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Riveted Joints for Steel Penstocks and Tanks

Formulae and Tables for Their Design—Selection of Proper Type of Joint—Examples of Solution for Maximum Joint Efficiency — Discussion of the Heavier Types, Including Triple, Quadruple and Quintuple Riveted Butt and Double Strap Joints

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IN this paper the writers have endeavored to outline in a clear and practical way the essential points in connection with the choice and design of riveted joints in steel plate cylinders.

Very little is to be found in engineering texts on the design of the heavier type of riveted joints, that is the triple, quadruple and quintuple riveted butt and double strap joints. It is therefore hoped that the section of this paper covering that portion of the work may be of considerable interest to designers.

The selection of the proper type of joint to be used in any particular case, will first be discussed, followed by the method of design, numerical examples, and tables giving the dimensions recommended by the Hartford Steam Boiler Inspection & Insurance Co. for the various types of joints.

Nomenclature

e = Efficiency of joint, expressed in decimals.
f = Tensile strength of plate, in pounds per square inch.

Fig. 1—Eugenia Falls Penstock, 54-Ins. Diameter, with Triple-Riveted Butt Joint on Longitudinal Seam and Double-Riveted Lap on Girth Seam

t = Plate thickness, in inches.
b = Butt strap thickness, in inches.
P = Pitch of rivets, in inches, in row having greatest pitch.
d = Rivet diameter after driving, in inches.
D = Internal diameter of cylinder, in inches.
a = Cross-sectional area of rivet after driving, in square inches.
s = Ultimate strength of rivets in single shear, in pounds per square inch.
S = Ultimate strength of rivets in double shear, in pounds per square inch.
p = Internal pressure, in pounds per square inch.

Selecting Proper Type of Joint

Where the thickness of the plate is dependent upon factors other than the internal pressure, such as rigidity of the section against collapsing, the type of joint depends largely on the effiiciency required. To determine the efficiency, the following formula may be used:—

$$e = pD/2ft.$$

Fig. 2—Double-Riveted Lap Joint in 18-Ft. Diameter Pipe, Ontario Power Co.

Having thus determined the efficiency, and knowing the thickness of plate, the proper type of joint can be selected from the accompanying standard charts, or it can be designed by the methods given in the latter part of this paper.

Where the plate thickness is governed by internal pressure, for a pipe of given diameter, the problem resolves itself into one of choosing that type of joint which will give the most economical pipe section. This is not always accomplished by using the most efficient joint, as will be pointed out later.

Riveted Lap Joints

On girth seams, the single riveted lap joints are sometimes used, particularly in the case of small diameter pipes, but are not to be recommended for pipes over 5 ft. in diameter.

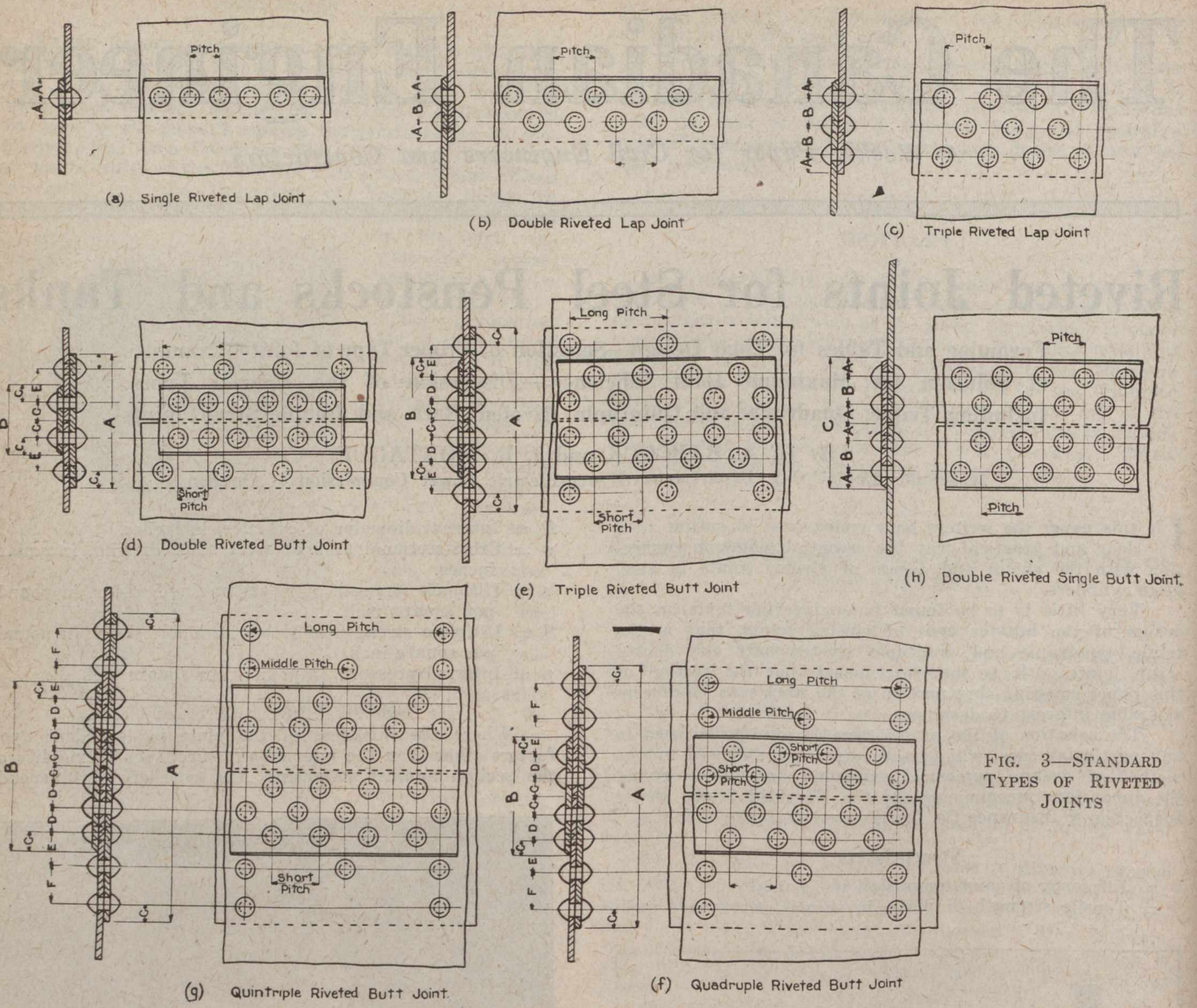


FIG. 3—STANDARD TYPES OF RIVETED JOINTS

They are seldom used in longitudinal seams unless the pressure is very light and the pipe diameter small. Under high presures there is a tendency for the joint to buckle, as shown in Fig. 6. It is apparent that such a tendency is very undesirable as far as watertightness is concerned. Single riveted lap joints are used almost exclusively in spiral riveted pipe, in which case they are satisfactory.

Double riveted lap joints are used very largely in girth seams, especially in large diameter pipes. Their use in longitudinal seams is quite satisfactory for pipes up to 8 ft. in diameter where they fulfill the requirements of efficiency and rigidity of section. When propertly caulked, they can be made entirely watertight. In girth seams, they are usually designed with the same diameter of rivet as is used in the adjacent longitudinal seams, for the sake of simplicity.

Triple riveted lap joints are far more satisfactory in longitudinal seams than either single or double riveted lap joints, because of their greater rigidity and consequent watertightness. For pipe diameters greater than 4 ft., they are uneconomical except where the required joint efficiency is not more than 75%.

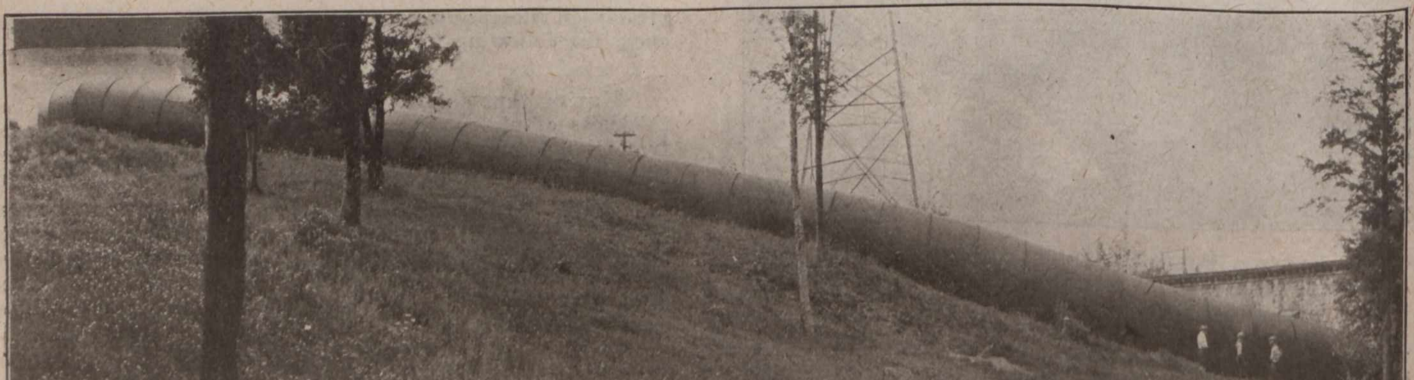


FIG. 4—PENSTOCK, 10-FT. DIAMETER, WITH SINGLE-RIVETED LAP JOINTS (AT HANNAWA FALLS, N.Y.)

It should be borne in mind that in no case should a lap joint be used for joining plates more than ½ in. in thickness, except in the case of circumferential joints.

Riveted Butt and Double Strap Joints

Double riveted butt joints are especially recommended for longitudinal seams where joint efficiency is not a prime factor, but where watertightness is essential. This is evident from the fact that the narrow strap has a well supported caulking edge, the pitch of rivets in the second row being much less than in either the double or triple riveted lap joints, as can be seen from the accompanying tables. In all butt strap joints, the narrow strap should be placed on the outside of the pipe. While both straps may be caulked, the narrow strap is the principal one in making the joint water tight, and must be accessible for recaulking in case a leak develops in testing.

TABLE 1—SINGLE RIVETED LAP JOINTS*

Thickness of Plate	Diameter of Rivet Holes	Efficiency %	Pitch	A	Method of Failure
¼″	11/16″	60.7	1¾″	1 1/16″	T.P.
9/32″	11/16″	60.3	1¾″	1 1/16″	S.R.
5/16″	13/16″	59.4	2″	1¼″	T.P.
11/32″	13/16″	59.4	2″	1¼″	T.P.
⅜″	15/16″	58.3	2¼″	1 7/16″	T.P.
13/32″	15/16″	58.3	2¼″	1 7/16″	T.P.
7/16″	1 1/16″	57.5	2½″	1⅝″	T.P.
15/32″	1 1/16″	57.5	2½″	1⅝″	T.P.
½″	1 1/16″	56.7	2½″	1⅝″	S.R.

*Joint efficiencies in Tables 1 to 6 are computed upon the following basis:—Tensile strength of plate = 55,000 lbs. per sq. in.; resistance to crushing of plate = 95,000 lbs. per sq. in.; strength of rivets in single shear = 44,000 lbs. per sq. in. In the columns headed "Method of Failure," T.P. indicates that the joint will fail by tearing the plate in the net section between rivet holes, and S.R. means that the failure will be due to shearing of rivets.

Triple riveted butt joints are used in longitudinal seams where the required efficiency cannot be satisfied by any of the simpler joints; or they should be used in the smaller diameter pipes where the increased cost of a quadruple riveted butt joint is more than the saving in the metal effected by its higher efficiency.

TABLE 2—DOUBLE RIVETED LAP JOINTS

Thickness of Plate	Diameter of Rivet Holes	Efficiency %	Pitch	A	B	Method of Failure
¼″	11/16″	69.5	2¼″	1 1/16″	1¾″	T.P.
9/32″	11/16″	69.5	2¼″	1 1/16″	1¾″	T.P.
5/16″	13/16″	69.1	2⅝″	1¼″	1⅞″	T.P.
11/32″	13/16″	69.1	2⅝″	1¼″	1⅞″	T.P.
⅜″	15/16″	68.9	3″	1 7/16″	2″	T.P.
13/32″	15/16″	68.9	3″	1 7/16″	2″	T.P.
7/16″	1 1/16″	68.5	3⅜″	1⅝″	2⅛″	T.P.
15/32″	1 1/16″	68.5	3⅜″	1⅝″	2⅛″	T.P.
½″	1 1/16″	68.5	3⅜″	1⅝″	2⅛″	T.P.

Quadruple riveted butt joints are used where maximum efficiency is required in the longitudinal seams of pipes having a diameter of 4½ ft. or more. For smaller diameters, it would be advisable to compute the cost of pipe per foot of length for both quadruple and triple riveted butt joints, and for very small diameters it would be well to consider also the double riveted butt joint.

Occasionally resort is made to quintuple riveted butt joints where a very high efficiency is essential, due to a necessary limit to the thickness of plate used, but on account of higher cost and increased resistance to the flow of water, their use in pipe should be avoided if possible. They may be found economical for use in the joints of tanks and standpipes, where friction is a negligible factor.

Another type of joint coming into more general use, especially for girth seams, is the single strap double riveted butt joint. The strap is made the same thickness as the main plates, and its mathematical treatment is the same as that of a double riveted lap joint. Its particular advantages lie in the smooth surface it presents on the inside of the pipe and, in girth seams, in the use of pipe sections having constant diameter.

Joint Efficiency Principal Consideration

The principal consideration entering into the design of a riveted joint is the determination of joint efficiency. Joint efficiency may be defined as the ratio of the strength of the joint to the strength of the uncut plate, and is usually expressed in percentage. The following formulæ may be used to determine the efficiency of the different types of joints:—

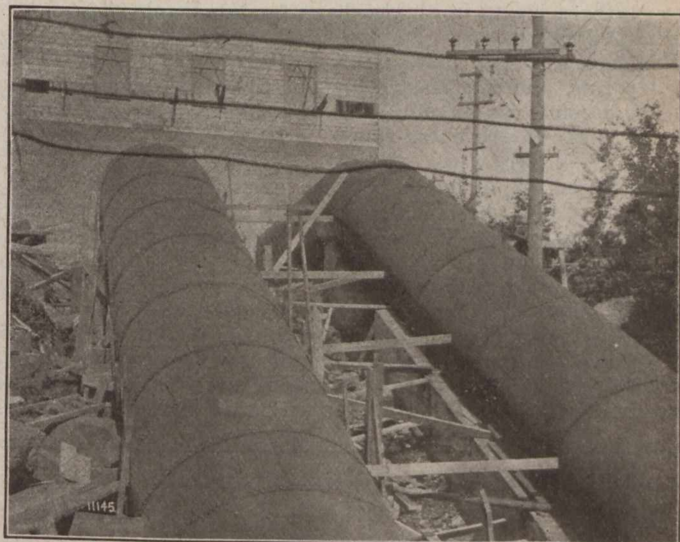


FIG. 5—BIG CHUTE PENSTOCK, 9-FT. DIAMETER, WITH SINGLE AND DOUBLE-RIVETED LAP JOINTS

Formulæ for Riveted Lap Joints

A = Strength of solid plate.
 = Ptf.
B = Strength of plate between rivet holes.
 = $(P-d)tf$.
C = Shearing strength of one rivet in single shear for single-riveted, of two rivets in single shear for double-riveted, or of three rivets in single shear for triple-riveted.
 = nsa.
D = Crushing strength of plate in front of one rivet for single-riveted, of two rivets for double-riveted, or of three rivets for triple-riveted.
 = $ndtc$.

To obtain the joint efficiency, divide B, C or D, whichever is the least, by A.

Formulæ for Riveted Butt and Double Strap Joints

A = Strength of solid plate.
 = Ptf.
B = Strength of plate between rivet holes in the outer row.
 = $(P-d)tf$.
C = Shearing strength of two rivets in double shear for double-riveted, of four rivets in double shear for triple-riveted, or of eight rivets in double shear for quadruple-riveted, plus the shearing strength of one rivet in single shear for double and triple riveted and three rivets in single shear for quadruple riveted.
 = $NSa+nsa$.
D = Strength of plate between rivet holes in the second row, plus the shearing strength of one rivet in single shear in the outer row.
 = $(P-2d)tf+nsa$.

E = Strength of plate between rivet holes in the second row, plus the crushing strength of butt strap in front of one rivet in the outer row.

$= (P-2d)tf+dbc.$

F = Crushing strength of plate in front of two rivets for double-riveted, of four rivets for triple-riveted, or of eight rivets for quadruple-riveted, plus the crushing strength of butt strap in front of one rivet for double-riveted, of one rivet for triple-riveted, or of three rivets for quadruple-riveted.

$= Ndtc+ndbc.$

G = Crushing strength of plate in front of two rivets for double-riveted, of four rivets for triple-riveted, or of eight rivets for quadruple-riveted, plus the shearing strength of one rivet in single shear for double-riveted, of one rivet in single shear for triple-riveted, or of three rivets in single shear for quadruple-riveted.

$= Ndtc+nsa.$

H = Strength† of plate between rivet holes in the third row, plus the shearing strength of two rivets in the second row in single shear and one rivet in single shear in the outer row.

$= (P-4d)tf+nsa.$

I = Strength† of plate between rivet holes in the third row, plus the crushing strength of butt strap in front of two rivets in the second row and one rivet in the outer row.

$= (P-4d)tf+ndbc.$

To obtain the joint efficiency, divide *A, B, C, D, E, F, G, H* or *I*, whichever is the least, by *A*.

The first step in the design of a riveted joint for a given thickness of plate is to assume a rivet diameter within the limits given in Table 8, and with this diameter, various

TABLE 3—TRIPLE RIVETED LAP JOINTS

Thickness of Plate	Diameter of Rivet Holes	Efficiency %	Pitch	A	B
⅜″	1³⁄₁₆″	75	3¼″	1¼″	2⅛″
⁷⁄₁₆″	1⁵⁄₁₆″	75	3¾″	1⁷⁄₁₆″	2⅜″
½″	1⁵⁄₁₆″	75	3¾″	1⁷⁄₁₆″	2⅜″

values for the pitch of rivets, within the limits described below, should be tried out until that pitch which gives a maximum joint efficiency is obtained. Having determined the proper pitch for a given rivet diameter, the same process should be repeated using various rivet diameters until

TABLE 4—DOUBLE RIVETED BUTT JOINTS*

Thickness of Plate	Thickness of Strap	Diameter of Rivet Hole	Efficiency %	Long Pitch	Short Pitch	A	B	C	E
¼″	¼″	1¹⁄₁₆″	82.8	4″	2″	8½″	4¼″	1¹⁄₁₆″	2⅛″
⁹⁄₃₂″	¼″	1¹⁄₁₆″	82.8	4″	2″	8½″	4¼″	1¹⁄₁₆″	2⅛″
⁵⁄₁₆″	⁹⁄₃₂″	1³⁄₁₆″	81.9	4½″	2¼″	9⅞″	5″	1¼″	2⁷⁄₁₆″
1¹⁄₃₂″	⁹⁄₃₂″	1³⁄₁₆″	81.9	4½″	2¼″	9⅞″	5″	1¼″	2⁷⁄₁₆″
⅜″	⁵⁄₁₆″	1³⁄₁₆″	81.9	4½″	2¼″	9⅞″	5″	1¼″	2⁷⁄₁₆″
1³⁄₃₂″	⁵⁄₁₆″	1³⁄₁₆″	81.9	4½″	2¼″	9⅞″	5″	1¼″	2⁷⁄₁₆″
⁷⁄₁₆″	⅜″	1⁵⁄₁₆″	81.3	5″	2½″	11¼″	5¾″	1⁷⁄₁₆″	2¾″
1⁵⁄₃₂″	⅜″	1⁵⁄₁₆″	81.3	5″	2½″	11¼″	5¾″	1⁷⁄₁₆″	2¾″
½″	⁷⁄₁₆″	1⁵⁄₁₆″	81.3	5″	2½″	11¼″	5¾″	1⁷⁄₁₆″	2¾″

*All joints in above table fail by tearing the plate between rivet holes in the outer row. For convenience in driving rivets, the back-pitch (dimension E) may be increased if desired without affecting the joint efficiency, but it should not be decreased.

that combination of pitch and rivet diameter which will give the maximum efficiency, is obtained. A fairly broad range of rivet diameters may be used, the limits for a given plate thickness being shown in Table 8.

Pitch of Rivets

The maximum pitch of rivets is controlled by the limits for caulking along the joint having shortest pitch (see Fig. 3). It is evident that if the pitch (or short pitch in the case of butt joints) is very great in proportion to the thickness of the plate or butt strap, there will be a tendency for the plates to spring apart between rivets. This maximum distance is one which is difficult if not impossible to determine analytically, but which has been found in practice to conform very closely to values given in Tables 1 to 6. In the case of lap joints, the maximum pitch for various combinations of plate thickness and rivet diameter is given in Table 7. For butt strap joints, the values for short pitch given in Tables 4 to 6 should not be exceeded except according to the following rules:—

Rule 1.—The short pitch *may* be increased by 1½ times any increase in rivet diameter plus 1½ times any increase in butt strap thickness.

Rule 2.—Should either the rivet diameter or butt strap thickness be decreased below the values given in Tables 4 to 6, the short pitch *must* be decreased by 1½ times the change in rivet diameter plus 1½ times the change in butt strap thickness.

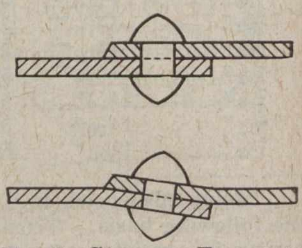


FIG. 6—SHOWING TENDENCY OF SINGLE-RIVETED LAP JOINT TO BUCKLE OR TWIST

The minimum pitch of rivets for either lap or butt strap joints can be obtained from Fig. 3 for various distances between gauge lines, and vice versa. The distances between gauge lines given in Fig. 7, while not rigidly adhered to in all cases, are based on the recommended minimum distance between rivets for good shop practice. To go below this minimum distance may mean the use of special rivet dies for driving the rivets, for quadruple or quintuple riveted butt joints, tance between gauge lines is usually made greater than the allowable minimum, for convenience in assembling and riveting the joints.

On butt strap joints the dimension *E* is determined by adding to dimension *C* one-half the diameter of a standard rivet die for the particular size of rivet used, plus ¹⁄₁₆ in. for clearance.

Expressing this as a formula:—

$$E = C + (\tfrac{1}{2}\text{diameter of rivet die}) + \tfrac{1}{16}\text{ in.}$$

The dimension *F* between the first and second rows of rivets, for quadruple or quintuple riveted butt joints, should not be less than that given in Table 6, for given rivet diameters and butt strap thicknesses.

Thickness of Butt Strap

The thickness of butt strap should be chosen so that the net section along the inner row of rivets has sufficient area to take in tension the total force carried by the joint. The formula.

$$b = [P/2(P-nd)]te,$$

where n = number of rivets in distance P on inner row, will give the required thickness of each butt strap.

General Remarks

The dimensions for riveted joints given in Tables 1 to 6, both inclusive, are those recommended by the Hartford Steam Boiler Inspection & Insurance Co., and are computed upon the following basis:—

Tensile strength of plate = 55,000 lbs. per sq. in.

Resistance to crushing of plate = 95,000 lbs. per sq. in.

Strength of rivets in single shear = 44,000 lbs. per sq. in.

Strength of rivets in double shear = 88,000 lbs. per sq. in.

In cases where different stresses are used, the efficiency may vary accordingly, and should be computed for the new condition. The dimensions for pitch and spacing between rows of rivets are based on well-recognized standards and should be adhered to as closely as possible.

The formulæ for obtaining joint efficiency are based

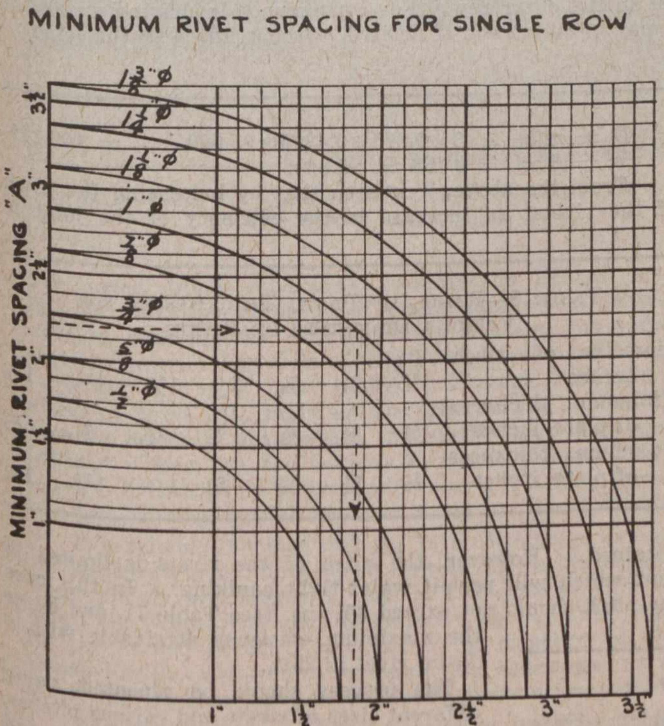
†For quadruple-riveted and quintuple-riveted butt and double strap joints only.

TABLE 5—TRIPLE RIVETED BUTT JOINTS*

Thickness of Plate	Thickness of Straps	Diameter of Rivet Holes	Efficiency %	Long Pitch	Short Pitch	A	B	C	D	E
¼″	¼″	11/16″	87.5	5½″	2¾″	12″	7¾″	1 1/16″	1¾″	2⅛″
9/32″	¼″	11/16″	87.5	5½″	2¾″	12″	7¾″	1 1/16″	1¾″	2⅛″
5/16″	9/32″	13/16″	87.5	6½″	3¼″	13⅝″	8¾″	1¼″	1⅞″	2 7/16″
11/32″	9/32″	13/16″	87.5	6½″	3¼″	13⅝″	8¾″	1¼″	1⅞″	2 7/16″
⅜″	5/16″	13/16″	88.4	7″	3½″	13⅝″	8¾″	1¼″	1⅞″	2 7/16″
13/32″	5/16″	13/16″	88.4	7″	3½″	13⅝″	8¾″	1¼″	1⅞″	2 7/16″
7/16″	⅜″	15/16″	87.9	7¾″	3⅞″	15¼″	9¾″	1 7/16″	2″	2¾″
15/32″	⅜″	15/16″	87.9	7¾″	3⅞″	15¼″	9¾″	1 7/16″	2″	2¾″
½″	7/16″	15/16″	88.3	8″	4″	15¼″	9¾″	1 7/16″	2″	2¾″
17/32″	7/16″	15/16″	88.3	8″	4″	15¼″	9¾″	1 7/16″	2″	2¾″
9/16″	7/16″	1 1/16″	86.7	8″	4″	17″	11″	1⅝″	2¼″	3″
19/32″	½″	1 1/16″	86.7	8″	4″	17″	11″	1⅝″	2¼″	3″
⅝″	½″	1 1/16″	86.7	8″	4″	17″	11″	1⅝″	2¼″	3″
21/32″	½″	1 1/16″	86.7	8″	4″	17″	11″	1⅝″	2¼″	3″
11/16″	½″	1 3/16″	85.6	8¼″	4⅛″	18½″	12″	1 13/16″	2⅜″	3¼″
23/32″	½″	1 3/16″	85.6	8¼″	4⅛″	18½″	12″	1 13/16″	2⅜″	3¼″
¾″	½″	1 3/16″	85.5	8¼″	4⅛″	18½″	12″	1 13/16″	2⅜″	3¼″
25/32″	9/16″	1 5/16″	84.6	8½″	4¼″	20¼″	13¼″	2″	2⅝″	3½″
13/16″	9/16″	1 5/16″	84.6	8½″	4¼″	20¼″	13¼″	2″	2⅝″	3½″
27/32″	9/16″	1 5/16″	84.2	8½″	4¼″	20¼″	13¼″	2″	2⅝″	3½″
⅞″	⅝″	1 5/16″	84.1	8¾″	4⅜″	20¼″	13¼″	2″	2⅝″	3½″
29/32″	⅝″	1 5/16″	83.6	8¾″	4⅜″	20¼″	13¼″	2″	2⅝″	3½″
15/16″	11/16″	1 5/16″	83.7	9″	4½″	20¼″	13¼″	2″	2⅝″	3½″
31/32″	11/16″	1 5/16″	83.2	9″	4½″	20¼″	13¼″	2″	2⅝″	3½″
1″	¾″	1 7/16″	83.4	9½″	4¾″	22″	14½″	2 3/16″	2⅞″	3¾″

*Joints for plate thickness from 27/32″ to 1″ (both inclusive) fail by tearing the plate between rivet holes in the second row and shearing a rivet in the outer row. This also applies to the joint for the ¾″ plate. All other joints in the above table fail by tearing the plate between rivet holes in the outer row. For convenience in driving rivets, either of the dimensions for back-pitch (D and E) may be increased without affecting the joint efficiency, but not decreased.

Diam Riv. ins	½″	⅝″	¾″	⅞″	1″	1⅛″	1¼″	1⅜″
Min. Spcg. ins	1¾″	2″	2¼″	2⅝″	2⅞″	3⅛″	3⅜″	3⅝″



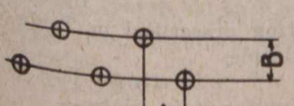


FIG. 7—CURVES FOR MINIMUM RIVET SPACING AND DISTANCES BETWEEN PARALLEL ROWS OF STAGGERED RIVETS

on the rules formulated by the Massachusetts Board of Boiler Rules.

Numerical Examples

Design of a triple-riveted lap joint for a 7/16-in. plate.

From Table 8, the sizes of rivets that may be used in 7/16-in. plates range from ⅝-in. to 1¼-ins.

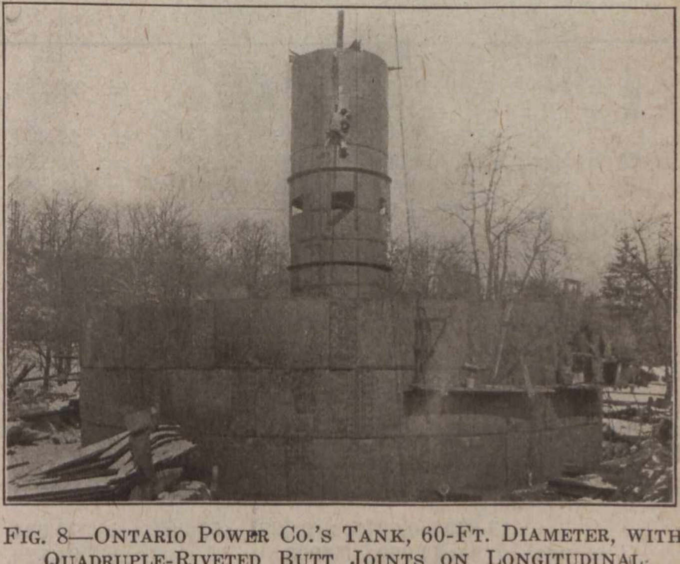


FIG. 8—ONTARIO POWER CO.'S TANK, 60-FT. DIAMETER, WITH QUADRUPLE-RIVETED BUTT JOINTS ON LONGITUDINAL SEAMS AND SINGLE-RIVETED LAP ON GIRTH SEAMS

First trial: Assume the same size and pitch of rivets as shown in Table 3, that is ⅞ in. diameter and a pitch of 3¾ ins. Then

t = 7/16 in. = 0.4375 in. f = 55,000 lbs. per sq. in.
P = 3¾ ins. = 3.75 ins. s = 44,000 lbs. per sq. in.
d = 15/16 in. = 0.9375 in. c = 95,000 lbs. per sq. in.
a = 0.6903 sq. in.

From the formulae for determining the efficiency of lap joints, we have:—

TABLE 6—QUADRUPLE RIVETED BUTT JOINTS*

Thickness of Plate	Thickness of Strap	Diameter of Rivet Hole	Efficiency %	Long Pitch	Middle Pitch	Short Pitch	A	B	C	D	E	F
1/4″	1/4″	11/16″	93.8	11″	5 1/2″	2 3/4″	16 1/2″	7 3/4″	1 1/16″	1 3/4″	2 1/8″	2 1/4″
9/32″	1/4″	11/16″	93.8	11″	5 1/2″	2 3/4″	16 1/2″	7 3/4″	1 1/16″	1 3/4″	2 1/8″	2 1/4″
5/16″	9/32″	13/16″	93.8	13″	6 1/2″	3 1/4″	18 7/8″	8 3/4″	1 1/4″	1 7/8″	2 7/16″	2 5/8″
11/32″	9/32″	13/16″	93.8	13″	6 1/2″	3 1/4″	18 7/8″	8 3/4″	1 1/4″	1 7/8″	2 7/16″	2 5/8″
3/8″	5/16″	13/16″	94.2	14″	7″	3 1/2″	19 1/8″	8 3/4″	1 1/4″	1 7/8″	2 7/16″	2 3/4″
13/32″	5/16″	13/16″	94.2	14″	7″	3 1/2″	19 1/8″	8 3/4″	1 1/4″	1 7/8″	2 7/16″	2 3/4″
7/16″	3/8″	15/16″	94.0	15 1/2″	7 3/4″	3 7/8″	21 3/8″	9 3/4″	1 7/16″	2″	2 3/4″	3 1/16″
15/32″	3/8″	15/16″	94.0	15 1/2″	7 3/4″	3 7/8″	21 3/8″	9 3/4″	1 7/16″	2″	2 3/4″	3 1/16″
1/2″	7/16″	15/16″	94.1	16″	8″	4″	21 1/2″	9 3/4″	1 7/16″	2″	2 3/4″	3 1/8″
17/32″	7/16″	15/16″	94.1	16″	8″	4″	21 1/2″	9 3/4″	1 7/16″	2″	2 3/4″	3 1/8″
9/16″	7/16″	15/16″	94.1	16″	8″	4″	21 1/2″	9 3/4″	1 7/16″	2″	2 3/4″	3 1/8″
9/16″	7/16″	1 1/16″	93.4	16″	8″	4″	23 5/8″	11″	1 5/8″	2 1/4″	3″	3 5/16″
19/32″	1/2″	1 1/16″	93.4	16″	8″	4″	23 5/8″	11″	1 5/8″	2 1/4″	3″	3 5/16″
5/8″	1/2″	1 1/16″	93.4	16″	8″	4″	23 5/8″	11″	1 5/8″	2 1/4″	3″	3 5/16″
21/32″	1/2″	1 1/16″	93.4	16″	8″	4″	23 5/8″	11″	1 5/8″	2 1/4″	3″	3 5/16″
11/16″	1/2″	1 3/16″	92.8	16 1/2″	8 1/4″	4 1/8″	25 5/8″	12″	1 13/16″	2 3/8″	3 1/4″	3 9/16″
23/32″	1/2″	1 3/16″	92.8	16 1/2″	8 1/4″	4 1/8″	25 5/8″	12″	1 13/16″	2 3/8″	3 1/4″	3 9/16″
3/4″	1/2″	1 3/16″	92.7	16 1/2″	8 1/4″	4 1/8″	25 5/8″	12″	1 13/16″	2 3/8″	3 1/4″	3 9/16″
25/32″	9/16″	1 5/16″	92.3	17″	8 1/2″	4 1/4″	27 7/8″	13 1/4″	2″	2 5/8″	3 1/2″	3 13/16″
13/16″	9/16″	1 5/16″	92.3	17″	8 1/2″	4 1/4″	27 7/8″	13 1/4″	2″	2 5/8″	3 1/2″	3 13/16″
27/32″	9/16″	1 5/16″	91.8	17″	8 1/2″	4 1/4″	27 7/8″	13 1/4″	2″	2 5/8″	3 1/2″	3 13/16″
7/8″	5/8″	1 5/16″	91.2	17 1/2″	8 3/4″	4 3/8″	28″	13 1/4″	2″	2 5/8″	3 1/2″	3 7/8″
29/32″	5/8″	1 5/16″	90.5	17 1/2″	8 3/4″	4 3/8″	28″	13 1/4″	2″	2 5/8″	3 1/2″	3 7/8″
15/16″	11/16″	1 5/16″	90.1	18″	9″	4 1/2″	28 1/8″	13 1/4″	2″	2 5/8″	3 1/2″	3 15/16″
31/32″	11/16″	1 5/16″	89.5	18″	9″	4 1/2″	28 1/8″	13 1/4″	2″	2 5/8″	3 1/2″	3 15/16″
1″	3/4″	1 7/16″	90.2	19″	9 1/2″	4 3/4″	30 1/2″	14 1/2″	2 3/16″	2 7/8″	3 3/4″	4 1/4″
1 1/32″	3/4″	1 7/16″	89.6	19″	9 1/2″	4 3/4″	30 1/2″	14 1/2″	2 3/16″	2 7/8″	3 3/4″	4 1/4″
1 1/16″	3/4″	1 7/16″	89.0	19″	9 1/2″	4 3/4″	30 1/2″	14 1/2″	2 3/16″	2 7/8″	3 3/4″	4 1/4″
1 3/32″	3/4″	1 7/16″	88.5	19″	9 1/2″	4 3/4″	30 1/2″	14 1/2″	2 3/16″	2 7/8″	3 3/4″	4 1/4″
1 1/8″	3/4″	1 7/16″	88.0	19″	9 1/2″	4 3/4″	30 1/2″	14 1/2″	2 3/16″	2 7/8″	3 3/4″	4 1/4″
1 5/32″	3/4″	1 7/16″	87.5	19″	9 1/2″	4 3/4″	30 1/2″	14 1/2″	2 3/16″	2 7/8″	3 3/4″	4 1/4″
1 3/16″	13/16″	1 7/16″	87.7	20″	10″	5″	30 5/8″	14 1/2″	2 3/16″	2 7/8″	3 3/4″	4 5/16″
1 7/16″	13/16″	1 7/16″	87.2	20″	10″	5″	30 5/8″	14 1/2″	2 3/16″	2 7/8″	3 3/4″	4 5/16″
1 1/4″	7/8″	1 7/16″	86.8	20″	10″	5″	30 5/8″	14 1/2″	2 3/16″	2 7/8″	3 3/4″	4 5/16″

*Joints for plate thickness from 27/32″ to 1 1/4″ (both inclusive) fail by tearing the plate between rivet holes in the third row and shearing the rivets in the outer two rows. This also applies to the joint for 3/4″ plate. All other joints in the above table fail by tearing the plate between rivet holes in the outer row. For convenience in driving rivets, any of the dimensions for back-pitch (dimensions D, E and F) may be increased, if desired, without affecting the joint efficiency, but they should not be decreased.

$A = Ptf = 3.75 \times 0.4375 \times 55{,}000 \quad = \quad 90{,}234.$

$B = (P-d)tf =$
$(3.75-0.9375) \times 0.4375 \times 55{,}000 \quad = \quad 67{,}677.$

$C = nsa = 3 \times 44{,}000 \times 0.6903 \quad = \quad 99{,}120.$

$D = ndtc = 3 \times 0.875 \times 0.4375 \times 95{,}000 \quad = \quad 116{,}689.$

$e = B/A = 0.75 = 75\%.$

Second trial: Assume the same diameter of rivet and a pitch of 3⅝ ins. Then $P = 3.625$ ins., and

$A = Ptf = 3.625 \times 0.4375 \times 55{,}000 \quad = \quad 87{,}338.$

$B = (P-d)tf =$
$(3.625-0.9375) \times 0.4375 \times 55{,}000 \quad = \quad 64{,}669.$

$C = nsa = 3 \times 44{,}000 \times 0.6903 \quad = \quad 99{,}120.$

$D = ndtc = 3 \times 0.875 \times 0.4375 \times 95{,}000 \quad = \quad 109{,}102.$

$e = B/A = 0.74 = 74\%.$

Third trial: Assume the same diameter of rivet and a pitch of 3⅞ ins. Then $P = 3.875$ ins., and

$A = Ptf = 3.875 \times 0.4375 \times 55{,}000 \quad = \quad 93{,}242.$

$B = (P-d)tf =$
$(3.875-0.9375) \times 0.4375 \times 55{,}000 \quad = \quad 70{,}684.$

$C = nsa = 3 \times 44{,}000 \times 0.6903 \quad = \quad 91{,}120.$

$D = ndtc = 3 \times 0.875 \times 0.4375 \times 95{,}000 \quad = \quad 109{,}112.$

$e = B/A = 0.758 = 75.8\%.$

From the above, it is seen that by increasing the pitch of the rivets, an increase in the efficiency of the joint is obtained. However, the pitch of the rivets is limited to that which will permit water-tight caulking. In this case the pitch should not exceed 3¾ ins. (see Table 7), and hence the maximum efficiency attainable with a ⅞-in. rivet is 75%.

The process should be repeated, using different sizes of rivets and various pitches. That combination of rivet diameter and pitch that gives the greatest efficiency, and [illegible] does not exceed the maximum rivet spacing prescribed in Table 7, is the most desirable.

[illegible]uple riveted butt and double strap joint for ¾-in. plate:—

(Concluded on page 209)

TABLE 7—MAXIMUM LIMITING PITCHES FOR LAP JOINTS

Diameter of Rivet ..	5/8″	3/4″	7/8″	1″	1 1/8″	1 1/4″	1 3/8″
" " Hole ..	11/16″	13/16″	15/16″	1 1/16″	1 3/16″	1 5/16″	1 7/16″
Plate Thickness							
1/4″	2 7/16″						
5/16″	2 7/16″	3″					
3/8″	2 1/2″	3 3/16″	3 1/2″	3 3/4″			
7/16″	2 7/16″	3 1/4″	3 3/4″	4 1/16″	4 5/16″	4 9/16″	4 13/16″
1/2″	2 3/8″	3 5/16″	4″	4 3/8″	4 9/16″	4 13/16″	5 1/8″

TABLE 8—RANGE OF PLATE THICKNESSES FOR VARIOUS DIAMETERS OF RIVETS

Diameter of rivet, inches	5/8	3/4	7/8	1	1 1/8	1 1/4	1 3/8
Minimum thickness of plate, inches..	1/4	5/16	3/8	3/8	7/16	7/16	1/2
Maximum thickness of plate, inches..	1/2	5/8	3/4	7/8	1	1 1/8	1 1/4

WATER PURIFICATION UNITS MOUNTED ON MOTOR TRUCKS*

By William J. Orchard
Sanitary Engineer, Wallace & Tiernan Co., Inc., New York City

In every line of endeavor, the world war brought forth many novel developments, and although the water supply field was but one of the many, it is pleasing to present before this convention of water works men, a discussion of the units developed and manufactured by members of this association, to be operated in France, and elsewhere, by other members engaged in delivering safe water supplies to the allied military forces.

The portable, motor-truck-mounted, water-purification units about to be described, present nothing new in the fundamental principles of water purification, but show the applicability of the principles used in stationary domestic plants, to portable plants for military use.

In 1914, the necessity for a specially organized water service was not recognized by any of the allied forces, water supply functions being the duty of engineering troops. The purity of the water was determined by the medical department.

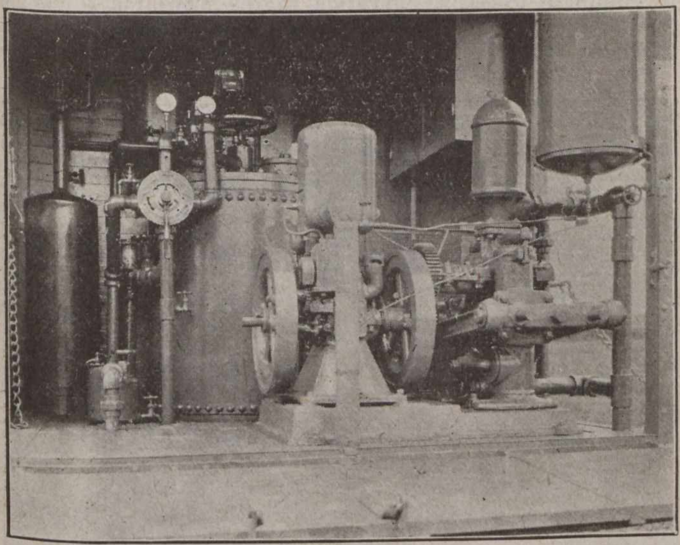


Fig. 1—Rear of Completed Truck, Showing Filters, Power Plant, Pump, etc.

The water supply conditions presented in France and in Belgium, and the problems of water supply met in trench warfare, were entirely different from problems presented in previous wars. The soils of Northern France and Belgium were for the most part highly cultivated, fertilized for scores of years with night soil and other refuse, so that water supplies normally obtained in the battle area were highly polluted. Then, too, the German forces, in passing over the country, indescribably polluted all water left behind when retreating, making special measures necessary for purification.

It is reliably reported that the 1915 Champaign campaign of the French army broke down largely due to inadequacy of water supply arrangements, and at the close of this campaign, the French war office organized a special water service for the Second French Army, under the direction of Major Bunau-Varilla, well-known through his endeavors to construct the Panama Canal with French financial support.

The chlorination of all water supplies used for drinking and cooking purposes, was required by the French military authorities. Calcium hypochlorite or sodium hypochlorite was applied in such quantities that fifteen minutes after treatment there remained two-tenths parts per million of residual chlorine.

It should be pointed out that such excessive amounts of residual chlorine, greatly in excess of American practice, left objectionable tastes and odors in the treated water, so that the troops were apt to take the more palatable, but dangerous, untreated water from flowing streams, shell holes and the like, when possible.

The United States forces, in entering the conflict, taking advantage of the lessons learned by the allied forces, created a water supply regiment, the 26th Engineers, which was

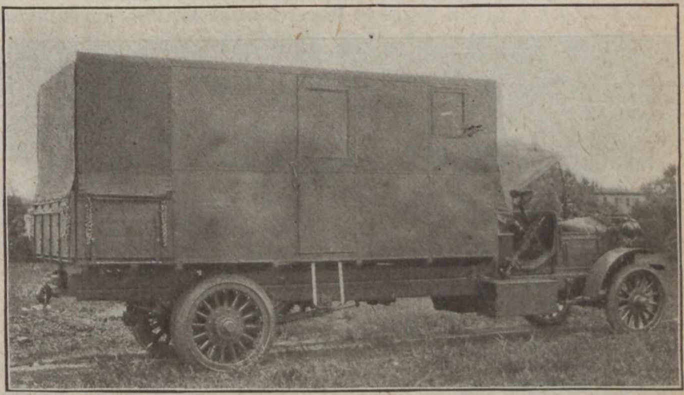


Fig. 2—Ready for a Long Journey

officered by experienced water works men, most of whom are members of the American Water Works Association. This regiment had charge of the water supply of the American Forces, both in the advanced area and in the rear.

Early in the war, the need for portable water wagons for the purification of supplies, was presented, and bulky equipment, with filters and devices for treating the water with hypochlorite, were put forth. In 1916, the availability of apparatus of American manufacture to control liquid

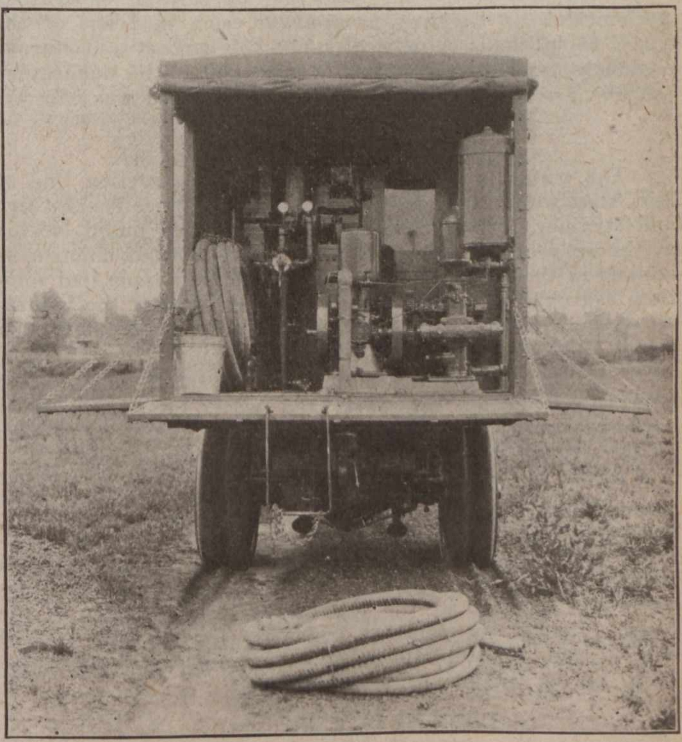


Fig. 3—End and Side Gates Down, Ready for Operation

chlorine made possible the first efficient motor-truck-mounted, water-purification unit.

Experience had been gained by the Wallace & Tiernan Co. through co-operation with its British house in the construction of equipment for the British forces. Equipment based on the British unit was constructed and tested under varying conditions at Maplewood, N.J. Water was taken

*Paper prepared for the recent Buffalo Convention of the American Water Works Association.

from the west branch of the Rahway River, a grossly polluted stream.

This first unit was equipped with rotary pumps, which did not prove suitable, and subsequent units were equipped with gasoline-operated force pumps.

Various members of the American Water Works Association, who were officers in the Engineer Corps, or in the Sanitary Corps, offered helpful suggestions and contributions toward the development of this unit, which, when placed in operation, gave highly satisfactory results.

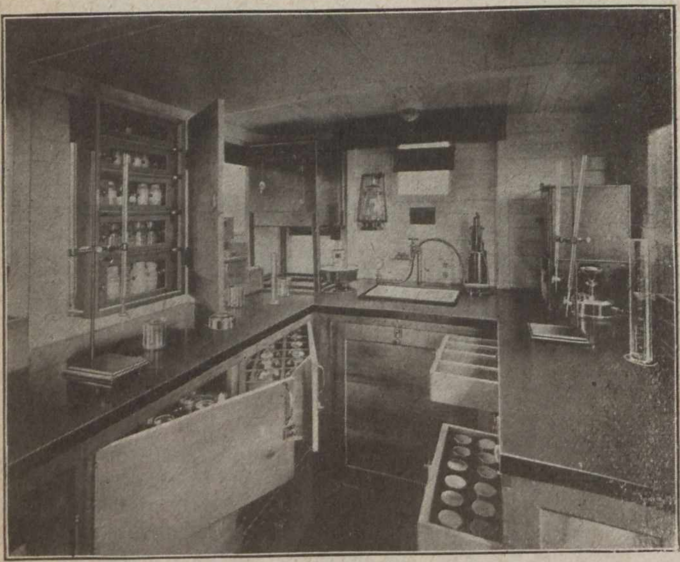


FIG. 4—LABORATORY, LOOKING TOWARD DRIVER'S SEAT

Separate water analytical laboratory trucks were contemplated, and it was ultimately concluded to modify the design to permit the incorporation of suitable laboratory equipment. By building a separate room in front of the truck, using small cylindrical tanks for contact and storage chambers, and placing these tanks under the laboratory benches, a marked saving in the space required was effected.

Description of Operation

The water is pumped through a 50 ft. suction line of 2-in. steel-woven suction hose, fitted with bronze check valve and strainer, by the gasoline-engine-operated pump located at the rear of the body. A very heavy dose of chlorine is applied in the pump suction, from a manually-operated solution-feed chlorinator located on the rear wall of the laboratory room. When waters of low alkalinity are treated, soda ash is applied with the chlorine solution.

Passing through the pump, with a relief valve set to operate at 50 lbs. pressure, the water is passed to a specially designed pressure filter, being treated en route with alum through the standard dash-pot arrangement.

From the filter, the water passes through a 1½-in. water meter, thence through a diaphragm pressure-regulating valve to maintain constant back pressure on the chlorinator water supply line, thence through the storage and contact tanks located beneath the laboratory benches, to the point of discharge at the forward left-hand corner of the truck. Just at the point of discharge, the water is treated with sodium thiosulphate solution, regulated and controlled by a special dechlorinating equipment.

These units were designed having in mind the grossly polluted and befouled waters that would have to be treated. Based on the British practice and experience, high doses of chlorine were introduced into the raw water. The filters served to clarify the water, and at the trial tests, absolutely sterile water was obtained at the point of discharge.

It was thought necessary to make provision for removing the excessive residual chlorine that would be in the water after passing through the contact tanks, and a proportional pressure-feeding thiosulphate dosing device was developed. It should be mentioned that provision for dechlorinating was made in accordance with the British experience, which used the process of dechlorination, by the application of compressed sulphur dioxide gas, in all portable units.

On the British truck, the sulphur dioxide was controlled by a standard direct-feed manually-controlled chlorinator of American manufacture. On the American truck, the chlorinator used was the standard manually-controlled solution-feed type.

Control valves for the soda ash and thiosulphate solutions were in the rear of the laboratory below the chlorinator, so that all chemical application could be centrally controlled by the laboratory operator.

The first several trucks were constructed with horizontal pumps, and it was found that special provision was required to eliminate excessive vibration in the laboratory. With this in view, special spring supports were developed. On the later trucks, a vertical force pump was used, and this

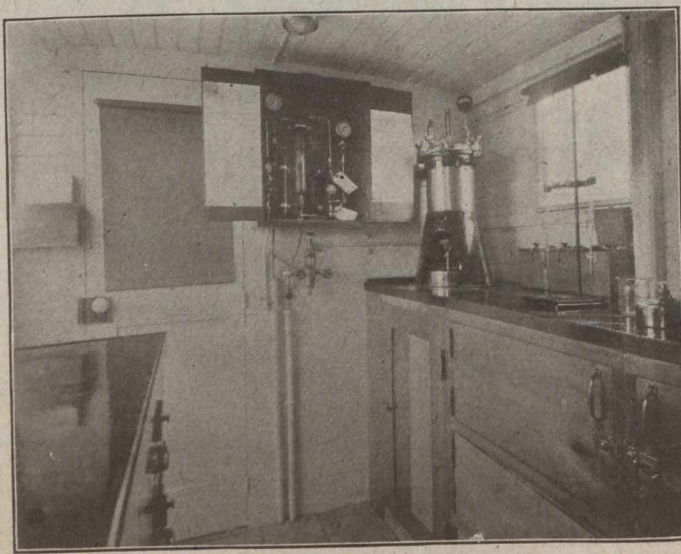


FIG. 6—LABORATORY, LOOKING TOWARD REAR OF TRUCK

so eliminated the vibration as to obviate the necessity of special spring supports.

The development, construction and testing of the first lot of trucks, and the tests and recommendations of the Board of Inspection officers representing the office of the Chief of Engineers, the Engineer Depot and the Sanitary Corps, resulted in many modifications of design and rearrangement of equipment, but not in any change in the basic principles involved.

The value of these units became so apparent that increased facilities were required for their manufacture. An

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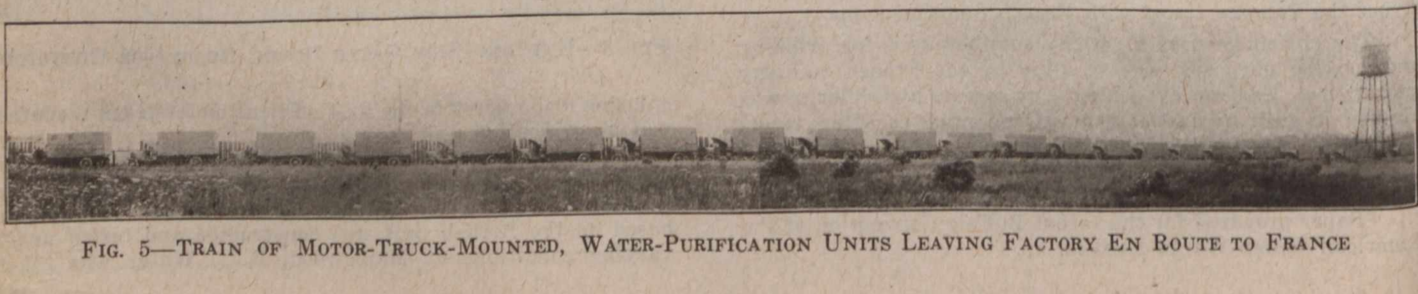

FIG. 5—TRAIN OF MOTOR-TRUCK-MOUNTED, WATER-PURIFICATION UNITS LEAVING FACTORY EN ROUTE TO FRANCE

PROGRESSIVE METHOD OF ROAD IMPROVEMENT*

By Gabriel Henry
Chief Engineer, Department of Roads, Province of Quebec

In a country with a comparatively sparse population grouped in centres generally remote from one another, the general problem of road improvement is solved by means of two methods which may be used concurrently according to the amount of money available. On the one hand there is the method generally followed for main communication highways known as "trunk roads." This method is the normal one which is of the same nature as that followed in building railways, with the same complete preliminary studies and a similar organization for carrying out the work. On the other hand, there is what is called the "progressive method," which is better suited for rural road properly so-called. The object of this paper is to call attention to this second method, to describe it properly and make its advantages known.

The population of the province of Quebec is scattered over a very large area, generally in groups and living on long ranges sometimes remote from one another, from railways and from main highways, at distances which, in a densely populated country, would be considered very great.

The consequence of this is that every rural municipality has a very considerable length of roads under its charge. The average length of roads per municipality in this province probably exceeds 40 miles. Some townships have as much as 100, 150 and even 200 miles of roads under their control.

Roads in Agricultural Districts

Their population is chiefly an agricultural one and naturally has not sufficient capital for improving such a long stretch, all the more so owing to the fact that, outside the St. Lawrence Valley, the country is generally undulating and sometimes broken; on the other hand, agriculture and trade have greatly developed within the past four years, and the need of connecting rural municipalities with one another, with railways and highways is becoming more and more felt. The use of automobiles is increasing even in the most remote districts. Requests for roads, on which at least automobiles can run, are becoming more and more insistent every day and the problem is becoming complicated from a domestic standpoint. How can all these requests be even partly satisfied? Such is the question answered by the second method.

Needless work must be avoided and as little as possible of work offering but transitory or short-lasting advantages should be done. All the work executed should be with a view to real, progressive definite improvement, and preference should be given to the work urgently needed. Thus, the works on rural roads may naturally be classified in two principal categories: Works of a permanent nature, and works of a non-permanent nature.

This distinction, as will be seen further on, is very important not only from the standpoint of the capital to be spent in making roads, but also from a technical point of view. It also naturally applies to road-making according to the first method. It must never be lost sight of.

Permanent Works

Permanent works comprise: Drainage, underdrainage; bridges and culverts; earthworks; special work, such as retaining walls, rip-rap, random rip-rap, etc.; work of minor importance, such as cobble gutters, small dry stone walls, earth basins, etc.; lastly, the foundation, which is one of the most important of permanent works.

All these works are called "permanent" because their duration must be unlimited and because the capital spent on them must be a life-long investment. For instance, reducing the slope of a hill from 15% to 5%, is a permanent work. Interest on the capital required for this work is and will always be represented by a lower cost per ton-mile as well as by reduction in the cost of maintaining the road, and the amount of interest will be all the greater as the traffic on the road increases.

As a rule, the cuts and fills for improving the profile of a road are permanent works. Deviating a road to get around a low-lying or wet spot, when drainage and underdrainage cannot be done and where no top course can be maintained except at a heavy cost; raising, by means of a fill, a road running through a low place in order to protect it from dampness and from flooding along a stream, are permanent works. All these works must be so arranged for that the capital to be spent on them will permanently yield good interest through the advantages they will procure.

Straightening is Frequently Profitable

The straightening of a road in order to decrease its length, is also a permanent work. If, for instance, one reduces by half a mile the length of a road four miles long on which a wearing course has to be put which will cost $10,000 per mile, the total cost of that top course will be lowered by $5,000. Such straightening may sometimes be effected for a smaller sum, including the purchase of the land required, while the expense of its maintenance will be reduced by one-eighth. The more expensive top courses are, the greater will be the advantage of reducing their length by well-arranged straightening.

Concrete bridges and culverts to replace wooden ones, may last indefinitely if they are solidly and carefully built, and the interest on the capital spent on them will be represented by a decrease in the cost of maintaining the road. Wooden bridges are comparatively costly to keep in order and require to be rebuilt from time to time. This cost of maintaining and remaking bridges is heavier, as a rule, than the interest on the cost of properly built concrete bridges.

Generally speaking, the works called "permanent" in connection with road-making, are the same as for railways, less the cost of purchasing, transportation and laying ties and rails. To sum up, their feature, as we have just said, is the effecting of a life-long investment and they must always be understood and executed so that the investment may be an advantageous one. These permanent works also possess the following important characteristics:—

Annual Maintenance Costs Decrease

If properly understood and carried out, the yearly cost of their maintenance will be greatly decreased. Such cost is practically independent of the volume of traffic. It is greater, as a rule, during the years immediately following their execution and it decreases gradually, as the years go by, to a certain fixed lower limit as the road settles down and nature establishes a new equilibrium in the place of that which was disturbed by the execution of the work. In good ground, the new equilibrium is very soon attained and the cost of maintenance rapidly drops to a trifle. But, in bad ground the cost, which may have been rather considerable at the outset and for some years, always ends by reaching its fixed limit.

The maintenance expenses of these permanent works consist chiefly in keeping the slopes in order, clearing the drainage system, repairing the drystone works and the foundations, for the latter often sink owing to uncontrollable changes in the regimen of the underground waters.

Such are the economic features of permanent works. Comparison with non-permanent works will bring them out still more clearly. From an economic standpoint, non-permanent works do not absolutely, constitute a permanent investment, but are rather a yearly expense. In industrial accountancy, they would be considered as more or less transitory investments and be classed among those represented by cost of equipment. Expenditure in connection with them would be classed partly among the items interest, renewals, depreciation, and in the list of fixed charges, and partly among the items of labor, supplies and repairs in the operating charges.

Contrary to the permanent works, the maintenance expenses in connection with them vary with the traffic volume and also with their age. They are almost nothing during

*Paper prepared for the last convention of the Canadian Good Roads Association. Included in association's report of proceedings (now on press) but not read because Mr. Henry was ill during the convention.

the first years after being done and progressively increase during a certain number of years, determined by the duration of their useful existence, which may, however, be lengthened by increasing the yearly cost of repairs and maintenance.

The non-permanent parts of the road consist almost entirely of what may be called "wearing-courses" or "top-courses" and correspond to the whole of the ties and rails in the case of railways.

As the wearing courses, which last for some time, are expensive as a rule, it can easily be seen that in the case of non-permanent works, the items of interest, renewals and depreciation in the fixed charges on the one hand, and those of labor, repairs and supplies in the operating charges, on the other hand, are comparatively high, and that consequently, the choice of top courses and their use is one of the most important problems in connection with road-making.

A Typical Problem

When we consider the general problem of improving the highways of a province or of a state, the pre-going remarks lead to the conclusion that in the case of roads, there is no drawback in doing permanent work progressively from year to year on roads, provided a well-defined plan has been adopted and is followed and that no work, or as little as possible of work, of a more or less temporary nature is done.

The following example will make this better understood:—Let us take a road 40 miles long which connects two important rural centres or makes a short cut between two main roads and runs, for instance, through five villages and a district exclusively inhabited by farmers and by settlers far from one another; a road which the population is really unable to maintain properly owing to difficuties in connection with the nature of the land and lack of money; which is impassable during a portion of the year and on which automobiles can hardly venture. Let us suppose that at present, in order to go from one centre to another, one must do so by rail or by a long round-about way and the five villages between the two centres are consequently isolated; that if this road was made at least passable, relations between the two centres and the villages would become more active, that the value of the properties along it and in the district generally would increase; and lastly, that this would greatly accommodate the travelling public in general, would promote the development of motoring as well as relations with the interior of the district and with neighboring districts.

Obstacles to be Overcome

On a length of six or seven miles this road is encumbered with large boulders, there is a hill with a 20% grade and two other long ones with a 15% grade all three being actually climbed with difficulty; there are also eight low-lying spots impassable in rainy weather. The bridges and culverts, mostly wooden, are in bad condition and even dangerous. In many places there are dangerous and soft springy spots and bad holes. The remainder of the road is nearly passable. There are field stones in the adjacent fields and good gravel banks here and there in its vicinity.

The chief obstacles to the opening of this road are the three hills, the rocks in the road, the low-lying spots and the soft springy spots. If only these defects were removed the road would become passable and automobiles could run over it.

The problem is this: Shall the road be built immediately at a great expense according to the normal method followed in the case of an entirely modern road with an improved wearing course, or shall capital be spent progressively and judiciously on the works of a permanent nature most urgently needed to open it at once to traffic?

By virtue of what has just been said, there is certainly no doubt that the second method is not only the most justifiable, but also the more advantageous, all the more so as there are many similar cases in the country to be considered, the carrying out of which according to the first method would necessitate the immediate investment of a considerable amount of capital.

It seems reasonable, therefore, first of all to improve the hills and to fill in the low-lying spots with the stones to be found in quantities in the neighboring fields. This filling can be done at first on a sufficient width of road to allow for vehicles passing over such spots without danger and the road may afterwards be widened as funds become available. The boulders should be removed from the road and the soft spots permanently cured.

All these works are permanent and the money spent on them will be a good investment, they will not cost much and in a short time in a single season the road might be made passable for automobiles. Improvements may be made, year by year, until the whole permanent portion of the work is finished, including even the foundation. A modern top course should be laid as soon as it becomes necessary, beginning at the villages where traffic concentrates, in the vicinity of the churches and shops. It is curious to note, even with a small investment in permanent works of this nature, roads can rapidly be made passable when the farmers themselves work at the improvements and furnish the stone which they remove from their fields.

This manner of proceeding is called the "progressive method." It progressively increases the value of the immoveable property of the country. The capital so spent is, or should be, as has been said, a good investment. This method must not, however, be followed to an exaggerated extent, for when a trunk road has to be built, traffic rapidly becomes so considerable that the laying of a regular wearing course becomes necessary at once and, in such cases, the normal method is the only justifiable and recommended one.

A full study of the various works above mentioned would take too much time under present circumstances. The following important remarks should, however, not be forgotten.

Complete Details Not Planned

When the progressive method is followed in improving a rural road, a complete study of the details and a general detailed plan with cross-section of all the road are not usually made beforehand. The details are studied only as need arises. Then it must not be forgotten that works which are not permanent or not of a sufficiently permanent nature must never be done and that all the capital spent on improvements must constitute a life-long and paying investment; and again that, in doing such works, they should be done so that it will never be necessary, when completing improvement work; to undo and do differently any works already done.

As rural roads are sometimes very winding and of irregular width, it is often difficult to obtain the land required for straightening them and equalizing their width. Consequently, when this method is followed in winding places of regular width, the axis of the road should be traced and given such a direction that it may, in each case, be prolonged in a straight line as far as possible, reserving enough land on either side between the ditches for the roadway proper and for suitable shouldering. The inequalities in the ditches and in the width of the shouldering may be attended to later on, but the roadway itself should be built in straight sections as long as possible. It is a permanent work which should not have to be begun over again later on. The straight sections should be connected by curves having as large a radius as possible. This radius should never be less than 300 ft. With such curves care should also be taken to raise the outside of the road higher than the inside before laying the foundation.

Heavy and Light Work

In this method as in the normal method, earth work is divided into heavy and light work, but with a difference. As in the normal method, heavy earth work consists of large fills and cuts of which a special and complete preliminary survey, with plans and cross-sections must be made. Such work must be staked out separately, but may be performed in sections at different times as funds becomes available. In this method, light earth work usually comprises light grading, cleaning ditches, etc., outside of sections staked out for heavy earthwork. In these sections no heavy work is to be carried on. Such sections are also separately staked out. Light grading may be largely performed by means of the road machine, and is generally carried out without a special preliminary and complete survey but under the superintendence of a competent foreman accustomed to such work. In this method, heavy earth work is reckoned by the cubic yard, light work by the mile. It must be added that road lengths requiring heavy earth work represent as a rule only a small proportion of the total length.

Cutting Down Grades

It is useless to reduce gentle slopes but it should not be forgotten that a road with a very wavy longitudinal profile is most disagreeable. Hence all the slight undulations in the road should be machine levelled so that the slopes may everywhere be gentle and regular and their length nowhere be less than from 150 to 200 ft.

If 5% be the maximum limit allowed for grades of steep hills, it is useless to reduce slopes of less than 5%, unless they are too close and form narrow ravines, in which case it is better to reduce to 3 or 4%, and sometimes less.

In the method of progressive improvement, it is better where there is no heavy earth work to do, and whenever possible, to proceed by successive thin layers which are beaten down by traffic one after the other and cause less obstruction. When too much digging is done at the same time and too deep layers of earth are spread on the surface of a road, the latter usually becomes impassable in rainy weather and dragging is more costly.

No road can be kept in good order if its substructure is damp. No wearing course, however costly it may be, can last on an insufficiently drained substructure. It is needless to insist on this universally admitted fact. Drying and draining the road are difficult undertakings and call for much experience, judgment and time.

Drainage and Underdrainage

To dry and drain a road there are two requisites: First, to drain off rain and melted ice and snow as rapidly and completely as possible; second, to dispose of the dampness which the subsoil always contains.

The surface waters are discharged; subsoil moisture is removed by underdrainage. *Drainage* and *underdrainage* are the two essential requisites for starting road improvement. They must be undertaken beforehand because a real and sufficient solidifying of the substructure through underdrainage often cannot be obtained in our climate before several months and sometimes a whole year and even more. Drainage is obtained by means of a complete system of ditches, gutters, culverts and bridges.

Ditches should not be dug or maintained where they are not absolutely needed. Of the permanent road works, ditches are the most expensive to maintain and their length should be reduced as much as possible. They should also be made as shallow as possible. Deep ditches, besides being expensive to keep up, are very dangerous. Deep ditches are often supposed to dry the body of a road. It is not always the case; in this climate, it is so only in soils which easily part with their moisture.

Construction of Ditches

Permanent ditches should be as straight as possible. Winding ditches are more exposed to erosion by water and consequently cost more to keep up. The longitudinal slope of ditches should not be less than five inches per hundred feet when it is possible without too much expense. Nor should the slope be too considerable, on account of erosion. Naturally in more resistant soil it may be more pronounced. They should empty rapidly and completely after rain and retain no stagnant water at any place. Their side slopes should not be over 45 degrees. When the latter are steep, they should be strengthened by means of dry stone walls or rip-rap, at least up to a certain height. Where the slope is pronounced and the land non-resistant, the bed should be paved to prevent erosion, and the curves reinforced by dry stone walls. The gutters should be the continuation of the shoulders and no stagnant water should remain in them anywhere in hollows. The outlets in which the ditches empty should be put in order and be large enough easily to carry off all the water they receive under the heaviest rains.

To sum up, the ditches, gutters, culverts, bridges and outlets all together should form a system capable of draining completely and as rapidly as possible and without erosion anywhere, the water from the heaviest rains and spring thaws, leaving no stagnant water in hollows.

In the subsoil there is nearly always a sheet of subterranean water at a certain depth. The depth at which it is met with varies greatly from one point to another. It varies also with the seasons and diminishes in the spring. In many places, the level of this sheet of water is almost flush with the soil and when the spring thaws occur it rises even above the soil. On the other hand, there are soils in which the water easily rises by capillarity, and also soils which hold fast water absorbed by them. When the sheet of water is at a small depth and the ground covering it of the former nature, the water may rise by capillarity to the level of the soil. The air circulating at the surface of the soil evaporates this water and there is thus established a kind of vertical current between the sheet of water and the surface. Though the surface appears dry, the subsoil is moist and soft. If the surface is covered with an impervious wearing course, the action of the air is no longer felt, the water continues to rise until the soil is saturated and the earth becomes still softer.

The Plague of Roads

In cold weather all these moist earths easily freeze to a great depth and then swell. When earth freezes water is attracted, as it were, by the ice crystals forming everywhere, especially at the surface. In the process of freezing land can absorb much more water near the surface and hold it in the shape of ice than it could absorb and hold under ordinary temperature conditions. Thawing begins at the surface. As the water cannot escape through the subsoil which is still frozen, or clayey, stony or of some other impervious substance, it gathers, producing "soft spring spots" on a foundation of ice, clay, rock or generally impervious substance.

These spots, called by the farmers "ventre de beoufs," are truly the plague of roads in this latitude. They are to be found everywhere. They occur every year at the same places, making roads dangerous until the end of June. They even occur on improved roads at places where they did not previously exist. All earth should, therefore, be freed as completely as possible from subterranean moisture before a road becomes sufficiently resistant.

V-Drains and Cobbled Trenches

Work, whose object is to free the soil from subterranean water and drain it, is called underdrainage. This underdrainage is done by means either of earthen or concrete pipes or of field stones. The object is to prevent water from rising in the soil by capillarity to less than 18 ins. beneath the bottom of the foundation.

Drain pipes should be used only when springs are met with or when the surface of the subterannean water rises at times or remains continually at a small depth beneath the surface of the soil. This is ascertained by digging small wells to a depth of about 4 ft. If at the end of 24 hours, for instance, water is found there, the surface of this water marks the level of the subterannean sheet of water, and pipes should then be used. If no water appears and the earth is still moist and soft, it is the case previously mentioned of land absorbing and holding humidity. In such lands, which frequently contain soft, springy spots, pipes have little or no effect. Other means must be used. Generally, field stones are disposed in thick layers, serving at the same time as foundation, made in the shape of a V to economize stone and to drain the water, or else trenches filled with cobble stones are used. V-drains are frequently expensive on account of the large quantity of stones required. Drains made of trenches filled with cobble stones, when they are judiciously used, well laid and proportioned, give as good results in the long run and are less expensive.

Obviously, drying and underdraining the subsoil, while indispensable, are not always an easy task, and it may be said again that suitable results take much time to achieve unless the cost is increased in order to obtain a quick result. However, it is drainage and underdrainage that should be first carried out in order to allow the soil to dry and settle before laying the wearing courses. The modern top courses are generally expensive, and it is neither recommended, nor even justifiable, to risk them when the substructure is not sufficiently dry or firm, even though there is a good foundation.

The progressive method of improving roads gives all the time necessary for a proper preparation of the substructures, and traffic hardens them. When the time comes for laying the foundations and top courses, the firmness of the soil on which they are to be laid is accurately known. It must always be borne in mind that undulations in the wearing courses which appear after a few years, are nearly always due to lack of firmness in the substructure, whatever the resistance of the foundations and the quality of the materials may be. Undulating surfaces with many depressions will be found even in wooden pavements resting on concrete foundations, due to the above cause.

Foundation Problems

The foundation is one of the most important things in road-making. Its object, as everybody knows, is to distribute wheel pressure over a sufficient surface of the structure so that the latter, and consequently the wearing course, will not be sunk or perforated by the wheels. It constitutes a resistant protective cushion between the wearing course and the soil. Foundations are classed among the permanent works because they have all the above-mentioned characteristics of such works.

In laying foundations it must always be borne in mind that a permanent work is being done, and care should be taken to make it a durable one. Vehicle wheels must never reach them, and they must be thick and solid enough to prevent their being broken or crushed out of shape by the heaviest vehicles. This, unfortuntely, has not always been understood, and there have been many disappointments, especially since heavy trucks have come into use. At present this is better known and is receiving more attention.

Foundations are made of concrete, stone, boulders or gravel, and even of sand when the soil is clayey. Without entering into the details of their construction, it is nevertheless useful to call attention to the following points of importance: Homogeneity and hygroscopicity. When stones of different sizes are used in making the foundations, the different sizes must be laid one upon the other in uniform layers, and they must not be made throughout their whole thickness of stones of the same size in one place and of another size in an adjacent place. Too much gravel, dust or sand must not be used at one place to fill voids and a smaller quantity in another location.

Materials of Uniform Size

The best foundations are those made of uniform size throughout all their thickness and laid in a uniform manner. When stones from four to six inches in size are used, they must be of good quality, pressed solidly against one another by hard rolling so as to break the excessively thin corners and edges and to interlock them firmly. If the stones are unstable, too soft or alterable, the vibration caused by passing vehicles will wear them out at the points of contact, and, in the long run, the foundation will sink irregularly.

The stones must touch each other, and filling the voids with too much dust, sand or even gravel is another drawback, as the stones then will not touch; and in such a case the firmer particles have a tendency to drop and the larger pieces of stones to rise, at least in this climate, causing, in the long run, harmful movements and some kind of segregation in the foundation.

Foundations of coarse sand, not hygroscopic, where laid on clay soil, give good results under water-bound macadam, and are economical in places where stone is dear. Well-made Telford foundations are excellent, but very expensive.

The concrete foundations are the best, but their cost is generally considered too high in the case of rural roads. They are subject to cracks in soil not dry or firm enough, especially on account of frost, and it frequently happens that the cracks rise to the top course.

In calculating the thickness of foundations, it is absolutely necessary to take the heavy weight of modern motor trucks into account.

Temporary Gravel Roads

When the regular wearing course is laid, their solidity and lowed, foundations may be laid long before the regular wearing courses, and may, if covered with a layer of gravel, be used as gravel roads until a regular top course becomes necessary owing to increased traffic. During the interval, the roads are kept as gravel roads, and arrangements are made so that, when the regular wearing course is laid, it will not be necessary to scarify them or do any other work over again. Following the same method, the foundation may also be made wholly of gravel covered with an additional layer of gravel, and used as a gravel road till a regular top course becomes indispensable.

The temporary use of foundations covered with gravel as a wearing course allows of regular compacting by the traffic and of correcting their defects whenever they appear. When the regular wearing course is laid, their solidity and resistance are exactly known. The soft places have become hardened, and there is less likelihood of the defects which occur in wearing courses laid on an insufficiently firm foundation.

I may add also that, in this province, the rural roads are covered with snow during a portion of the year, and, consequently, the wearing of the top courses of the rural roads by traffic is much less than in countries where there is traffic throughout the year, and this may have much influence on their choice.

It would be advisable also to consider substituting one kind of top course for another, taking existing conditions in this province into account; also to consider what precautions should be adopted when laying cheap temporary top courses for avoiding certain expenses which otherwise would be incurred when it becomes necessary, owing to increase of traffic, to use them later on as foundations and to cover them by improved top courses.

Senator G. D. Robertson, Minister of Labor, has notified D. K. Trotter, secretary of the Association of Montreal Building and Construction Industries, that the association will be invited to select its own delegates to the National Industrial Conference to be held Thursday, September 11th, in Ottawa.

The annual convention of the Associated Boards of Trade of Vancouver Island was held July 10th in Courtenay, B.C. The principal proposals endorsed were the extension of the Esquimalt & Nanaimo Railway to the northern end of the island, the construction of about twenty-two miles of road to open the Sayward district for settlement, and the continuation of the Strathcona Park road.

"Town planning in Great Britain," says "Conservation," "has so far advanced beyond the experimental stage that it has now been decided to make it compulsory for every town, having 20,000 inhabitants or more, to submit a town planning scheme for its own area to the Local Government Board, not later than 1926. The British people realize that haphazard growth of towns leads to serious evils and they are determined to control it. In future, land will have to be developed so as best to serve the interests of the community, which, in the long run, is usually in the interests of the landholders themselves. Only the land speculator is adversely affected. If the public wish to put that individual out of business, they cannot do it more effectively than by actively promoting proper schemes of town planning. In Canada, the province of Nova Scotia took the lead in making town planning compulsory in 1915. The only other province which has a compulsory Act is Saskatchewan. These are therefore the only two provinces abreast of the Old Country in town-planning progress, though most of our provinces have enabling Acts in force."

COLLECTION AND DISPOSAL OF REFUSE IN THE FUTURE*

By F. W. Brookman
Cleansing Superintendent, Rochdale, England

GENERALLY speaking, refuse collection resolves itself into transport and loading strength; and transport may be petrol, steam or electric, or horse-drawn vehicles.

Petrol wagons, in spite of the cost and difficulty in obtaining petrol, have been a great help during the war, and I want to suggest that as the cost of the wagons gets easier and the petrol becomes more plentiful, the home-manufactured benzol should be used either alone or mixed with petrol, for several reasons. First, it is an English product, and before the war was less in price than petrol, while 15% more power can be got out of the gallon. It is a saving in shipping also, and for some years to come we shall have none too many ships to carry the trade of the country, to say nothing about buying petrol abroad when we have a good home-made article. For all users of petrol vehicles it would be a good thing if there were inspectors on the road to send home all badly-running vehicles, and if the wagon was taken in hand at the first warning there would be many less breakages.

While many of the petrol wagons were commandeered early in the war, the better type of steam wagon seemed to disappear entirely, and thus municipalities had not the same chance with these as with the petrol wagons. The fact that they were extensively used in France and elsewhere on road-making and repair, points to their use after the war for the heavier classes of work, and where transport schemes are being fixed up, they will no doubt be much used for the heavier traffic such as road materials, coal, etc.

The Choice of Wagons

It is not always easy to decide what size of wagon is the best to adopt, but where its work is more or less of a certain type, or, shall we say, suppose a wagon is to work nine-tenths of its time on one job, naturally that job should rule the size, and it should always be remembered that a 6-ton wagon costs no more in labor to run than a 4-ton does, and there is less time taken per ton at each end of the journey getting into position and also in loading and unloading.

The electric wagon has been much to the fore during the war, and could they have been obtained there is no doubt that they would have been in evidence almost everywhere. Where they have been adopted for comparatively level work I have heard them well spoken of, but in cases where the roads are other than level this has not always been the case. This does not by any means condemn the electric wagon, but only shows that sufficient care has not been exercised in purchasing the wagon, or that the makers may have been so eager to sell that they have sold a less power wagon than was warranted for the work in view, and that both buyer and seller be to blame. Of course, this also obtains with petrol wagons, and a wagon is purchased for 30 cwt. load and often works to 2 tons and trouble soon results. To my mind the electric wagon is a most economical wagon to run if of a sufficiently powerful type without it being necessary to undermine its constitution by want of energy.

Horse Transport

We now come to our old friend and servant the horse. Owing to the high price of horses and provender it is now a question as to just where the dividing line should come in. This must depend on the district, for in one case it may pay better to work a horse in a four-wheeler as far out as a mile, while in another case half a mile might be over the mark. Now that the 48 hours is the limit, the horse journeys may be so shortened that the old number of journeys can be done, and the quicker-moving motor wagons put on all outside the horse area. In this outside area you can use either a moderately-sized wagon or a wagon about half the size and holding about the same as a horse four-wheeler. Suppose, however, you put on a large wagon and put all the men on it that you would put on to three small ones, your result would be nothing like the same. You might possibly not get done more than half what the three small wagons would do because of the distance the large wagon would have to travel to get a load, and the unwieldy character of the machine in small areas.

Tipping and Loading

As to tipping wagons, the tipping arrangements should be of the simplest possible character. The experiment has been repeatedly tried on two wagons—one a tipper and the other a non-tipper—of moving the same material from and to the same place, and the non-tpper could easily beat the tipper owing to the character of the tipping arrangements.

Whenever possible the vehicle should be such as to be readily loaded by a man on the pavement without the use of a ladder. Wagons of the type used at Bury are easily loaded and tipped, and it is not difficult to get comparatively low-bodied wagons of other types to fill this requirement, and recently I have seen steam wagons that could easily be loaded over the side and at the same time give a passable tip. These wagons will carry up to 5 tons in weight and run well on coke breeze, with which a cleansing department could easily supply itself from the refuse.

The matter of the blowing about of dust, etc., by the wind during the operation of loading is very important, not only from the annoyance caused to people in the vicinity, but also from the fact that this dust once adrift never ceases (as long as the wind lasts) to annoy someone, and even the street-sweeping machine helps to make the nuisance worse, unless it is of the sprinkler type and thus brings the dust to rest.

It is not easy to find a complete cure without disadvantages. There are carts and wagons elaborately covered in and having side or flap doors through which to pass the refuse. There are vans with bodies partly covered over with a permanent hood, and from the end of this hood an ordinary sheet covers the remainder. There are wagons and carts with lorry poles down the centre, supported by iron hoops, something like a grocer's lorry with rain-sheet spread; and there is the loose cart or wagon sheet tied down at the front end on to the cart, wagon or lorry, and unrolled as it is required to cover the refuse and tied down so far each time in sections as the load is completed. These are all more or less satisfactory, and in some places more than others, for in some towns strong winds are much more prevalent than in others. The disadvantage is that the loading, etc., cannot be so easily watched or checked as with open vehicles. The wear and tear with permanent covered vehicles is considerable, and the additional weight is a great consideration, particularly in hilly towns, which, as a rule, are also those towns with more than their share of wind. It has been suggested that ash bins should be taken to the depot and there emptied, which, while being the ideal method, I am afraid will not appeal to us at this time of high prices, for by working in this way every load would be as great a weight of bins as of bin contents, and this is absolutely out of consideration. Further, to work in this way the municipality would have to own and supply all the bins and keep them in repair. I fear we are not yet in a position to do this.

I take it, then, that it is up to each authority—and, of course, every official—to decide what alterations they can make in methods of collection, and particularly think out the problem as to which is best adapted to their respective district, because it does not follow that the electric wagon will be best for Halifax or Bradford just because it does well for Southport or Blackpool.

Position of Ash Bins

In connection with refuse collection, another point requires constant attention in the future. In many districts now a wagon could be loaded in half the time at least, if the ash bin or ash place were accessible from the passage without having to go the length of the garden or yard, not to mention locked yards. I thing the position of the ash bin is an important item on a building plan, and that it should be

*From a paper read at the annual conference of the Institute of Cleansing Superintendents, England.

put in the most accessible position. In the case of old property it would be time well spent in many cases when any alterations or repairs are being executed, whether to the ash-places or not, to talk the matter over with the landlord and point out to him not only the advantages that an alteration in the site of the ashplace or bin would be to us, but also how such an alteration would benefit him and his tenants. It is no uncommon thing for a load in one particular district to take as long as two loads in a better arranged part of the town.

Another point that tends to waste time is where dwellings have their own particular utensils for containing ashes and refuse, in which case every particular bin or tub has to be carried back again after being emptied into the cart or wagon. In some cases the refuse must be carried from the back round the end of the house to the front and the length of the front garden or lawn into the front street. These are the places that waste time, get the men out of sight, and cause trouble all round.

Sometimes we do see something quite contrary to the time-wasting process above mentioned, and I shall never forget a little performance I once saw in the collection of refuse.

I had appeared on the scene quite without notice, and in the absence of the local superintendent. The ash bins (all galvanized) were previously deposited along the kerb-stone edge by the tenants, and while the motor-wagon travelled up the centre of the street the ashmen simply hoisted up the bins onto the wagon (without it stopping) and the man in the wagon picked up the empty bin and dropped it over the side into the hands of the man who brought it. I thought that was ideal refuse picking up. Unfortunately, ninety-nine towns out of the hundred have not the authority to order the tenants' ash-bin to parade at the kerb-stone. I suppose there is often a fly found in the ointment, and while in the case cited I did not find it, in some cases where the "kerb-stone parade" is in vogue, an awful mess is made in the street by rag-pickers and others pulling the stuff over.

Special Collections

Prior to the war in many towns there were special collections (besides the refuse and nightsoil or excreta) of waste fish and butchers' offal, infectious fever pails, fruiterers' refuse, etc., and during the war others have been added such as paper, leather trimmings, broken food, rubber, potato peelings, etc. As to how many of these will fall out again, only time will demonstrate. While in some cases it was necessary to use every effort to obtain certain materials irrespective of cost during the war, it is quite certain in some cases that such effort is not being maintained, and time only will demonstrate how many of the above will lapse. One thing is certain, with the present price of labor even municipalities cannot be expected to pick out and collect materials which are difficult to dispose of and at the same time do not pay for the handling; for while such collections were very necessary during the war, the end of that catastrophe ends the necessity.

Disposal of Refuse

Having collected the town's refuse, we must dispose of it in some way.

I want you to realize the fact that if you have anything at all you can make into a decent manure, it is up to you to do it, and I do not think you are likely to create a glut in the market in that direction.

In a few towns the pail contents are dried and thus made into a valuable manure, for the mere act of drying (along with a little acid) can under certain conditions increase the percentage of ammonia up to 12%, which makes it work out about half as much as sulphate of ammonia for this item alone, and there are also present certain phosphates, potash, etc., so that it is a good all-round manure. The production will continue until the pails are replaced by water carriage, when we shall look to the sewage works to have produced a good substitute, and they will have no little problem in that the town manure will be intermixed and partly dissolved in millions of gallons of water.

With reference to the ash refuse we are not much nearer a good solution. In pre-war times it was almost the unanimous opinion that the refuse should be burnt so as to get rid of the putrefactive or organic matter and to make an innocuous clinker that could be used for many purposes, or tipped anywhere without being detrimental to health. While the matter of cost was at the time fairly heavy, both in collection and burning, it was low compared to what it is now. Given that we shall eventually exterminate the pail closet, there is no chance of eliminating the ashes collection, for while it is possible in certain factories and manufacturing premises to establish suction conduits to carry off the dust, sawdust, shavings, shoddy, etc., it would be quite a different problem to instal a system to draw away to the depot or the tip the ashes refuse of a town, intermingled with the pots and pans, tins, broken bricks, etc.

Screening and Washing Plants

Recently there have been put down screening and washing plants for screening out of the refuse the cinders and washing them so as to recover this valuable fuel. This, of course, separates out the inert fine ash—a material in itself which cannot be burnt, and which acts as a drag on the burning of the better fuel. Further, this is taken out at the first handling, and thus is not left either to be matted up against the clinker in the destructor and afterwards laboriously withdrawn and deposited on the clinker bank, or to be as laboriously riddled through the destructor grate if the stoker is sufficiently energetic so to dispose of it. In my opinion the screening of the refuse is a much better proposition than grinding up the whole of the material, good and bad, for it does enable you to use the good fuel, which, in its turn, may be used as fine ashes later. As I previously mentioned, the inert fine ash is thus eliminated from the good fuel, which is then washed to dispose of adherent damp ash, etc. Where the fuel is to be used for steam raising (or like purposes) on the premises, the washing may be dispensed with and the plant simplified; but this must, of course, be left to local requirements. In some particular cases it may suit the conditions to get all the fine ashes possible, but I wish to point out that the material that will not pass through a ¼-in. screen is not the same class as that which will go through it; and even if you grind it the composition remains what it was before, and unless you want the material purely as an absorbent or as a mechanical lightener of clay land, you may have had your labor for nothing. Supposing, however, you ground the clinker to a fine powder, you would render the lime contained in it available for agricultural purposes, and (depending upon the kind of coal used in a particular district) it would act on the land in exactly the same way as the lime in sewage sludge does, but it would save the carriage of the water in the latter and be much easier to spread and to work in. The availability of the lime for this purpose would depend upon its fine grinding, just as it will be remembered the now much-valued basic slag many years ago failed for want of proper milling. In that case the Germans bought all the production, and we have not yet fully recovered; but the war has set the material at liberty again.

In the past many novelties have been tried in the shape of moving and rocking grates, high blasts and low ones, fan and steam blasts, etc., for our furnaces. Top feeds, back feeds and feeds in front, by hand and machine, sloping and flat grates and furnaces without grates at all; many fairly successful, other failures, and still we have not the ideal furnace into which the loads can be tipped in bulk, and while everything combustible is consumed, what is not consumed is melted and comes away from the furnace (without laborious clinkering operations) in the fluid condition. Attempts have been made in this direction, but as yet without success, owing largely to the refractory nature of a very small percentage of the whole, acting as a block to the operations. I feel sure that eventually this will be overcome; but while the necessity for screening refuse might then cease, the average percentage of the clinker produced is not likely to be below 33%, in spite of the assurance of some years ago that two-thirds of ordinary destructor clinker could be easily consumed.

RIVETED JOINTS FOR STEEL PENSTOCKS AND TANKS

(Continued from page 200)

In Table 6, for ¾-in. plate the thickness of butt strap is given as ½ in. In Table 8, the minimum rivet diameter for ¾-in. plate is ⅞ in., and the maximum for ½-in. plate is 1⅜ ins.

First trial: Assume 1⅛ ins. diameter rivet and a long pitch of 16⅜ ins. Then

$t = 0.75$ in. $c = 95{,}000$ lbs. per sq. in.
$P = 16\frac{3}{8}$ ins. $= 16.375$ ins. $s = 44{,}000$ lbs. per sq. in.
$d = 1\frac{3}{16}$ ins. $= 1.1875$ ins. $S = 88{,}000$ lbs. per sq. in.
$a = 1.1075$ sq. ins. $b = \frac{1}{2}$ in. $= 0.5$ in.
$f = 55{,}000$ lbs. per sq. in.

$$A = Ptf = 16.375 \times 0.75 \times 55{,}000 = 675{,}469.$$

$$B = (P-d)tf = (16.375-1.1875) \times 0.75 \times 55{,}000 = 626{,}484.$$

$$C = NSa+nsa = (8 \times 88{,}000 \times 1.1075) + (3 \times 44{,}000 \times 1.1075) = 925{,}870.$$

$$D = (P-2d)tf+nsa = [(16.375-2 \times 1.1875) \times 0.75 \times 55{,}000] + (3 \times 44{,}000 \times 1.1075) = 723{,}690.$$

$$E = (P-2d)tf+dbc = [(16.375-2 \times 1.1875) \times 0.75 \times 55{,}000] + (1.1075 \times 0.5 \times 95{,}000) = 630{,}114.$$

$$F = Ndtc+ndbc = (8 \times 1.1875 \times 0.75 \times 95{,}000) + (3 \times 1.1875 \times 0.5 \times 95{,}000) = 846{,}094.$$

$$G = Ndtc+nsa = (8 \times 1.1875 \times 0.75 \times 95{,}000) + (3 \times 44{,}000 \times 1.1075) = 823{,}065.$$

$$H = (P-4d)tf+nsa = [(16.375-4 \times 1.1875) \times 0.75 \times 55{,}000] + (3 \times 44{,}000 \times 1.1075) = 625{,}721.$$

$$I = (P-4d)tf+ndbc = [(16.375-4 \times 1.1875) \times 0.75 \times 55{,}000] + (3 \times 1.1875 \times 0.5 \times 95{,}000) = 648{,}756.$$

$$e = H/A = 0.926 = 92.6\%.$$

Maintaining the same diameter of rivet, a long pitch of 16½ ins. gives an efficiency of 92.7%. The short pitch in this case is 4⅛ ins., which is approaching closely to the maximum limit for caulking that should be used.

Using 1⅜-in. diameter rivets, the maximum permissible pitch may be increased above that for 1⅛-in. rivets by 1½ times the change in rivet diameter, making $P = 18$ ins., for which the efficiency is 92%.

To obtain an efficiency of 92.7% with 1⅜-in. diameter rivets, a long pitch of 19¾ ins. is necessary. Since this exceeds the 18-in. limit, it cannot be used; therefore the proper joint is obtained by using 1⅛-in. diameter rivets with a long pitch of 16½ ins.

To find the necessary thickness of butt strap,

$$b = [P/2(P-nd)]te.$$
$$= [16.5/2(16.5-4 \times 1.1875)] \times 0.75 \times 0.927.$$
$$= 0.489 \text{ in.}$$

Therefore, butt straps ½ in. thick, as given in Table 6, are sufficient.

PUBLICATIONS RECEIVED

MANUFACTURE OF MUNITIONS IN CANADA.—Presidential address of H. H. Vaughan at the last annual meeting of the Engineering Institute of Canada. 92 pages and cover, 6 by 9 ins., illustrated.

TESTING OF ANEROID BAROMETERS.—Bulletin 42 issued by the Topographical Surveys Branch of the Department of the Interior, Ottawa, describing the testing of aneroid barometers at the laboratory of the Dominion Lands Surveys, and commenting briefly on the errors of aneroids and their general characteristics.

D. H. McDougall, president of the Nova Scotia Steel & Coal Co., Ltd., has completed, for his company, the purchase from the British Ministry of Shipping, represented by Director J. B. Whyte, of New York, of the coal-handling plant at the Canadian National Railway terminals, Halifax.

WATER PURIFICATION UNITS MOUNTED ON MOTOR TRUCKS

(Continued from page 202)

admirable factory in Camden, N.J., was obtained, and here, in conjunction with our construction work, a school was conducted for Sanitary Corps men, members of the water-tank train, and officers who were to have charge of the trucks in operation.

Fig. 2 shows the units as finally developed, closed and ready for the road, and the detailed arrangement is indicated by Figs. 1, 3, 4 and 6.

Fig. 3 shows the rear of the completed truck, with the rear and side gates let down for operation. The gasoline storage tank is to the right of the pump. The provisions made for carrying and chaining the suction hose are shown.

The filter, central control valve for operation of the filter, soda ash solution tank, alum pot, dechlorinator and further details of the pumping room are shown in Fig. 1.

Arrangement of Apparatus

In the upper right hand corner of Fig. 1 may be seen a tool box in which a complete set of pipe cutting and fitting tools are kept, in addition to hand tools needed about a machine shop, and beneath this tool case, is the chemical bin for storage of alum, soda ash and thiosulphate.

The laboratory arrangement in the final truck is shown in Figs. 4 and 6. The provision made for carrying chemical bottles is indicated, as is also the sink for washing glassware, and a hand air-pump for creating pressure in the storage tanks when the pumping equipment is not in operation. A 37 deg. incubator for bacteriological samples, oven for sterilizing glassware and electric lighting equipment are shown, while in the rear of the laboratory is seen a standard solution-feed chlorinator, and beneath it, the thiosulphate and soda ash controls. On the bench beside the chlorinator is a pressure auto clave for sterilizing purposes.

The first several trucks were mounted on 3½-ton White truck chassis, but by far the largest number were mounted on 5-ton, 17 ft.-wheel-base Pierce-Arrow chassis. Novo 3 h.p. gasoline engines were used, with Gould 5 by 5-in. force pumps. The filter was constructed by the Roberts Filter Mfg. Co., of Darby, Philadelphia, Pa., and the electric lighting equipment by the Vesta Storage Battery Co. The rated capacity of the unit was 1,000 gals. per hr., although the actual delivery was nearer 1,500 gals.

The support of the filter, which weighed 2,400 lbs. without the water, presented problems that required careful study. The final solution was to fasten 5-in. steel H-beams to the chassis frame by U-bolts, bolting the filter to the H-beams by feet cast on the special filter base.

Over Thousand Articles Carried

In addition to the equipment shown in Figs. 1 and 3, 1,031 articles were carried; still, much to our dismay, when the trucks were first placed in operation, we found that we had overlooked the very obvious item of a box of matches!

These units rendered valuable service under actual military operation in France. Some of them were damaged by shell-fire and some members of the Sanitary Corps were wounded while operating the units near the firing line.

Acknowledgement must be made of our appreciation of the co-operation extended by the surgeon-general's office, the Sanitary Corps, the Engineer Depot, and particularly to the following officers:—Col. F. F. Longley, Lt.-Col. Edward Bartow, Major H. McC. Yost, Capt. Morris Scharff, Capt. Gerald W. Knight, Capt. W. F. Wells, Capt. J. J. Newman, Lt. A. H. Wagner, Lt. H. H. Scott and Lt. T. W. Smith.

Without the suggestions and co-operation of M. F. Tiernan, and C. F. Wallace, of our organization, these units could not have been constructed, and special thanks are due to two members of our staff until recently in service in France, Capt. A. R. Murphy, who materially contributed to the development of the first unit in the tests at Maplewood, N.J., and Capt. R. V. Donnelly, who was in charge of their construction at Camden, N.J. Thanks are also due to the engineers of the Roberts Filter Mfg. Co. for their special co-operation.

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PRINCIPAL CONTENTS

RIVETED JOINTS FOR PENSTOCKS

IN many of the more recent hydro-electric developments of large capacity, it has been necessary to use steel penstocks of large diameters under high heads, and in order to keep the thickness of metal within reasonable limits, so that the work can be handled by the ordinary equipment of structural shops, it is quite essential to use the most efficient types of joints.

The article by H. A. Babcock and J. R. Montague in this issue assembles information on the design of these heavier joints which is not readily obtained in text books, and which should, therefore, be of value to designers who have to handle problems of the nature discussed.

The strength of a joint depends upon three main factors, namely, tension in the plate, shear on the rivets and bearing on the rivets; and as in the heavier types of joints one finds several combinations of these three factors, these *combinations* must be carefully considered when solving for the maximum efficiency.

CONTRACT FORMS

CONTRACT forms and specifications have been the subject of special study by engineers and architects for a number of years. The American Institute of Architects has developed the Standard Documents; the American Railway Engineering Association has adopted a uniform general contract form; a special committee of the American Society of Civil Engineers has the subject now under consideration. To date, the only voice which the general contractor, who is the man most vitally interested in contract forms, has had in the matter, has been either on the invitation of some one of the committees of these associations, as an ineffectual protester in some local exchanges, or as the victim of circumstances on an individual contract. What he has said before the committees of engineers and architects has doubtless had some effect on the final results, and at least has put the contractor's position on file. What he has said in his local exchange or in the secluded recesses of his own office, will doubtless never be allowed publication. Both the Association of Canadian Building and Construction Industries and the Associated General Contractors of America now propose to make the general contractor's position clear and effective on the subject of contracts. They intend to make a careful study of existing forms, both good and bad, of every kind, and in co-operation with the engineers and the architects, to eliminate unfair practices and to establish clear, definite and equitable clauses in contracts under which general contractors of recognized standing will work.

OWEN SOUND'S INTERSWITCHING PROBLEM

OWEN SOUND lies in the valley of, and at the mouth of, the Sydenham River. The harbor was formed by widening and deepening the river. The mouth of the river at the entrance has a width of 295 ft.; the main harbor has an average width of 350 ft. The upper or narrow portion, near the Tenth Street bridge, is only about 100 ft. wide. The town is served by branches of the Canadian Pacific and Grand Trunk railways. The yards and stations of each immediately adjoin the harbor, the Grand Trunk being on the west and the Canadian Pacific on the east. There is no connection between them. Each railway enters the town through an industrial district which it well serves. Neither road, in any place, traverses a residential or business district or crosses an important street. The station of each is within about one-half mile of the business centre of the town. But there is no connection between the two railways, thus preventing the interswitching of either passenger or freight cars.

A number of methods of interswitching have been proposed, and W. F. Tye, consulting engineer, Montreal, was recently asked to investigate them. Mr. Tye has reported that the best method, from a strictly railway point of view, would be to permit the Grand Trunk to follow First Avenue West to a point between Ninth and Tenth Streets, cross the Sydenham River at the bend, switch back at a point on First Avenue East just south of Ninth Street, and run back to the Canadian Pacific Railway on First Avenue East. "As such a route would be highly objectionable to the residents of First Avenue West," says Mr. Tye, "I did not seriously consider it."

Of the other suggestions, he reports that only three appeared to be worthy of detailed examination:—

1.—Crossing the river at its mouth.

2.—Crossing the harbor at Tenth Street traffic bridge and switching back on First Avenue East.

3.—Electrical switching.

Of these three Mr. Tye recommends the second method despite the fact that it would bring steam locomotives into the mercantile districts, passing and shunting directly behind a number of the best shops, with all the attendant disadvantage of noise, soot, dirt, smoke, etc. They would also pass within 300 ft. of some of the best residences of First Avenue West. Moreover, this method would involve considerable shunting across busy Tenth Street at the east end of the bridge. The switch would be located immediately to the south of Tenth Street, and each train passing between the two roads in either direction would have to cross Tenth Street twice.

With all these disadvantages, it is indeed unfortunate for Owen Sound that the second method is the only one that Mr. Tye can recommend from an economical point of view.

The only objection from an engineering standpoint that Mr. Tye takes to crossing the river at its mouth, is that for a considerable distance the interswitching trains must back up, and that this is objectionable in the winter. Exactly how insuperable this difficulty is, Mr. Tye does not say. He also refers to interference with navigation, but this could be obviated, at considerable expense, he intimates, by the construction of a bascule bridge instead of a swing bridge. "This route is economically justifiable as a whole," states Mr. Tye, but he estimates that the railways would lose about $1,500 a year as a result, at full switching charges. This crossing, however, has the decided advantage that it confines the railways entirely to the industrial districts, where they belong, keeping them out of the mercantile and residential sections.

Mr. Tye frankly makes it plain that he does not try to place any monetary value upon this advantage, which is a matter of civic convenience, esthetics and town planning. But the citizens of Owen Sound, expecting their city to grow and to become better able in the future to support, even at an annual loss, enterprises that are of benefit to the city as a whole, will no doubt take these items into serious consideration. Mr. Tye evidently expects them to do so, inasmuch as he carefully points out the very great disadvantages —from a community standpoint—of the plan that he recommends mainly for economical reasons.

Would it not be well for the officials of Owen Sound, before finally deciding this very vital question, to consult Thomas Adams, the town planning adviser to the Dominion government, or some other town-planning authority, regarding possible disastrous effects that any one of the various proposed plans might have upon the future growth, beauty, comfort, assessed valuation and general welfare of their city?

ENGINEERING INSTITUTE ELECTIONS

At a meeting of the Engineering Institute of Canada held July 22nd in Montreal, the following elections and transfers were announced:—

Members.—H. W. Buck, Hewlett, N.Y.; A. R. Chambers, New Glasgow; G. P. Cole, Montreal; F. O. White, Temiskaming.

Associate Members.—J. R. Black, Sault Ste. Marie; J. L. Charles, Toronto; F. W. Clark, Niagara Falls; G. A. Colhoun, Hamilton; C. D. Dean, Toronto; L. L. Jacobs, Sault Ste. Marie; A. C. Loudon, Montreal; H. D. Maccaulay, St. John, N.B.; J. A. H. Marchand, Three Rivers; E. S. Martindale, Ottawa; H. R. McClymont, Toronto; C. R. McColl, Sandwich, Ont.; W. L. McFaul, Sault Ste. Marie; H. B. Pickings, Halifax; F. L. Richardson, St. John, N.B.; K. G. Ross, Sault Ste. Marie; H. N. Skolfield, New Glasgow; Francis Stidwill, Cornwall; C. W. Stokes, Montreal; G. M. Tripp, Victoria; W. D. Walcott, Toronto; C. S. Whitney, Niagara Falls; D. S. Wickwire, Halifax.

Juniors.—P. B. Buckley, Montreal; C. R. McCort, Montreal; R. C. Moore, Halifax; W. H. S. Richardson, Belleville; S. O. Roberts, Ottawa; B. N. Simpson, Toronto; G. O. Vogan, Toronto; C. O. Whitman, Sault Ste. Marie.

Transferred, Associate Members to Members.—A. E. Caddy, Campbellford, Ont.; J. A. DeCew, Mount Vernon, N.Y.; L. B. Elliot, Edmonton; B. M. Hill, Fredericton; S. B. Johnson, Ottawa; N. B. McLean, Ottawa; G. G. Murdoch, St. John, N.B.; A. V. Redmond, Winnipeg.

Transferred, Juniors to Associate Members.—L. C. Dupuis, Levis; J. A. Keefer, Victoria; A. M. Kirkpatrick, Ottawa; A. G. McLerie, Toronto; J. N. Stinson, Ottawa; L. W. Wynne-Roberts, Toronto.

Transferred, Students to Associate Members.—C. R. Avery, Toronto; J. H. A. E. Drolet, Quebec; J. E. Heroux, Quebec; R. P. Johnson, Niagara Falls; P. C. Kirkpatrick, Ottawa; C. C. Lindsay, Quebec; J. E. Ratz, Ottawa; W. E. Stephens, London; A. C. Wright, Ottawa.

Transferred, Students to Juniors.—R. D. Galbraith, Toronto; W. B. Redman, Toronto.

PERSONALS

James, Loudon & Hertzberg, Ltd., consulting engineers, Toronto, have been asked by the council of Chatham, Ont., to investigate the city's water supply and to report upon proposed improvements.

John Hepinstall, of St. Thomas, Ont., who has been in Washington, D.C., engaged in special work for the U.S. Navy, is reported to have been appointed supervising engineer of design at the Charleston, W. Va., naval base.

D. A. R. McCannel, who has been acting city engineer of Regina since April, 1917, can now drop the "acting" from his title, as the city council have appointed him as permanent head of the city's engineering staff, which he joined in 1911.

Hon. Frank Carvell, who last week resigned as Minister of Public Works, has been appointed chairman of the Board of Railway Commissioners for Canada, succeeding Sir Henry L. Drayton, who resigned to accept the post of Finance Minister in the Dominion cabinet.

William Snaith, office engineer for the Hydro-Electric Power Commission of Ontario on the construction of the Chippawa-Queenston power canal, has resigned to accept a position as principal assistant engineer on the staff of Frank Barber and R. O. Wynne-Roberts, consulting engineers, Toronto.

Prof. E. G. Matheson, assistant engineer on the staff of the University of British Columbia, and acting head of the Department of Civil Engineering, has been appointed, under A. D. Swan, consulting engineer, to take charge of the surveys and borings in connection with the contemplated development of Vancouver Harbor.

Capt. R. G. Sneath, formerly a member of the Welland Canal engineering staff, has returned from overseas and has joined the radial railway department of the Hydro-Electric Power Commission of Ontario. Capt. Sneath graduated in civil and sanitary engineering at the University of Toronto in 1911 and 1912. He went overseas in the spring of 1916 with the 4th Division, and took part in a large number of important engagements.

Lt.-Col. William G. MacKendrick, president of the Warren Bituminous Paving Co. of Ontario, and formerly director of roads for the Fifth British Army, has been appointed an officer of the Legion of Honor by the French government. Col. MacKendrick rendered very valuable services while at the front, saving hundreds of thousands of dollars in road construction for the allied armies. For this work the British government conferred upon him the Distinguished Service Order and the Order of the British Empire.

R. R. Shafter, who is well known among Canadian engineers and contractors, has been appointed manager of the New York district office of the Traylor Engineering and Manufacturing Co., of Allentown, Pa. Mr. Shafter's territory will include New York State, New England and Eastern Canada. Before the war Mr. Shafter travelled throughout Eastern Canada as the Traylor Co.'s representative, but during the war he was general superintendent for the Traylor Shipbuilding Corporation, Philadelphia. Under Mr. Shafter's management, that corporation completed more 3,500-ton cargo carriers within two years than did any other shipyard on the Atlantic and Gulf coasts.

Major A. J. McPherson, formerly chairman of the Local Government Board of the Province of Saskatchewan and at one time deputy minister of public works of that province, has been appointed consulting engineer to the Saskatchewan Bureau of Public Health, succeeding the late T. Aird Murray. Major McPherson will also act as consulting engineer to the Local Government Board. He returned not long ago from France, where he served throughout the years 1917 and 1918 with the Canadian Engineers, at first as a field engineer on roads and defences, and later as second in command of the 11th Battalion. Major McPherson graduated in 1893 at the University of Toronto, Faculty of Applied Science and Engineering.

CONSTRUCTION NEWS SECTION

Readers will confer a great favor by sending in news items from time to time. We are particularly eager to get notes regarding engineering work in hand or proposed, contracts awarded, changes in staffs, etc.

ADDITIONAL TENDERS PENDING

Not Including Those Reported in This Issue

Further information may be had from the issues of *The Canadian Engineer*, to which reference is made.

PLACE OF WORK	TENDERS CLOSE	ISSUE OF	PAGE
Anse aux Gascons, Que., wharf.	Aug. 14.	July 31.	42
Bridgeville, N.S., school......	Aug. 30.	July 31.	41
Chicoutimi, Que., station	Aug. 9.	July 24.	46
Cornwall, Ont., wharf	Aug. 12.	July 31.	44
Halifax, N.S., schools	Aug. 30.	July 31.	41
Indian Head, Sask., office building	Aug. 12.	July 31.	41
Odessa, Ont., bridgework	Aug. 8.	July 31.	44
Orangeville, Ont., culverts, bridges and abutments....	Aug. 11.	July 31.	39
Ottawa, Ont., pumps, engines, etc.	Aug 30.	July 31.	44
Saskatoon, Sask., steel and concrete bridges	Aug. 12.	July 31.	39
Saskatoon, Sask., turbo-generator	Sept. 23.	July 24.	44
Strathroy, Ont., cannery buildings	Aug. 8.	July 31.	42
Toronto, Ont., grading and road construction	Aug. 18.	July 31.	40
Toronto, Ont., highway structures	Aug. 19.	July 31.	46
Toronto, Ont., pavements, curbs and sidewalks	Aug. 11.	July 31.	40
Toronto, Ont., railway ties....	Aug. 25.	July 31.	46
Truro, N.S., girls' home	Aug. 8.	July 31.	42
Walkerville, Ont., pumping station	Aug 12.	July 31.	40
Winnipeg, Man., water recorder	Sept. 1.	July 31.	46

BRIDGES, ROADS AND STREETS

Amherstburg, Ont.—Contract has been awarded by the town council for construction of Silex stone walks on St. Arnaud, Laird, Alma and William Sts., to Henry Robidoux, 15.25 cents per ft. Rejected tenders from Pettypiece, Ltd., 20 cents per ft.; C. M. Ferriss, 17 cents per ft. W. A. McCormick, town clerk.

Brantford, Ont.—The city council contemplate building a concrete pavement on West St. to connect with the country road to Mount Hope Cemetery.

Brechin, Ont.—Contract was awarded by the committees from Victoria and Ontario counties for construction of a reinforced concrete bridge to Mr. Kehoe, Brechin. Contract price, $2,125 (less the price of the steel). Chairman Thompson, Victoria county.

Chilliwack, B.C.—The Yale road at Chilliwack will be paved this summer, utilizing the present macadam pavement as a base. J. W. Blackman, city engineer, New Westminster, B.C.

Chilliwack, B.C.—Arrangements have been made between the city council and the provincial department of works to proceed with construction of an 18-ft. pavement this year on the Westminster-Yale road.

Crowland, Ont.—Contract has been awarded by the township council for construction of concrete pavements on South Main and Ontario St. to Somerville and Dilworth, Welland, Ont. Contract price, $1,845. H. L. Pratt, clerk.

Douro, Ont.—The townships of North Monaghan, Otonabee and Asphodel have adopted the good roads scheme and will proceed with construction at an early date.

Galt, Ont.—The board of works has announced its intention to commence construction of pavement on Park Ave. Work will start immediately. Chairman McKellar.

Halifax, N.S.—The board of works will pave the following streets in the order mentioned: Kempt Rd., Livingston to Macara; Robie St., Macara to Quinpool Rd.; Bell Rd., Quinpool Rd. to Sackville St.; Coburg Rd., Robie to Oxford; Agricola St., Cunard to Almon; Morris St., Water to South Park; Spring Garden Rd., Tower Rd. to Robie; Gottingen St., Gerrish to Young; Sackville St., Barrington to South Park; Grafton St., Spring Garden Rd. to Blowers; Argyle St., Blowers to Jacob; Prince St., Water to Argyle; Cornwallis St., Brunswick to Gottingen; Brunswick St., Sackville to North; Jacob St., Argyle to Brunswick; Quinpool Rd., Willow Tree to Arm Bridge; Cunard St., Gottingen to Robie; North St., Barrington to Robie; Salter St., Water to Hollis; Granville St., Sackville to Salter; Buckingham St., Barrington to Brunswick; Windsor St., Quinpool Rd. to Cunard; Hollis and South Sts. will take precedence as soon as they are in shape to be paved. F. W. W. Doane, city engineer.

Mimico, Ont.—The Toronto-Hamilton Highway Commission have opened their new reinforced concrete bridge over Mimico Creek.

Montreal, Que.—The commissioners of the city of Montreal have awarded contract for block and asphaltic pavement on Redpath St. to the city department of works. A. E. Doucet, director.

Montreal, Que.—No tenders were received by the commissioners of the city of Montreal for the demolition of the old and construction of a new wooden bridge over the Aqueduct at Woodland Ave. New tenders will soon be called. A. E. Doucet, director.

Montreal, Que.—Sidewalks will be constructed on the following streets: Northcliffe Ave., both sides, from Sherbrooke to Notre Dame de Grace Ave., cost $15,184; Wilson Ave., from Sherbrooke to the C.P.R. tracks, cost $4,096; Old Orchard Ave., from Church to Monkland, cost $4,600; Ste. Marguerite, from St. Antoine to Richelieu, cost $880; Ste. Emelie St., both sides, from de Courcelles to Beaudoin St., cost $7,084; Sir George Etienne Cartier, both sides, from Emelie southwards, cost $1,300; Maria, from St. Augustin to Ste Emelie, cost $2,800; both sides of Lenoir St., from St. James to St. Antoine St., cost $3,014; Desnoyers St., along its entire length, cost $6,853; both sides of Walnut St., for its entire length, cost $4,273. Rene Bauset, city clerk.

Niagara Falls, Ont.—Contract has been awarded by the city council for construction of concrete pavements, curbs and gutters to the works department, city of Niagara Falls. D. T. Black, city engineer.

Odessa, Ont.—Tenders will be received by the department of highways, Toronto, until 12 o'clock noon, August 8th, for construction of concrete abutments, concrete roadway and sidewalk floors. Plans, etc., at the offices of the resident engineer, Napanee and city engineer, Kingston. W. A. McLean, deputy minister.

Orangeville, Ont.—It is proposed to erect a new bridge in place of the present wooden structure over the creek at Mill St. as a soldiers' memorial.