed into the conduit with cement mortar of 1:2:4 mix. The steel pipe with a diameter of 7 feet left a space of one foot on each side, and of 4 inches above and below, between the concrete conduit and the inner shell. Bricks, dropped in bitumen, were inserted as filling, and the concrete was poured directly on the top of the steel tube through holes drilled through the top of the conduit. Steam heating was introduced into the conduit to expedite drying, and coke ovens assisted, at the top and sides of the pipe.

Upon first trial the repair was found to be very inefficient due perhaps to hasty workmanship and insufficient time having been allowed for the concrete to set. The joints, which were equipped with rubber gaskets, were not tightly bolted and the flow of water through them resumed its undermining effect. This necessitated another emptying of the conduit, and more accurate work being done. The wooden staging supporting the new section was well overhauled. The concrete was more carefully introduced, after all perceptible leaks had been stopped, and was given a full 24 hours in which to set. In the meantime the conduit was very minutely inspected on the inside, throughout its length. As a final precaution large quantities of oakum and bitumen were forced into all interstices which showed any liklihood of weakness.

The head-gates were opened on the evening of January 2nd, and up to the time of writing the restored water supply has suffered no further interruption. Should a repetition of the break occur the old aqueduct will necessarily be put into commission as a means of water supply —a step against which the Board of Health has warned the city because of imminent danger from impurities.

During the eight days' deprivation the civic life of Montreal was in an inextricable state. At three points where the distribution system of the Montreal Water and Power Company approached that of the city, connections were made which provided 15 million gallons a day toward allaying the normal demand for 50 million gallons. Otherwise the circumstance would undoubtedly have been disastrous. Sanitary conditions were becoming alarming; residence heating was severely crippled, while several fires, luckily, mastered in time, showed the extreme helplessness of the situation in case they gained any considerable headway.

The paralytic effect upon industrial activities constituted a loss to be measured in millions. Practically all the large industries, of necessity, acted upon the advice of the mayor and closed down, throwing thousands out of employment.

OIL FUEL.*

By Alfred J. Liversedge.

THE philosopher-historian of the future will pay a good deal of attention to Power—Mechanical Energy—as a factor of the life and growth of nations. When, therefore, he reviews the closing years of the nineteenth century and the early decades of the twentieth, he will note a remarkable expansion in the development and utilization of mechanical energy, throughout nearly the whole of the inhabited globe. He will find this phenomenon manifested particularly in two directions, neither new—one, indeed, old almost as recorded history—but both of which have remained relatively dormant in the past—that is to say, water-power on the one hand, oil-power on the other. It is possible that he will date the rise of an oil age from somewhere about this period. He will surely remark that in the history of organized industry there had not been known hitherto an expansion more rapid in its pace, more remarkable in its character or farther reaching in its effects, than the growth in the use of oil fuel which this period exhibited.

The subject of oil fuel is a very large one, and it would be impossible to do justice to it as a whole within the limits that could be assigned to it here. Fortunately, it divides itself conveniently into several phases, according to the character of the appliances employed to develop the latent energy of the oil. There are three of these general divisions: oil as used for the direct production of light; oil as used in explosion or internal combustion motors for the direct development of mechanical energy; and oil as used in furnaces for the generation of steam, or for metallurgical operations. It is the last of these three phases with which we are here particularly concerned; the others may well be left for consideration on some future occasion, since their importance in industry also deserves our careful attention.

One is so accustomed to associate the idea of fuel with visible combustion in some form of furnace or fireplace that it is, perhaps, desirable to emphasize, in passing, the fact that, whether burned merely for the direct production of light, or consumed without visible flame in the cylinder of an explosion motor, oil is all the time being consumed as a fuel, just as truly as when it is burned in the furnace of a steam boiler. Elementary as this circumstance unquestionably is, it would appear to be often overlooked by those who advocate the substitution of oil for coal. A due recognition of this elementary fact will reveal how wide and varied may be the demand for oil fuel and how many different conditions may require to be taken into account in considering its possibilities in any particular connection.

The whole question has an interest of the first importance; indeed, it may be of a vital character for England. The foundations of the manufacturing greatness of the United Kingdom were laid on the banks of the little streams of Lancashire and Yorkshire, the Midlands, the West of England, the South of Scotland and the North-East corner of Ireland. Those insignificant streams furnished the mechanical energy needed in early days. The superstructure, represented by our position to-day as a manufacturing and commercial nation, has been built with pit coal. In other words, the sources of the mechanical energy by which our eminence in manufactures and in commerce has been won have hitherto been within our own borders and under our own control. The raw material for our greatest manufacturing industry comes entirely from overseas; much the greater part of our wool and a large proportion of our iron come also from abroad; and now it is suggested that we must look outside our borders for the raw material for our power. It is a serious proposition; a proposition which must, certainly, one day be faced, in view of the known limits to our stores of coal; and it is just as well to look at it now while the circumstances permit a calm and leisurelv survey.

Again, it must be remembered that power as a factor of the cost of manufactures is not diminishing in value, it is rather appreciating, and if oil can be substituted on the large scale for coal with the economy which may be attained under certain circumstances, it seems inevitable that the manufacturing centres of the world must gravitate to oil regions, provided only that such regious, of a sufficiently permanent character, are to be found. There, however, lies the crux of the whole position, and the first question calls for consideration.

The use of oil for steam raising is not new. Compared with its employment in explosion motors, its use in association with steam boilers is much the older proposition. Nearly fifty years ago petroleum was tried for some time on a railway locomotive in France, on the line from Paris to Epernay, with results quite encouraging from a

*Abstracted from his article in No. 1, Vol. 1, of the International Review, Dec., 1913.

technical point of view. The speed attained was nearly thirty miles an hour; the oil consumption something under 12 lbs. a mile. About the same time the United States government appointed a commission, of which the chief engineer of the navy was a member, to report as to the feasibility of substituting petroleum for anthracite on ships. The report was favorable, again from a technical point of view. The commissioners found that in regard to evaporation, petroleum had more than twice the efficiency of anthracite, weight for weight, while steam could be raised in one-third the time needed for coal. They, therefore, recommended the government to make a trial on a large scale on one of the ships of the navy, which was done. There were oil enthusiasts then as now, the claim being made that the net saving which the use of petroleum could effect on such a vessel as the then great Cunarder, the "Persia," would amount to $10,000 a trip.

The report of the United States commission was severely criticized on this side, but excited our own naval authorities sufficiently to lead them to make experiments and investigations as to the possibilities of the new fuel—at the time crude petroleum merely was in question. The whole proposition, however, collapsed on the publication of the results of the trials in the States, the conclusions arrived at being that the evaporative efficiency of petroleum as compared with anthracite was only 1.38 to 1, and thus fell far short of the theoretical anticipations, while, generally, "convenience, comfort, health, and safety, were against the use of petroleum in steam vessels, the only advantage proved being a, not very important, reduction in bulk and weight of fuel carried."

The world, of course, has moved since that time; what is more, the cost of oil has gone down with an enormously increased production, while the price of coal has gone up. Even so, until recently it was almost solely in connection with railway locomotives that the use of oil fuel for steam raising had been developed on any large scale. Naturally, the convenience of a liquid fuel which could be supplied and carried as easily as the water needed has appealed powerfully to railway engineers, and nearly every line of any importance has made experiments, more or less, with oil fuels.

In this country, (England) it may be said, the Great Eastern has, perhaps done more in this direction than any other of our railways. In the early stages of this development it was largely a question of utilizing the waste residues of the oil fields because they were waste, and thus relatively cheap fuel. Some interesting problems have in this way presented themselves. Very large quantities of waste residues of the Baku field, converted into a kind of briquette by a process analogous to the formation of a resin soap, have been used on the Russian railways, while the Roumanian railways use similar residues from the Roumanian oil fields combined with their lignite, soft, brown coal. It is obvious that in such cases it is the waste character of the residues which is the determining factor in their utilization as fuel, while it is also clear that this very character must limit the use to relatively local regions.

Needless to say that on the oil fields themselves these residues are utilized as far as possible for heating purposes. Such residues are so used in the works of the Scotch shale oil industry.

It is quite natural to find that in the United States the use of oil fuel on locomotives has been more fully developed—and, perhaps, on more scientific lines—than in any other quarter. The Southern Pacific alone, on its lines in Oregon, Nevada, Utah, California, Louisiana, and Texas, and on the steamship lines which it controls, uses over 25,000 barrels, about 3,500 tons, of fuel oil a day, or nearly 9,000,000 barrels a year. The company has now over 800 locomotives burning oil fuel. Tests made by the engineers of this company have shown that where the mileage per ton of coal has been 5.7, the mileage per barrel of oil has been 1.63, equivalent to 11.4 per ton of oil. The total consumption of oil fuel by the locomotives of the United States, which in 1910 was nearly 24,000,000 barrels, or 3,400,000 tons, is now, probably, at the rate of 28,000,000 barrels, or 4,000,000 tons a year, which, if the tests just mentioned may be taken as a fair guide, is equivalent to 8,000,000 tons of coal. The railways of the States also use large quantities of oil fuel at their depots in the furnaces of stationary boilers. The railways of Mexico and of Austria-Hungary are also now largely operated by oil fuel.

In Canada the Canadian Pacific are using oil on their main line from Kamloops to Field, British Columbia, while the Grand Trunk are also using some proportion. At present these companies have to obtain their oil from the Californian fields, but it is apparently expected, or at least hoped, that future discoveries in Alberta and British Columbia may place the companies in a better position, in due time, in regard to this class of fuel.

It has always been on board ship where oil fuel has been expected to display most fully its advantages over coal. Certainly there is nothing like marine experience to test the merits and develop the capabilities of a fuel proposition, and there can be no question that very great improvements have been made during recent years in the construction of the apparatus employed to burn oil fuel in the furnaces of steam boilers. All the appliances used for this purpose operate by spraying or pulverising the oil with the object of "atomizing" it to the fullest possible extent and thus securing perfect combustion. In a recent French technical journal twenty-three different systems of such oil burners were illustrated. The systems mostly employed may be divided into three classes, as follows:—

1. Spraying by steam jet.
2. Spraying by compressed air.
3. Spraying solely by mechanical pressure on the oil.

The first is the cheapest arrangement to install, but apart from other objections which may be raised to it, so far as ships are concerned, it is practically put out of court by the fact that it necessitates an extra supply of fresh water, a serious consideration where all the fresh water must be distilled. Air-spraying has attained a certain measure of success, but it is the third, or pressure system, which is now being most generally adopted. The British Admiralty use the pressure system exclusively. Very successful apparatus embodying the principle of mechanical pressure are represented by the Babcock and Wilcox system, which has been fitted to over 300 boilers, equivalent to about 500,000 horse-power; the Wallsend-Howden system, made by James Howden & Co., of Glasgow; and the system supplied by Messrs. Kermodes, of Liverpool, who were the pioneers of this method of oil burning. There is no reason to question the substantial accuracy of the evaporative results said to have been obtained by these systems of oil burning for the raising of steam.

The oil fuel used for steam raising on board ship may vary considerably. It may be shale oil or crude petroleum, or any fraction or combination of fractions of crude petroleum, left after the spirits and (generally) the illuminating oils have been removed, except that it must have a certain limpidity to permit it to flow freely, when slightly heated, through the pipes of the oil burners. The latest specification of the British Admiralty does not permit a lower flash point than 175° F.-Abel close test, or more than 3 per cent. of sulphur or 0.5 per cent. of water, but within the broad limits thus allowed the oil may be anything. As commonly sold as fuel oil, the calorific value may range between 17,000 and 20,000 B.t.u. The best Welsh steam coal will have a calorific value of from 13,500 to 14,500 B.t.u., hence the theoretical relative heating values of oil fuel to the best coal may be taken as 18,500 to 14,000, or the oil has not quite 33 per cent. more value than the coal. A much higher relative efficiency is usually claimed, and must be admitted where average bituminous coal is made the basis of comparison.

Some exhaustive tests made by the U.S.A. naval authorities gave an average relative efficiency expressed in lbs. of water, evaporated from and at 212° F., of 14.45 per lb. of oil consumed to 9.31 per lb. of anthracite coal, thus giving the oil an advantage of over 55 per cent.; but it would certainly appear that a better result should have been obtained from the coal, as it no doubt would be in the best modern steam boilers burning the best coal. As a matter of fact, another series of tests by the same authorities, using hand-picked Pocahontas coal, having a calorific value, dry, of 15,200 B.t.u., gave the relative values of 14.2 for the oil and 10.9 for the coal, the advantage of the oil being thus a fraction under 33 per cent. Still it may be taken that oil fuel has an advantage over good coal of from 33 to 55 per cent. in heating value. It is, of course, this undoubted higher value, *combined with the other advantages* of liquid fuel, which is leading to the adoption of this fuel for ships, and appears likely to result in its use to the exclusion of coal, by all the war navies of the world.

A very competent authority has recently stated that, "The time is fast approaching when oil will be exclusively adopted for all ships, notwithstanding possible higher cost, estimated at 33 per cent., when allowance is made for higher evaporative efficiency." So far, however, the actual tonnage of shipping driven by oil fuel is a very small proportion of the shipping of the world. Probably the total number of merchant vessels now fitted for burning oil fuel does not exceed 250, representing, perhaps, 700,000 tons gross, and very few of these burn oil fuel only. These are exclusive of oil-tank steamers, which now constitute a fleet of something over a million gross tons. In the Pacific, naturally, the conversion into oil burning is proceeding rapidly for the same reason that the United States railways and the railways of Mexico and of Austria-Hungary have so largely adopted oil—the fuel is at hand.

Nor is the proportion of the fighting vessels of the world burning oil fuel as yet very large. Most modern torpedo-boats and destroyers burn only oil, but of the battleships and cruisers none burn oil exclusively. The newer ships are fitted to burn either coal or oil, but coal still retains an enormous preponderance, and must for some time keep it, as the fuel of the fighting ships of the first class. Hence the interest which has been aroused by the announcement of the U.S.A. naval authorities that their new super-Dreadnoughts shall burn oil only, and of our own First Lord that the British Admiralty, in certain of our newest vessels, will follow the American example. At the moment it would appear that the German navy is, perhaps, more completely fitted for oil burning than any other navy of the world.

The situation on land in regard to oil fuel is a very interesting one. Professor Vivian B. Lewes, in the admirable little work on "Oil Fuel," recently issued as one of the "Nation's Library" series, remarks, "At the present time the internal combustion motor plays not only the most important part in power reduction, but also in fuel economy." The statement cannot, of course, mean that gas and oil engines now develop a greater amount of power than the steam engine, but undoubtedly the time is coming when they will do that. At the moment, however, while oil is, to a certain limited extent, through the medium of the oil engine, displacing coal as a source of mechanical energy, it is not displacing coal to any appreciable degree as a fuel for steam boilers in the great manufacturing centres of the world, and that for obvious reasons. The present price of oil fuel in this country, for example, is $17.50 a ton in bulk ex wharf; it was recently more, and may be so again at any time. Thus, granting the highest value, from a calorific point of view, claimed for oil fuel, it is still more than twice as costly as the best steam coal, and up to three-and-a-half times as expensive as other good coal, according to locality. We are thus brought back to the crux of the whole question of oil fuel. What are the prospects or probabilities in regard to the supplies? It is impossible to deal fully here with this vital point, but one or two general considerations may be briefly set out.

Our most eminent authority on mineral oil, Sir Boverton Redwood, opens one of the sections of his great work on "Petroleum" as follows: "In the solid, liquid or gaseous forms bitumen is one of the most widely diffused of substances. It is found in greater or less quantity in almost every part of the globe, while its geological limits include the whole range of strata, from the Laurentian rocks to the most recent members of the Quaternary period." Almost exactly the same thing may be said of gold; but, meanwhile, the actual production of mineral oil, notwithstanding its wide dissemination through the rocks of the earth, does not keep pace with the world's needs. The countries of the world now producing a million tons or more of petroleum a year are the United States, Russia, Mexico, the Dutch East Indies, Roumania, and Galicia. The oil of these countries accounts for 97% of the world's output at the present time.

Of these countries the Russian and Galician productions appear to be actually declining; the increase in the output of the United States in 1912, as compared with 1911, was trifling—if, indeed, there was not an actual decline. The productions of the Dutch East Indies and of Roumania are slightly gaining, but the only one of these great oil regions which shows any important expansion is Mexico. What appears to be happening in most of these regions is well illustrated by the case of the United States, and, after all, the States still provide practically 60 per cent. of the world's output. The production of crude petroleum in the States for the three years, 1904-6, was 50,400,000 tons. The output for the following three years, 1907-9, was 70,370,000 tons, an increase of 20,000,000, or 39 per cent. The yield for the three years, 1910-12, amounted to 87,000,000 tons, representing a gain on the receding triennial period of 16,600,000 tons, equivalent to 23 per cent. Thus the rate of increase in the production of the States is rapidly falling off. It remains to be seen what will be the next phase, but there can be little doubt as to what it must prove to be.

It must be remembered that the production of mineral oil in the United States is no longer confined to a small area—as is still the case in Russia, for example. Every State in the Union has been exploited for oil, and at the moment seventeen States contribute supplies. It would appear, therefore, that the United States cannot hold any more new oil regions, and that if the output is to grow, or even to maintain its present dimensions, it can only be by more perfectly exploiting the existing fields.

In the British Dominions there is only one region which yields any appreciable amount of mineral oil—Burmah; and while the production of Burmah, with some other regions of British India, shows a gratifying expansion, the total does not yet amount to a million tons a year. The production of Canada is trifling and is not increasing, while Trinidad, of which so much has been expected, is still in the "hopeful" stage.

Nor can it be too often or too insistently impressed upon everyone interested in the question of oil fuel as a substitute for coal for steam-raising on land or sea that the proportion of the petroleum of the world available for use in this connection is very small even now, while the rapid development of the spirit-motor on the one hand, and of the oil-engine on the other, is certain to make that proportion much smaller in the immediate future. Moreover, while much may be expected in due time from modified methods of treating coal, and something from shale, at the moment petroleum represents practically the only source of oil fuel.

It is obvious, therefore, that a policy of the most careful circumspection in regard to the adoption of oil fuel, whether in the Navy or in the mercantile marine, or for use on land, can be the only safe policy for this country to pursue. The authorities of the U.S.A. navy are under no misapprehensions in regard to the chances of oil fuel, and one cannot better conclude the present writing than by setting out the following extracts from a recent letter of Mr. Secretary Lane to the Secretary of the Navy. Mr. Lane remarks: "Crude oil will be available, particularly in Californian fields, for at least a generation to come. . . . . . Twenty years hence the price of fuel oil, which then, as now, will be produced chiefly in California, will be much higher than at present, and the production will probably have seriously declined. . . . No relief can be expected in the price of oil fuel at Atlantic ports for commercial uses. Relief for the navy can probably be secured only by the development of its reserves, where it should be possible to produce oil at approximately the present price of 50 cents or less per barrel plus the cost of transportation."

The safety of St. Paul's Cathedral, London, England, which has caused a great architectural controversy for several years, continues to exercise the minds of engineers. It has produced the suggestion that the foundations of the cathedral should be immersed in a moist earth tank. It is proposed to utilize the blue London clay subsoil as a floor on which to build a reinforced concrete wall below the street level of the cathedral and then water the enclosed earth by vertical perforated pipes. It is argued that the recent alarming subsidences are not due to traffic vibrations, but that the moisture has been drawn off the foundations, leaving the foundations parched and unstable and tending to spread.

CONTRACTS AND SPECIFICATIONS FROM THE STANDPOINT OF THE CONTRACTOR.*

By C. A. Crane,
Secretary of The General Contractors' Association.

A CONTRACT, according to the legal definition, is an agreement, for a consideration, to do or not to do a certain thing. Construction contracts usually consist of four elements, the proposal, the plans, the specifications and the contract proper. As you all know, the proposal contains a brief description of the work contemplated, the preliminary quantities and instructions for bidders as to how, when and where bids will be received, the amount of security required, etc. The plans indicate the location and general design of the work; the specifications describe the method of construction and the materials; and the contract itself is the motive power that carries the work to completion. No matter how theoretically perfect a set of specifications you may devise, their successful attainment depends largely upon the form of contract.

In one of the Paris cemeteries there is a fine equestrian statue of a French military hero. The horse is shown rearing aloft at an angle which excites admiration for the nicety in which the balance has been calculated, with the rider gallantly pointing his saber in one hand while with the other he grasps the reins in the tug which has apparently caused his horse to rear. I say apparently, because the sculptor omitted the reins—and it is related that when he discovered this omission his chagrin and mortification drove him to suicide.

Many a piece of work, otherwise faultlessly prepared, has failed because the reins were lacking—the contract form was defective.

We are frequently told that contract forms and clauses are matters for a lawyer to look after—that the engineer is concerned solely with the proper fulfilment of the specifications. It is just because of that view, that so many contracts are a failure. The contract, the plans and the specifications are inter-dependent, and their combined strength is not stronger than its weakest part. The essence and terms of the contract are as much a part of the engineer's province as the plans and specifications. It is the lawyer's province to put into proper legal form the ideas which the engineer desires incorporated. You wouldn's consult a lawyer to draw up your will, and leave the matter of bequests to his discretion. You need him to attend to the legal phraseology and nothing else. And yet too many of our contracts—especially government and municipal contracts—are left entirely to be drafted by the legal departments. The result has been that the engineer is endowed with powers which he never would have thought of himself, and the possession of which sometimes proves embarrassing.

Now, possession of power doesn't necessarily imply misuse of power. History teaches us that there have been many absolute monarchys that have dispensed wise and beneficial government. On the other hand, we've read of some which were quite the reverse. It's the use of power that demonstrates the fitness to possess it—and sometimes it's very costly to determine that fitness.

The broad-gauge engineer knows how to wield this power. But the chief engineer cannot be always on the work—in the field—and his lieutenant, the engineer in

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* Paper read before the Society of Municipal Engineers of Philadelphia, Dec. 9, 1913.

immediate charge of the work, is clothed with all the powers of his superior in his absence, and the success of an undertaking often depends upon his judgment and the ability to make instant decisions.

Here are some clauses in Philadelphia contracts which are typical of this power:

"**Changes; Separate Contract.**—Should the Director of the City of Philadelphia change the design or specifications, or both, or any part of the work during its progress, the Contractor shall conform to such change, and the value of the changes, as made, shall be estimated by the Chief Engineer, approved by the Directors, and accepted by the Contractor as final, and no consequential loss of profit on work not executed shall be estimated to the Contractor. The Contractor shall apply in writing for an estimate of the value of the change at the time the change is ordered, and before the next succeeding estimate and payment. Any change to be made at an increased cost of the work shall, at the option of the Director, be executed under separate contract therefor; the work under a prior contract shall be suspended, if necessary, until said changes are completed. The Contractor shall give every facility for making these changes and will not be allowed compensation for delay, except by an extension of the time for the completion of the contract.

"**Construction of Specification.**—To avoid disputes and litigation it must be expressly understood by the bidder that the Chief of the Bureau of Water shall construe this specification, and explain any obscurity herein, and shall have the right to correct any errors or omissions, and shall decide as to its purpose and intent, and his decision upon any doubtful or disputed condition, when approved by the Director of the Department of Public Works shall be final and conclusive and binding upon the City of Philadelphia and the Contractor.

"**Extra Work.**—Whenever, in the opinion of the Director of the Department of Public Works, it shall become necessary to use materials or perform labor which is neither contemplated in the plans of the work, nor implied in the specifications referring to said plans, the Contractor hereby agrees to furnish such materials and perform such labor as extra work, and agrees to accept in full payment therefor a price which shall be fixed by the Director of the Department of Public Works."

What a chance to make the contractor who wasn't in right wish he had never got in at all!

These clauses are clubs, nothing less, in improper hands. If there be any truth in the legal definition of a contract implying a meeting of the minds, there can be no justification for a clause which contemplates the total disregard of one of the minds when any change from the original intention becomes necessary or advisable.

Now, this has been met with the argument that the contractor in signing such a contract, agreed to those provisions, and that the meeting of the minds, for all legal purposes was evidenced by the signatures of the two contracting parties. This is of course true and it is also true that if the advice of counsel were sought every time a contractor intended bidding, he would undoubtedly be told either that he was a fool to sign such a document, or that its provisions could be broken in a court of law.

The success of a contract lies in its manner of execution—not in its wealth of legal protection for the contractee.

So long as the bidding on contracts is unrestricted and the law provides that the award shall be to the lowest bidder, the contract must of necessity be so drawn as to protect the contractee from dishonest practices, not only the dishonesty of contractors but of public officials as well. Contractors can hardly object to this condition nor deny its necessity, but what they do object to is that many clauses which are inserted in the contract more for protection than literal enforcement are often applied to them regardless of good and substantial performance because some inexperienced young engineer who is in charge of the work insists on strict compliance with the specifications. It is one of the difficulties which confront both the contractor and the fair-minded engineer in charge of the work to decide when a contract is not a contract, and these "club clauses," as they are called, furnish the text of the problem.

A prominent contractor in an address some years ago made the statement that if the engineer demands in full that every and all conditions of the specifications be carried out, the job is a failure financially. He went on to say:—

"Every unnecessary or unfair clause in a specification has its part in limiting competition and in lowering the standard of honesty among contractors. A clause that may be used as a club can be avoided in one or two ways—either by not bidding on work governed by the clause, or by using graft in ensuring that it shall be a dead letter."

This second alternative, however, is not always resorted to to avoid the effect of club clauses. They are put in there, as said before, more as a matter of protection than of information. They are to be treated as the chief engineer of one of our greatest public improvements told one of his assistants: "You must use your judgment in interpreting some portions of this contract; they are only meant for bad contractors." So it's evident he thought there were some bad contractors—but he must also have felt there were some good ones—and was able to differentiate.

In almost every contract the chief engineer is the arbiter of all questions and his decision is final. This clause has been kicked at and sued about and condemned by contractors perhaps as much as any other one thing in contracts. And yet there are thousands of contracts, containing just such a clause, completed with never a murmur. So we must conclude that in the long run the engineer is the proper party to wield this authority and that it has been wielded fairly. It bears testimony that the engineering profession as a whole is conducted on a high plane of honesty and intelligence—not even the learned profession of the bench and bar can point to so few reversals by higher authority. But there are exceptions—you all know of them—and it is those exceptions that cause the trouble and turn the contractors' profits into lawyers' fees.

We come back to the use of this power of absolute determination. How can an engineer who is employed by a party to the contract and is virtually the agent of that party render a fair and impartial decision when a dispute arises relative to the work which he himself designed and of whose requirements he is presumed to know more than anyone else? Simply by bearing in mind that the contractor also is an agent of the same party—not an enemy who must be outwitted.

Now, we have heard the adage, "Knowledge is power"—but oftentimes this power conferred by the contract is vested with an engineer before he has the knowledge. Some engineers are too narrow to realize that a specification is a standard, and that an approximation to that standard fulfils the contract. The man who rejects masonry because the joints deviate a fraction from the specifications, or piles because they are a half-inch under size at the butt, doesn't appreciate that he is standing in his own light—he never becomes a big engineer—he never has time to learn engineering—he is too busy inspecting.

It is amusing, sometimes, to note the very radical change of views which an engineer undergoes when he ceases to be the engineer for the contractee and becomes either a contractor himself or an engineer for a contractor. The very policies which he so tenaciously followed become most repugnant to him now that he is forced to toe the same mark himself. In fact, a prominent contractor who is to-day the president of a large contracting firm, stated in a public address that he could speak understandingly and feelingly on the relations between the engineer and the contractor because for the first few years after graduation he was employed as engineer for the owner and that now, when he looked back upon some of the ideas which he felt inspired by a conscious duty to enforce, he felt that he ought to pay a personal visit to certain contractors and try to square himself for the damage he had caused.

The knowledge requisite to use this power comes only through experience—and unfortunately there are some personalities that can never assimilate it in a bipartisan spirit. Such men have never been able to find out for themselves whether there really was any room at the top or not—and rather doubted it anyway. But most of the mistakes arise through an excess of zeal rather than from any desire to be drastic. Not long ago an instance of this came to my notice. A young engineer not long out of college was in charge of a party on one of the tunnels in New York and he was very much concerned over the method of timbering employed by the contractor in a piece of bad heading. He insisted on some changes but the contractor intimated that the suggestions weren't feasible. The chief engineer happened along and the young engineer complained that his orders were not being obeyed. The chief took him aside quietly and told him that they were very fortunate in having this particular contractor on that piece of work—he had been driving tunnels for over thirty years and knew more about timbering than the chief himself, "and," he remarked, "I guess we better let him do it his own way."

In this case there was no harm done—the matter was so tactfully adjusted by the chief that his subordinate suffered no loss of dignity—and the work was not endangered at a critical point by ill-timed experiments. Had the engineer prevailed, and his method failed, would the contractor have been responsible?

This brings us to a clause which is frequently found in contracts, which holds the contractor responsible for the performance and safety of his work while the method of construction is specified.

The specifications provide how the work shall be done, what materials shall be used, and the contract contains a clause shunting upon the contractor all responsibility for the accuracy and sufficiency of the plans to produce a structure that will insure a desired result. The contractor is required to guarantee the efficiency of the completed work without having a word to say as to its design. This is manifestly wrong. The contract should prescribe only one of two things—either the design or the performance. It should not stipulate both, for if it should occur that the design were insufficient, the contractor should not be held for the failure in performance. Contractors may be pardoned for feeling that the engineer who attempts to shift the responsibility for the work which he himself is paid to assume, upon a contract or is technically dishonest and betrays a lack of faith in his own ability. In such cases the courts will not always uphold the engineer.

An important case involving this very point was decided by the United States Court of Claims within the past year in what is known as the Boston Dry Dock case. The contract provided that the contractors would, at their own risk and expense, furnish and provide temporary structures of every description necessary for the construction of the dry dock, subject to the approval of the engineer in charge. A question arose about the design of a coffer dam and the engineer in charge designed a structure which the contractors protested was insufficient, but upon the insistence of the engineer they built it. It subsequently failed. The court found that the defects which caused the failure were such as an exercise of ordinary care and skill on the part of the government engineer would have foreseen, and awarded the contractors their claim for damages.

It is impossible to over-emphasize the importance of the relation of the engineer who is in direct charge. He is called upon to give immediate decisions on important questions, in the absence of his superiors. He is clothed with all the powers conferred in the contract and these are liable to be over rather than under-exercised by the too zealous and inexperienced engineer. Care in the selection of his deputies, and personal attention to their training by a chief engineer are tremendous factors in securing harmonious relations with the contractors. Constant bickering prevents good work, and the chief engineers who have been most successful are those who have impressed upon their subordinates the realization that tact and diplomacy win more battles than obstinacy.

There has been some agitation within the last year by some engineers and contractors to reform the present contract system by legislation—to enact universal statutes governing contract provisions. Personally, I am not a believer in the power of legislative enactment to effect any such reform. The engineers to-day have all the power at hand to revise, standardize and perfect their contracts that is necessary—statutes merely serve to tie their hands, and no statute can be devised that will fit every case. I believe in giving every latitude to the engineer—he has proved that he is about 90 per cent. fair and the other ten per cent. we continue to wrestle with in the hope of reform.

The attempt to regulate the relations between contractors and public officials and to prescribe by statute for nearly every contingency that may arise in a contract is in my humble judgment a mistake. Laws are no stronger than the men who enforce them, and if it be the fact that laws are necessary to curb our public officials, something is radically wrong with our system of government. You can't legislate honesty into a man—you may render him more cautious, but if he be dishonest he will beat any law you can make. What we need is better men, not more laws, and public office should offer the best men suitable compensation for their services to the public.

If the process of perfecting contract practice, the contractor should be considered. He is the practical factor in the game, and theory must go hand in hand with practice, or the result will be worthless. The contracting business to-day numbers among its members many of the leading engineers of the world, and their experience and advice must not be under-estimated. It wouldn't do for these matters to be discussed just between engineers. Two heads are not always better than one; if they be on the shoulders of two engineers there is apt to ensue a wrangle over technicalities and the subject matter is liable to suffer, but if one head be that of a contractor, expert in his line, and the other an engineer, each equally mindful of his reputation, the result will invariably prove the wisdom of the adage.

Now on the subject of bidding. Bids are usually invited in one of two ways, lump sum for the entire work, or on a unit price basis. There are also the methods of cost plus a percentage and cost plus a fixed sum, but they are not in general vogue. The lump sum method is followed more in building construction, and the owner knows just what the building is going to cost him, provided he doesn't change his mind and the plans too often. The character of the work is such that everything may be provided for and shown on the plans. There are no unforseen contingencies liable to occur that will affect either the plans or the quantities, and the bid is figured directly from the plans and specifications. If anything has been omitted, or any additional work is required, it is a matter of subsequent agreement between the owner and the contractor. Needless to say, these extras are sometimes fairly profitable to the contractor, since the owner is not in as good position to drive a bargain as before the work was awarded.

On engineering works, the unit price system is preferable, because of the impossibility to foretell just what conditions will arise as the construction advances, and with the price fixed on each item, there is less opportunity to claim extras. Not that they are not claimed, but the owner is in a better position to resist the demand than if he were bound down to a lump sum for a specified amount of work. We have already seen how the owner protects himself in the contract by disavowing responsibility for the accuracy of the estimated quantities, and how impregnable his defense is. There are extreme cases, however, where the contractor has won his point, when the original quantities proved to be so far out of the way as to present an entirely different proposition from that contemplated. But with proper investigation beforehand, including soundings and borings, this is inexcusable, and yet bear this in mind—that contractors every day are bidding on quantities prepared by engineers they never heard of—in many cases the job is the first some engineer has had—and he relies on the integrity and intelligence of that engineer and pins his hopes of profit on the accuracy of his survey and his figures. Is there any other profession in whose members so much trust and faith are reposed by utter strangers? If a contractor needs a lawyer he will retain the best he can get; if he needs a doctor he will call in one with an established practice, but he will risk his money on the mere say-so of an engineer he never heard of, who may be bearing the title of engineer merely by courtesy, or because of a correspondence diploma. Isn't it high time that engineers generally paid more attention to the preparation of their work than is so frequently the case?

While we are talking of bids, a few remarks on some peculiarities that they sometimes offer may be apropos. I refer to what is called the unbalanced bid—some call it balanced—but unbalanced seems a better definition. This occurs only under the unit price method of bidding. It is a very common practice for engineers in preparing the schedule of quantities to include items which there is some possibility of needing, in a merely nominal amount. The contractor who is doing work of a similar character in that vicinity believes that those items will not be used, and bids one cent or nothing on them. As it turns out they are not used and he has not lost anything. If they had been used, that would have been another tale. Now the unbalancing consists in placing the cost of an item which the contractor has reason to believe will be diminished, on another item which he is sure will be done, or perhaps increased.

There have been cases where the contractor who bid one cent on timber has been required to put in the full amount, but even should that be the case, he is fully protected by including its cost in another item. Of course, when he bids one cent on timber, he is going to use his best efforts to persuade the engineer that the timber is not necessary and when he bids a high price on an item he is going to be equally as persuasive that the job will be a failure unless a large quantity of that particular item is used. It would seem that the logical way to avoid this situation is to insert in the contract an agreed price for any item which may perhaps be required, but the necessity for which seems doubtful to the engineer in preparing his estimate. In this way every bidder would be on an equal footing and would be competing only on the items which were sure to go in the work.

Now, while there is much to be said on both sides about the subject of unbalanced bids, engineers should not lose sight of the fact that they themselves are directly blamable for any disastrous results. If engineers exercised the proper precautions in preparing their estimates, there would be no reason to fear the unbalanced bid, nor would there be any necessity for devising methods which would prevent them. Avoid unbalanced quantities and the unbalanced bid will disappear except occasionally where the contractor bases his price upon the work which is first to be done in order to get his largest payments at the start to finance the job.

There is very little unbalanced bidding on the contracts for the Catskill Aqueduct or for the subways. The estimates have been carefully prepared and the contractors generally have bid a suitable price on each item—but where a contractor has reason to believe the engineer's quantities are wrong, he should be privileged to use his own judgment in preparing his bid.

Bear in mind that a contractor is most generally a human individual—not nearly so wealthy as the newspapers love to depict him—and that for every crooked contractor there has been some crooked official somewhere in the offing. My experience with contractors, and it has been my privilege to know a great many, has led me to believe that they are as honest a lot as in any other line of business or profession. As an afterdinner speaker in the course of his remarks stated, it is one of the peculiarities of human nature that the indiscretion of one woman makes more noise than the good conduct of a thousand. And this is quite applicable to contractors, too.

MECHANICAL AND ELECTRICAL EQUIPMENT OF HOTEL FORT GARRY, WINNIPEG.

The power plant equipment for the Hotel Fort Garry is a notable instance of the placing of the complete equipment in the hands of one engineering firm instead of purchasing the various individual pieces of machinery and apparatus from various sources. The advantages of placing the entire responsibility on one company are apparent even to the layman. An engineering firm manufacturing equipment which has a reputation for satisfactory operation and economy, should be in a position to provide and install the complete equipment, eliminating the division of responsibility and insuring the purchasers an installation in which the various pieces of machinery and apparatus bear the proper relation to one another and are so proportioned as to give greatest satisfaction.

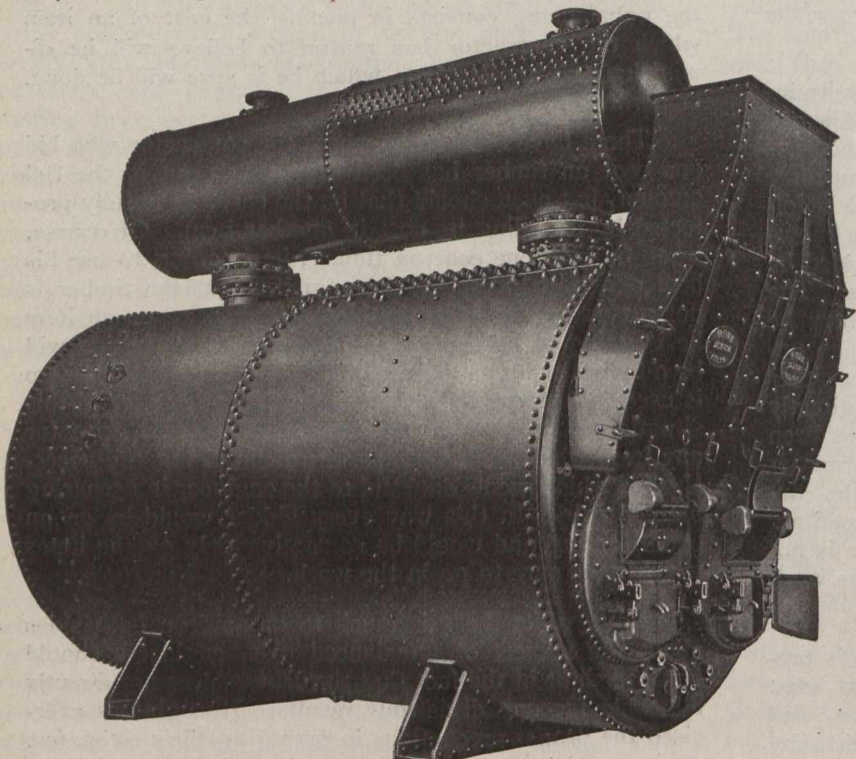

Fig. 1.—One of the Four 300-h.p. Boilers.

The International Engineering Works, Limited, of Amherst, N.S., undertook the complete power plant equipment of this hotel in accordance with the drawings and specifications prepared by Ross and MacFarlane, architects. The broad scope of this installation is shown from the fact that they were to supply not only the Robb boilers, engines, etc., of their own manufacture, but were to fit into the general scheme such other machinery and apparatus as would provide for refrigeration, electric light, water softening, etc., these larger pieces of apparatus of course to be accompanied by their accessories such as feed water heaters, boiler feed pumps, service pumps, switchboards, etc.

The four boilers selected for Hotel Fort Garry are of the Robb Scotch type which are internally fired. These boilers each of 300 horsepower are a modification of the standard Scotch marine boiler, the chief difference being the division of the one large drum into two drums. In this case the steam drum, 48 inches in diameter, is connected by short necks to the large shell 120 inches in diameter containing the two furnaces, combustion chamber and 220 three-inch tubes 14 feet long.

These boilers are equipped with corrugated furnaces 49 inches in diameter extending from the front to the combustion chamber. Although internally fired these boilers have very rapid circulation, which is accomplished by means of a circulation plate at the front which compels the water from the drum to pass around the shell and rise between the furnaces and amongst the tubes passing to the rear. The two features which contribute to the high economy of this boiler are rapid ciruclation and internal firing.

Another product of this company that was utilized, was the Macdonald shaking grate. These grates were supplied to all eight furnaces. They are of the shaking type with removable tops which reduce repair expense. The improved locking device insures long life by preventing any possibility of the points becoming burned off.

The three Robb vertical engines are of the compound, high-speed type direct-connected to 200 k.w. generators. The cylinders of these engines are 18 and 26 inches in diameter with a stroke of 10 inches. Their high speed,, 360 r.p.m., makes them ideal for direct connection to generators as well as furnishing a very powerful prime mover occupying a small space. An automatic system of lubrication which provides for pumping the oil by the engine itself to every sliding and revolving surface reduces care to a minimum, and complete enclosure of all moving parts insures perfect cleanliness of the engine room and protects the parts from accidents. These engines are also supplied with oil guards which prevent the oil creeping along the shaft to the generator.

The compound engines are operated at 120 pounds initial pressure and with five pounds back pressure have sufficient capacity to carry 25 per cent. overload on the generators. The automatic shaft governor is so sensitive that the speed does not vary more than 2 per cent.

The generators are compound-wound, manufactured by the Canadian Westinghouse Company, Limited, Hamilton. To fulfil the specifications these generators had to operate continuously without blackening the commutator and carry 25 per cent. overload for two hours with an increase in temperature not more than 55 degrees C. The International Engineering Works, Limited, through sub-contractors, the American Water Softener Company, installed a water softener of 6,000 gallons capacity per hour, with settling tanks 10 feet in diameter and 22 feet high. The water softening apparatus softens the water through chemical solutions so that the scale matter does not exceed five grains per United States gallon.

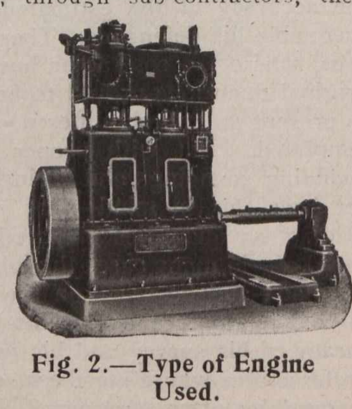

Fig. 2.—Type of Engine Used.

The refrigerating plant of Hotel Fort Garry consists of a 30-ton refrigerating outfit. Two 15-ton double-acting ammonia compressors made by the Linde Canadian Refrigerating Company are driven by two slide valve engines. The installation includes double pipe ammonia condenser with brine cooler, liquid ammonia reservoir, and brine storage tank. On the roof of the hotel there is a 5-ton condenser piped through the building to charcoal filters placed in series and double-pipe cooling coil.

COAST TO COAST.

Victoria, B.C.—Considerable discussion is being given to the advisability of the use of brick or concrete pipe in the north-west sewer construction. The city engineer is preparing a report upon the merits of concrete pipe.

Winnipeg, Man.—Recently, Reeve Bannatyne of Assiniboia, officially turned on the electric current at the St. James power house, setting in lumination 61 arc lights along Portage Avenue, west from the city limits to Headingly.

Woodstock, Ont.—One of the first problems with which the new town council will be called upon to deal, concerns the decision as to the application of the Maine and New Brunswick Power Company to bring its electric power to Woodstock.

Ottawa, Ont.—At Ottawa, 1913 has proven to be a record year in granolithic walk and macadam street construction. About 14 miles of walks and crossings were laid, while about 10 miles per year is the average mileage. Also 5 miles of asphalt pavement were laid.

Ottawa, Ont.—The financial statement for the township of Gloucester for 1913 shows the income to have been $47,464.53; the expenditures, $46,450.28; and the surplus, $1,014.25, the greatest the township has yet had. One of the most important works accomplished was the construction of the road from Gloucester to Cumberland at a cost of $1,170.10.

North Burnaby, B.C.—On December 23rd, the new extension of the Hastings Street east railway line to a point near the foot of Capitol Hill, was officially declared open for traffic by Reeve McGregor. Members of the Municipal Council and representatives of the B.C.E.R. Company were present at the formal inauguration; and some of these also took part in the formal proceedings.

Regina, Sask.—It is expected from the indications on the progress of the work of installing machinery and valve connections, that the new water distributing system for the city will be inaugurated and put in operation some time next month. The new pump of a 5,000,000 gallon capacity is expected to arrive early in February, and it is hoped to have all in readiness to mount it on the concrete foundations, and to assemble the parts.

Swift Current, Sask.—The large storage dam across the Swift Current river, which will ensure a supply of water for a population of at least 50,000, was formally opened recently. The dam, which is over 800 feet long and 25 feet high, was constructed by the Ambursen Hydraulic Construction Company, of Montreal, under the supervision of George K. Mackie, town engineer, at a cost of $100,000; and will have a capacity when filled of over one hundred million gallons.

Vancouver, B.C.—Work on the Point Grey partnership pipe has started under the supervision of Mr. J. T. Breckon, the city's new waterworks engineer. Seventy men were put to work on the trench at Chilco and Haro streets in the West End, where the pipe-laying was stopped pending the settlement of the route. This number, however, will likely be increased as soon as the work is properly under way. Waterworks Superintendent Maddison is in direct charge of the construction work.

Edmonton, Alta.—Steel on the Edmonton, Dunvegan and British Columbia Railway construction is reported to have reached mile 131, or where the town of Smith is located. Here, also, a temporary bridge has been constructed across the Athabasca River, which in time will be replaced by a steel structure. Grading has been carried out as far as mile 220, while surveys have been completed to mile 310. The road has advanced sufficiently to permit of announcement by Chief Engineer Smith that a freight service will be put in operation shortly.

Fort William, Ont.—Six hundred miles of double-tracking on the C.P.R. are waiting for steel, and the company has just closed an order for 125,000 tons of steel for this purpose. When that track-laying is completed the company will have on the entire system east and west but 488 miles to be built. The districts where double-tracking is proceeding at the present time are Sudbury to Fort William, Brand to Calgary, and Revelstoke to Vancouver. When this work is completed there will be 1,095 miles of double track between Fort William and Vancouver, and over 200 miles between Sudbury and Fort William.

Orillia, Ont.—The annual report of the water, light and power commission engineer, shows that the average pumpage for the period from May to November, 1913, was 502,090 per diem, or 67 gallons per head of population; and that the heaviest day's pumping was 841,500 gallons, or 112 gallons per head of population. In the electrical department, the report shows the amount of motor power in use to be 1,297 horsepower. Engineer Greenwood makes the comment that the electrical system is now in very satisfactory condition, and it should be possible to improve the record of service during the coming year very materially.

Vancouver, B.C.—It is reported from the office of the general superintendent in Vancouver that work on the "pioneer" bore in connection with the five-mile tunnel for the C.P.R., which is to be driven through Rogers Pass, at the summit of the Selkirk Mountains, is well advanced from the eastern portal; and that nearly 600 feet of the parallel tunnel has been excavated, the present rate of progress being about 5 feet per day. In order to facilitate the driving of the big bore the contractors are adopting a new method of procedure. They are running a small preliminary tunnel from which cross cuts will be made at short intervals so as to enable the workers to attack the larger bore simultaneously at scores of points. This "pioneer" passage will also solve the question of ventilation and provide for a considerable time an exit for removing the excavated material.

Vancouver, B.C.—In connection with the construction of the G.T.P., Mr. Morley Donaldson, vice-president of the company, has announced that at the present rate of progress, the two ends of steel will be connected by May 10; that construction, which is proceeding at the rate of 3 miles a day, 1½ on the western section and the same amount east of Prince George, will be carried on all winter; and that steel will be laid into Prince George by January 10. The Grand Trunk Pacific, during the year, concentrated, for the most part, its efforts on the completion of the main line of the western division, which will connect Winnipeg with Prince Rupert on the Pacific Ocean, and also on the completion of the branch lines in the provinces of Saskatchewan and Alberta, with the result that the 14 separate branch lines under construction in the provinces aggregating a total mileage of approximately 1,000 miles are now about completed. In addition to this, about 300 miles of main track line were laid in British Columbia.

Calgary, Alta.—At the annual meeting of the Industrial Bureau, it was announced in the report of Commissioner Miller that extensive investigations which have been completed by Government engineers, under the direction of Mr. J. B. Challies, superintendent of the water power branch of the Department of the Interior, as to the power possibilities of the Bow and Elbow Rivers within feasible transmission distance of Calgary, show that in the Bow River alone it is economically feasible to so regulate the flow as to warrant the development at four power sites of over 40,000 dependable 24-hour horsepower, all within 50 miles of Calgary. The Calgary Power Company has completed an installation at Horse Shoe Falls of a maximum output of 18,000 horsepower, which is mainly transmitted to Calgary; this company will within a few weeks have a second power installation completed at Kananaskis Falls, capable of an additional maximum output of 11,000 horsepower. With these water powers developed there would be 70,000 horsepower available in the Bow River alone.

Toronto, Ont.—Favorable progress is being made on the two Don bridges. The contractors for the concrete foundations of the new duplicate bridge over the east Don, Messrs. Dickenson & Burns, expect to complete the pediments in about two weeks, while the Canadian Bridge Company, of Walkerville, has its construction train and steam hoist upon the ground, and has already unloaded a large number of the girders and the beams for the towers. This bridge is about 1,000 feet in length, its widest span being on the west side and over the C.N.R. It is 80 feet above the C.N.R. and 120 feet above the bed of the river. In addition to the pediments, a retaining wall 8 feet wide, alongside the C.N.R., is required to carry one side of the tower. Over one half of the bridge over the west Don has been completed by the Dominion Bridge Company. This structure is over 800 feet long.

Winnipeg, Man.—The report on civic improvements carried out in Winnipeg 1913, shows a total cost of $1,224,730.60. The total cost of pavement laid by both Engineer of Construction Astley and outside contractors to have been $470,-848. The tender of the engineers of construction for asphalt pavements (No. 1) was $344,000; but the works were completed at a cost of about $11,000 less than that amount. The amount spent on asphalt pavements (No. 2) was $57,969. Small sections of macadam gravel and block pavement also were laid by the engineer of construction; and these as well as the asphalt pavements were laid at costs less than the tender prices. In the case of sewer construction for the year, however, the actual cost, $275,610, exceeded the tender price by about 10 per cent. This, in turn, was more than counteracted by a saving of 13 per cent. on granolithic sidewalks, made possible by the purchase and use of several concrete mixers. The total expenditure for the year on granolithic sidewalks was $116,875.60. The cost of water mains was $174,584, or 18 per cent. above tender price, the extra cost being incurred by the laying of three high pressure mains, and one domestic main during the winter when there was from 6 to 8 feet of frost in the ground. A saving of 3 per cent. and 7 per cent. on tender prices is shown in the construction of concrete pavements and plank walks respectively. The new 18,000,000-gallon reservoir was constructed at the very moderate cost of $307,000, which included the cost of foundations, though not the cost of land. Again, though the cost ($265,-000) of the Osborne Street bridge across the Assiniboine River was mostly paid for in 1912, yet this important improvement was completed last year, the approaches and towers projecting the work well into the summer. Other municipal works on which large sums were spent, were the erection of two hospitals, the building of two new fire stations, extensions to the street railway system, a new police signal alarm service, the improvement of the city light and power plant, the extension of the artesian well system, and some preliminary work in connection with the Shoal Lake water supply. The money expended in the last of these will be refunded to the city by the Winnipeg Water District Board. Of the $750,000 which was allotted to the light and power department, $250,-000 still stands to its credit to be used for the installation of additional turbines at Point du Bois, the contract for which has been let, the work to be completed next spring.

Sarnia, Ont.—The increasing business of the Standard Oil Company is occupying the directors with the devising of plans and means for increasing the present plant of the company to a capacity sufficient to handle all the work that can be ordered. The company has completed the pipe line to the great oil fields of Ohio, and thus has an unlimited supply of crude oil to draw upon at all times in the year. At the present time the company has on its payroll about 1,500 men, many of whom are at the work of rebuilding the refinery and increasing the capacity of all parts of the enormous works. It is reported that during this winter the company will erect over 20 stills, with condensers for the same, and buildings to look after the by-products. Four of these stills are now under erection on the west side of the yard. A start has already been made on a battery of 12 crude stills to be constructed south from the battery now opposite the Pere Marquette Station. A new set of six stills has already been constructed in the rear of the crude stills, and a battery of half a dozen more will be added to these. At the new works, which are about a quarter of a mile from the offices of the company, the work of building the new motor spirit refinery is being rushed. The foundation for a battery of ten stills, each with a capacity of 300 barrels, has been completed, and the work on the foundations for the necessary condensers is in progress. The digging for three large underground tanks has commenced. This work will incur great cost, but is very necessary for the storage of the new spirit, which is used for operating automobiles, as it is very explosive in comparison with the gasoline now in use.

Victoria, B.C.—In connection with the tunnel work on the northwest sewer, two shafts have been sunk at McLoughlin Point at either end of the bluff of rock which interposes between the end of Smith and Robert's streets, and at the junction of Bay Street and Anson Street, with a view to open a tunnel face. A section has been opened in an earth and rock cut a little further south; and although it is deflected from the original point set out for an outfall, to avoid the current washing back sewerage into the harbor, the character of the outfall may be gauged. The intention is to carry the sewerage out to a natural tank which can be contrived by damming up the ends, and covering a basin between the land and an islet of rock at Macaulay Point. From that tank the sewerage will be carried out to sea by a submerged pipe, the exact nature of which has not been determined, but will be dependent upon further tests to be made by the engineers upon the flow of the currents. From the piercing of the two shafts, it has been found that it is particularly hard material through which the tunnel has to be driven. The other large tunnel in Esquimalt municipality is the one at Dunsmuir Street. In this case, as in that of Smith Street, it will be necessary to excavate sufficiently not only for the actual pipe line, but for inspection. The third tunnel of large size will be in Victoria West, the location depending upon the point fixed for the crossing of the Victoria arm with a syphon. Assistant Engineer Payne, after an examination of the character of the district, has recommended to the city engineer that a direct tunnel from the Gorge Road to Dominion Road would be most satisfactory, but the subject is still under advisement. The pumping station to handle the low level sewerage north of the Gorge will be located at Cecilia Road, instead of at the waterside as has been proposed. In this section between Burnside Road and the Gorge waters earth is being excavated.

Vancouver, B.C.—The Burrard Inlet Tunnel and Bridge Company adopted a resolution recently to call for tenders for the bridge to be constructed across the Second Narrows. They took this action in view of the facts that the Provincial Government cannot yet give a definite answer to the company's request for information as to the construction of the proposed Second Narrows bridge, and that the company's charter expires next spring. They deemed it incumbent upon them to have some tangible evidence of their intention to proceed with the proposed construction, so as to strengthen their application for renewal of the charter privileges. The company is capitalized at $3,000,000, of which sum one quarter has been subscribed by the municipalities interested. The Dominion Government has granted a subsidy of $350,000, and the Provincial Government a subsidy of $400,000. Thus more than one-half of the total amount required for the project has been assured. The Provincial Government will be asked to guarantee a bond issue of $750,000, the amount upon which the company is allowed to raise funds under the terms of its charter. The structure will be of steel with wide spans, and will be supported on six piers founded on rock. The draw span will measure 581 feet 6 inches in length from centre to centre, and will revolve on a platform supported by four wrought steel cylinders, braced together and filled with concrete. The fixed spans will be 232 feet long. A clear headway of 45 feet above the level of high-water mark will be provided, and the bridge will cross the Narrows at an angle of 75 degrees to the average direction of the flood and ebb currents, which are very powerful at that point. A channel with an average minimum depth of 35 feet will be dredged to allow the passage of large ships. The bridge will be 64 feet 5⅜ inches in width. On the west side, a single line of railway tracks will be laid; in the middle of the roadway, which will be 39 feet 5⅜ inches in width, double street car tracks; on the east side, an eight-foot path for pedestrians. The approaches will be on an easy gradient, one foot in thirty, with a one per cent. grade continuing to the centre. The swing span will be operated by electric motors, and gates, also electrically controlled, will automatically safeguard traffic when the draws are opened. Wrought steel trestles will support the approaches to the bridge, strongly reinforced with longitudinal arms resting on concrete foundations. The superstructure will consist of wrought steel stringers, supporting deck ties of Douglas fir. The roadway will be paved with creosoted wood blocks; and extra substantial spans will carry the approaches for the steam tracks. Exclusive of the approaches the structure is estimated to cost around $2,225,000.

PERSONAL NOTES

R. G. SNEATH has joined the engineering staff of the New Welland Ship Canal at St. Catharines, Ont.

H. D. CLEMENSON has been appointed by Prince Edward County as commissioner to take charge of the county system of road improvement.

WALTER HAZLETT has been appointed mechanical superintendent of the Canadian Steamship Lines, Limited, with headquarters at Montreal.

PHILIP P. SHARPLES, Chief Chemist, Barrett Manufacturing Company, Boston, on December 27th delivered an illustrated lecture on "The Manufacture of Refined Coal Tar" before the graduate students in highway engineering at Columbia University.

W. NORRIS, general manager of the Chatham, Wallaceburg and Lake Erie Railway, has been mentioned for the position of general manager for the London and Port Stanley Railway. Mr. Norris was formerly engineer of the Winnipeg Street Railway.

ARTHUR N. JOHNSON, M. Am. Soc. C.E., State Highway Engineer of Illinois, Springfield, recently delivered an illustrated lecture on "Economics of Highway Engineering in the Middle West" before the graduate students in highway engineering at Columbia University.

SIR DOUGLAS COLIN CAMERON, K.C.M.G., Lieutenant-Governor of Manitoba, who was included in His Majesty's list of New Year's honors, is vice-president of the Manitoba Bridge and Iron Works, of Winnipeg, and has figured prominently in the engineering development of the West.

E. A. JAMES, engineer to the York County Highway Commission, Toronto; A. J. McPHERSON, chairman, Board of Highway Commissioners for Saskatchewan; JOHN STOCKS, Deputy Minister of Public Works, Alberta, and ALEX. McGILLIVRAY, Provincial Highway Commissioner for Manitoba, were chosen by the Automobile Federation of Canada as consulting engineers to advise the Federation respecting the road construction, improvement and materials most suitable to the needs in their respective provinces.

COMING MEETINGS.

MINING AND METALLURGICAL SOCIETY OF AMERICA.—Annual Meeting will be held in New York City, January 13th, 1914. Secretary, W. R. Ingalls, 505 Pearl Street, New York.

AMERICAN CONCRETE INSTITUTE.—Tenth Annual Convention to be held in Chicago, February 16th to 20th, 1914. Secretary, E. E. Krauss, Harrison Building, Philadelphia, Pa.

NATIONAL CONFERENCE ON CONCRETE ROAD BUILDING.—Meeting will be held in Chicago, Ill., February 12th to 14th, 1914. Secretary, J. P. Beck, 72 W. Adams Street, Chicago, Ill.

AMERICAN SOCIETY OF ENGINEERING CONTRACTORS.—Annual Convention to be held in New York City, January 16th, 1914. Secretary, J. R. Wemlinger, 13 Park Row, New York City.

CANADIAN SOCIETY OF CIVIL ENGINEERS.—Annual meeting will be held in Montreal, Que., January 27-29, 1914. Secretary, Prof. C. H. McLeod, 176 Mansfield Street, Montreal, Que.

AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS.—Annual Meeting to be held in New York, January 21st to 23rd, 1914. Secretary, E. A. Scott, 29 W. 39th Street, New York City.

COPIES OF JULY 4th, 1912, WANTED.

One of our subscribers is very anxious to obtain six copies of the issue of July 4th, 1912, and would be glad to pay 25 cents per copy for same. Will subscribers, who happen to have a copy of this issue and do not care to keep it, kindly send it into this office, and we will see to it that it is put in the hands of the right party?

ORDERS OF THE RAILWAY COMMISSIONERS OF CANADA

Each week on this page may be found summaries of orders passed by the Board of Railway Commissioners, to date. This will facilitate ready reference and easy filing. Copies of these orders may be secured from *The Canadian Engineer* for small fee.

21098—December 26—Extending, until June 30, 1914, time within which C.P.R. complete extension of existing siding for Quinlan and Robertson, in Lot 10, Con. 8, Tp. Huntingdon, Co. Hastings, Ont.

21099—December 27—Extending, until April 15th, 1914, time within which C.P.R. complete spurs for Moose Jaw Flour Mills, Limited, Moose Jaw, Sask., authorized under Order No. 20210.

21100—December 26—Approving location C.P.R. proposed station at Valor, on its Weyburn Westerly Branch, in N.E. ¼ Sec. 7-8-1, W. 3 M., Sask.

21101—December 26—Extending, until February 28th, 1914, time within which G.T.R. construct sidings for Otis-Fensom Elevator Co., Limited, at Hamilton, Ont., authorized under Order No. 20433.

21102—December 26—Relieving G.T.R. from providing further protection at crossing of highway east of Walkerville, Ont., known as Pellatt's Road crossing.

21103—December 23—Approving location G.T.P. Branch Lines station at Coalspur, at mileage 36.4, Alta. Coal Branch, Sec. 33-48-21, west 5th Mer., Alberta, station be erected in accordance with Co.'s Standard Structural Plan No. 1.

21104—December 22—Authorizing Algoma Eastern Ry. Co. to open for traffic its main line from mileage 79.80 to 80.80, and spur to station at Little Current from mileage 80.29 to 80.65, Ont.

21105—December 23—Suspending, for present, and pending investigation by Board, tariff C.R.C., No. E. 217, effective January 1st, 1914, increasing rates on pulpwood, in carloads, from points on the line of the Temiscouata Ry. to Riviere du Loup for local delivery.

21106—December 26—Authorizing Brandon Mun. Ry. Co. to operate its cars over crossing of C.N.R. on First St., Brandon, Man.; such cars to be flagged across by conductors of cars.

21107—December 29—Allowing C.N.R. to carry traffic over its railway between Avonlea and Gravelburg, Sask., a distance of 79 miles, until June 1st, 1914, subject to and upon condition that speed of trains over said line be limited to 20 miles an hour for first 26 miles and 15 miles for remaining 53 miles.

21108—December 27—Approving location Burrard Inlet Tunnel and Bridge Co.'s railway in city of Vancouver, from station 0.00 to station 130.03.6 on south shore of Burrard Inlet, B.C.

21109—December 27—Authorizing C.N.R. to construct across public road between Sec. 6-28-28, and Sec. 1-28-29, W. 3rd M., Sask., on its Alsask Southeasterly Line.

21110—December 27—Approving temporary diversion of G.T.R. Co.'s Seventeen Dist. Main Line tracks about 1 mile east of Merritton Station, Ont. 2. Approving plan showing superstructure of said temporary bridge to carry said diverted tracks over Welland Canal.

21111—December 29—Approving location C.P.R. station at Colborne, in Lot 32, Con. 1, Tp. Cramahe, Co. Northumberland, (East Riding), Ont., mileage 105.1 from Glen Tay.

21112—December 27—Authorizing Dominion Altantic Railway to open for traffic portion of grade revision of its line extending from a point on west side of St. George Street, Annapolis Royal, N.S., thence westerly to a point on west side of Allen's Creek, a distance of 2,790.5 feet; and use and operate bridge across Allen's Creek.

21113—December 30—Authorizing C.P.R. to open for traffic double track from mileage 0 to 6, Medicine Hat Subdivision, Alberta.

21114—December 30—Authorizing C.P.R. to construct across highways at mileages 68.18, 69.44, 73.76, 165.95. 111.81, 112.88, and 115.05, Bassano Easterly Branch.

21115—December 29—Authorizing C.P.R. to construct spur for C. H. Richards, Saskatoon, Sask., subject to certain conditions.

21116—December 30—Authorizing Vancouver and Lulu Island Railway Company to construct branch from its railway at intersection of 3rd Avenue, Vancouver, thence along and across 3rd Avenue, and Granville Street for a distance of about 578 feet, to property of British Columbia Electric Railway Company, Limited, adjoining 3rd Avenue and Granville Street Bridge, and through said property to passenger and freight station proposed to be erected on said property, to be completed within 6 months from date of this Order, subject to conditions that Applicant do as little damage as possible and make full compensation to all persons interested for all damage done. 2. Also approving location of said passenger and freight station proposed to be erected on property of leased by British Columbia Electric Railway Company, Limited, in city of Vancouver.

21117—December 29—Amending Order No. 19256, dated May 13th, 1913, by substituting plans Nos. 55257 and 54122 for plan approved under said Order No. 19256.

21118—December 27—Rescinding Order No. 20941, dated December 3rd, 1913, in so far as it approved plan showing location Bassano Easterly Branch of Canadian Pacific Railway, from point in Sec. 22-26-23, W. 3 M., mileage 170, to point in Sec. 19-26-22, W. 3 M., mileage 173.

21119—December 29—Approving and authorizing clearances as shown on Canadian Pacific Railway plan showing minimum clearances of suspended signals in train sheds at Windsor Street Station, Montreal, Que.; provided men are kept off top and sides of cars while operating through said train sheds.

21120—December 29—Authorizing C.P.R. to reconstruct bridge No. 0.7 across Wellington Street, Sherbrooke, Que.

21121—December 29—Relieving C.N.R. of the speed restriction of 18 miles an hour over its Goose Lake Line, between Kindersley and Alsask, Province of Saskatchewan.

21122—December 30—Authorizing C.N.O.R. to open for traffic certain portions of its Toronto-Ottawa Line; authorizing it to use bridges on said portions; and limiting the speed of trains operated over said line.

21123—December 27—Authorizing C.N.R. to construct across Three (3) highways, namely:—1. between Sec. 11 and 10-28-29, W. 3 M.; 2. 31-27-28 and 6-28-28, W. 3 M.; and 3. Secs. 1 and 2-28-29, W. 3 M., Sask.

21124—December 29—Authorizing C.N.R. to construct spur for Huff Gravel Company, Limited, in River Lot 20, Penitentiary Grounds, Edmonton, Alta., and to cross Government Avenue with said spur.

21125—December 30—Authorizing C.N.R. temporarily, until July 1st, 1914, to carry traffic over Oakland Branch from mileage 42 to end of track, in province of Manitoba, distance of 12 miles; operation of trains over said line be limited to a speed not exceeding 12 miles an hour.

21126—December 29—Authorizing G.T.P.R. to construct main line across Government Road at mileage 397.4 Prince Rupert Easterly, in Sec. 9-11-5, Coast District, B.C.

21127—December 29—Suspending, for the present and pending investigation by Board, following tariffs:—C.P.R. Co.'s C.R.C. No. W. 1893, and Esquimalt and Nanaimo Ry. Co.'s C.R.C. No. 256.

21128—December 27—Suspending for present and pending investigation by Board, tariff C.R.C. No. 395, of Dominion Atlantic Railway Company.