JOURNAL *of the*

BOSTON SOCIETY OF CIVIL ENGINEERS

1848
BOSTON
SOCIETY
OF CIVIL
ENGINEERS

JANUARY - 1945

VOLUME XXXII NUMBER 1

BOSTON SOCIETY OF CIVIL ENGINEERS

OFFICERS, 1944 - 1945

PRESIDENT

HARRY P. BURDEN

(Term expires March, 1945)

VICE-PRESIDENT

CARROLL A. FARWELL

(Term expires March, 1946)

SECRETARY

EVERETT N. HUTCHINS

TREASURER

CHESTER J. GINDER

DIRECTORS

EMIL A. GRAMSTORFF
JOHN B. WILBUR
(Term expires March, 1945)

ALBERT E. KLEINERT
HENRY A. MOHR
(Term expires March, 1946)

PAST PRESIDENTS

ALBERT HAERTLEIN
ATHOLE B. EDWARDS
HOWARD M. TURNER

SANITARY SECTION

FREDERICK S. GIBBS, Chairman
GEORGE C. HOUSER, Clerk

DESIGNERS SECTION

LAWRENCE M. GENTLEMAN, Chairman
FRANK L. LINCOLN, Clerk

HYDRAULICS SECTION

ALLEN J. BURDOIN, Chairman
HAROLD A. THOMAS, Clerk

HIGHWAY SECTION

CHARLES O. BAIRD, Chairman
GEORGE W. HANKINSON, Clerk

NORTHEASTERN UNIVERSITY SECTION

ARTHUR HEBERT, Chairman
GORDON SEARLES, Clerk

Editor—EVERETT N. HUTCHINS
715 Tremont Temple, Boston

JOURNAL OF THE

BOSTON SOCIETY OF CIVIL ENGINEERS

Volume XXXII JANUARY, 1945 Number 1

CONTENTS

PAPERS AND DISCUSSIONS

OF GENERAL INTEREST

Entered as second-class matter, January 15, 1914, at the Post Office at Boston, Mass., under Act of August 24, 1912

Published four times a year, January, April, July and October, by the Society
715 Tremont Temple, Boston, Massachusetts

Subscription Price $4.00 a Year (4 Copies)
$1.00 a Copy

Acceptance for mailing at special rate of postage provided for in Section 1103, Act of October 3, 1917, authorized on July 16, 1918.

The Society is not responsible for any statement made or opinion expressed in its publications.

THE HEFFERNAN PRESS
WORCESTER, MASS.

JOURNAL OF THE

BOSTON SOCIETY OF CIVIL ENGINEERS

Volume XXXII | JANUARY, 1945 | Number 1

DETAILS OF DESIGN WITH TIMBER CONNECTORS

BY ALBERT G. H. DIETZ*

(Presented at a meeting of the Designers Section of the Boston Society of Civil Engineers held on October 13, 1943.)

Recent investigations into the behavior of splitting timber connectors in various combinations and in various types of timber joints, coupled with the recently issued Directive 29 of the War Production Board, have introduced new procedures into the design of joints employing timber connectors. It is the purpose of this paper to illustrate the new approach by a few examples of detailed design.

As illustrated in Fig. 1, split-ring timber connectors consist of steel rings, split at one point in their periphery, which are fitted into pre-cut, matched grooves in adjacent timbers. Since one-half of the ring is embedded in each member, it is possible to transmit stress from one timber to the other and, as shown in Fig. 2, loads may be parallel, perpendicular, or inclined to the direction of grain. If P represents the allowable load on a ring loaded parallel to the grain and Q the allowable load perpendicular, the permissible load at any angle θ formed by the direction of load and the direction of grain is found by the Hankinson formula

$$P_\theta = \frac{P\,Q}{P \sin^2 \theta + Q \cos^2 \theta} \qquad (1)$$

Allowable loads on rings depend not only upon the angle of load to grain, but upon wood species, duration of load, the moisture content of the wood at the time of fabrication, the expected moisture

*Assistant Professor of Structural Design and Materials, Department of Building Engineering and Construction, Massachusetts Institute of Technology, Cambridge, Mass.

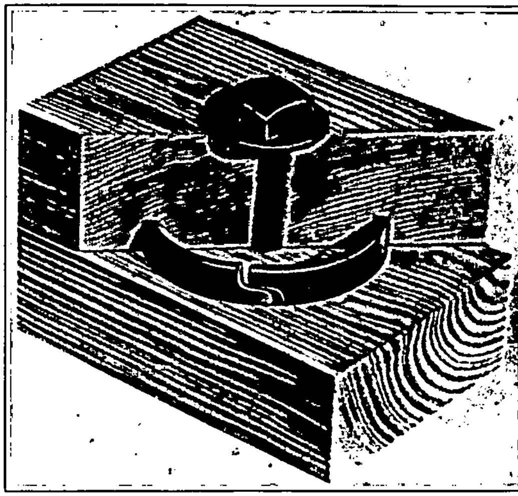


Fig. 1.

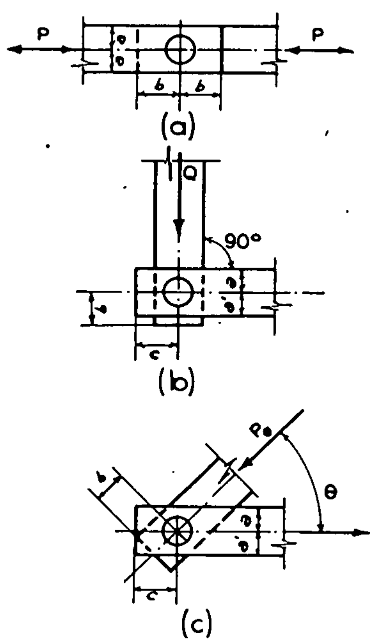


Fig. 2.

content during use, the thickness of timber, and whether rings are in only one or in both faces of a timber. Except for the latter two, no attempt will be made in this paper to evaluate these variables; they govern the load which may be placed upon a ring but do not otherwise affect the design procedure.

Edge and End Distances

If a connector is to sustain its full rated load, there must be enough wood in its vicinity to absorb and distribute the stresses. In Fig. 2(a) the edge distances a, and end distances b must be adequate. Distance a is the same whether P is tension or compression, but b must be greater if P is tension than if compression, since tension tends to pull the ring out through the end of the member. In Fig. 2(b) the load Q (governed by the side timber, loaded perpendicular to the grain) tends to push the ring through the lower edge of the horizontal member. The compression edge distance a' must therefore be greater than the edge distance a which is the same as in Fig. 2(a). Compression end distance b in Fig. 2(b) can be less than in 2(a) because Q is less than P. If the direction of Q is reversed, the positions of a and a' are also reversed and the end distance b becomes that required for a tensile load of magnitude Q instead of a comprehensive load. The same general reasoning holds for Fig. 2(c), except that as θ becomes smaller than 45°, required compression edge distance a' also diminishes until it becomes equal to a when θ is 0°. End distance b is intermediate between Figs. 2(a) and 2(b) because P_θ is less than P but greater than Q.

If horizontal members are cut off as shown in Figs. 2(b) and 2(c), the end distance c must be kept large enough to prevent splitting.

When rings are not fully loaded, as usually occurs, end and edge distances may be reduced.

The foregoing observations may be illustrated, using a 4-in. split ring as an example, by reference to Figs. 4 and 5. Fig. 4 is a solution of Equation (1) for allowable loads on 4-in. split rings employed under the conditions noted. Fig. 5 gives the required spacings and end distances of 4-in. split rings.

1. *Edge Distance.* (Fig. 4)

In Fig. 4 are given two sets of curves for allowable loads on 4-in.

split rings, one for full edge distance and one for minimum edge distance. Interpolated between the maximum and minimum curves are curves for edge distances varying by ¼-in. intervals. Minimum is 2¾ in. This is also standard for θ equal to 0°. If θ is 45° to 90°, a' must be 3¾ in., for full load P_θ, but a' may be reduced to 2¾ in., if Q in equation (1) is reduced to 83 per cent. For edge distances between 2¾ in. and 3¾ in., allowable load varies linearly between the two curves. For θ varying from 0° to 45°, the required edge distance a', for full load P_θ, varies linearly from 2¾ in, to 3¾ in., but if the edge distance actually is less than a', the allowable load is reduced accordingly.

In Fig. 2, for example, a is 2¾ in. in all instances. In 2(a), a' is 3¾ in. if Q is full load, but only 2¾ in. if Q is reduced to 83 per cent. If Q is 90 per cent, a' must be

$$2\tfrac{3}{4} + \frac{(90-83)}{(100-83)} \times 1 = 2\tfrac{3}{4} + 0.41 = 3\ 3/16 \text{ in.}$$

In 2(c), if θ is 30°, for example, a' need only be 3.42 or 3 7 16 in., but if P_θ is only 90 per cent of full allowable, a' can be 2¾ in. If P_θ is 95 per cent of full allowable, a' must be

$$2\tfrac{3}{4} + 5/10\ (3\ 7/16 - 2\tfrac{3}{4})$$

or 3⅛ in.

2. *End distance.* (Fig. 5)

(a) *Tension.* For any angle of load to grain, if a ring is loaded in such a manner that some component of the load tends to push the ring out through the end of the piece, it is considered to be in tension, and the required end distance for full load P, Q or P_θ is 7 in. If the end distance is reduced to an absolute minimum of 3½ in., the allowable load must be reduced to 62.5 per cent or less. For intermediate end distances, the allowable loads vary linearly. In 2(a), for example, if b is 7 in., P can be 100 per cent, if b is 3½ in., P is reduced to 62.5 per cent or less, if b is 5 in., P is reduced to 78.5 per cent. In Fig. 2(c), if P_θ is full allowable at angle θ, c must be 7 in., if P_θ is reduced to 62.5 per cent or less, c may be only 3½ in., or if P_θ *is* reduced to 78.5 per cent, c may be 5 in. Similarly, in 2(b), c may be 7, 3½ or 5 in., for Q equal to 100, 62.5, and 78.5 per cent respectively.

(b) *Compression.* If a ring is so loaded that it does not tend to push out through the end of a piece in which it is embedded, it is considered to be in compression. Three conditions arise, θ equal to 0°, θ equal to 90°, and θ lying between 0° and 90°.

1. θ equal to 0°. Fig. 2(a). For full compression load P, b must be 5½ in. but can be reduced to 3¼ in., if P is reduced to 62.5 per cent or less. For intermediate values of P, b varies accordingly.

2. θ equal to 90°. Fig. 2(b). This is the same as tension at $\theta = 90°$, and the distance c must therefore be 7 or 3½ in., depending upon whether Q is 100 or 62.5 per cent. For intermediate values of Q, c varies accordingly.

3. θ lying between 0° and 90°. Required end distances c vary linearly with θ between the conditions required for θ equal to 0° and θ equal to 90°.

Center-to-Center Spacing

If pairs of rings (Fig. 3) are employed, the observations just

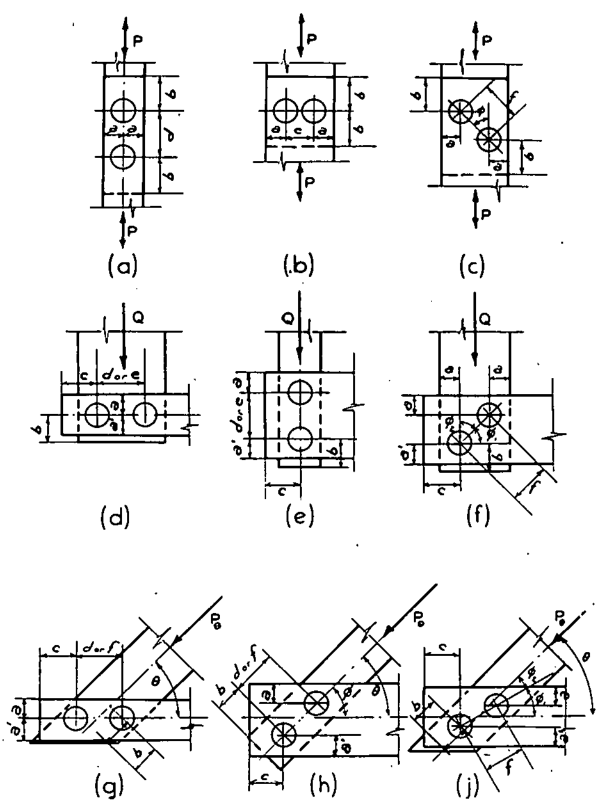


FIG. 3.

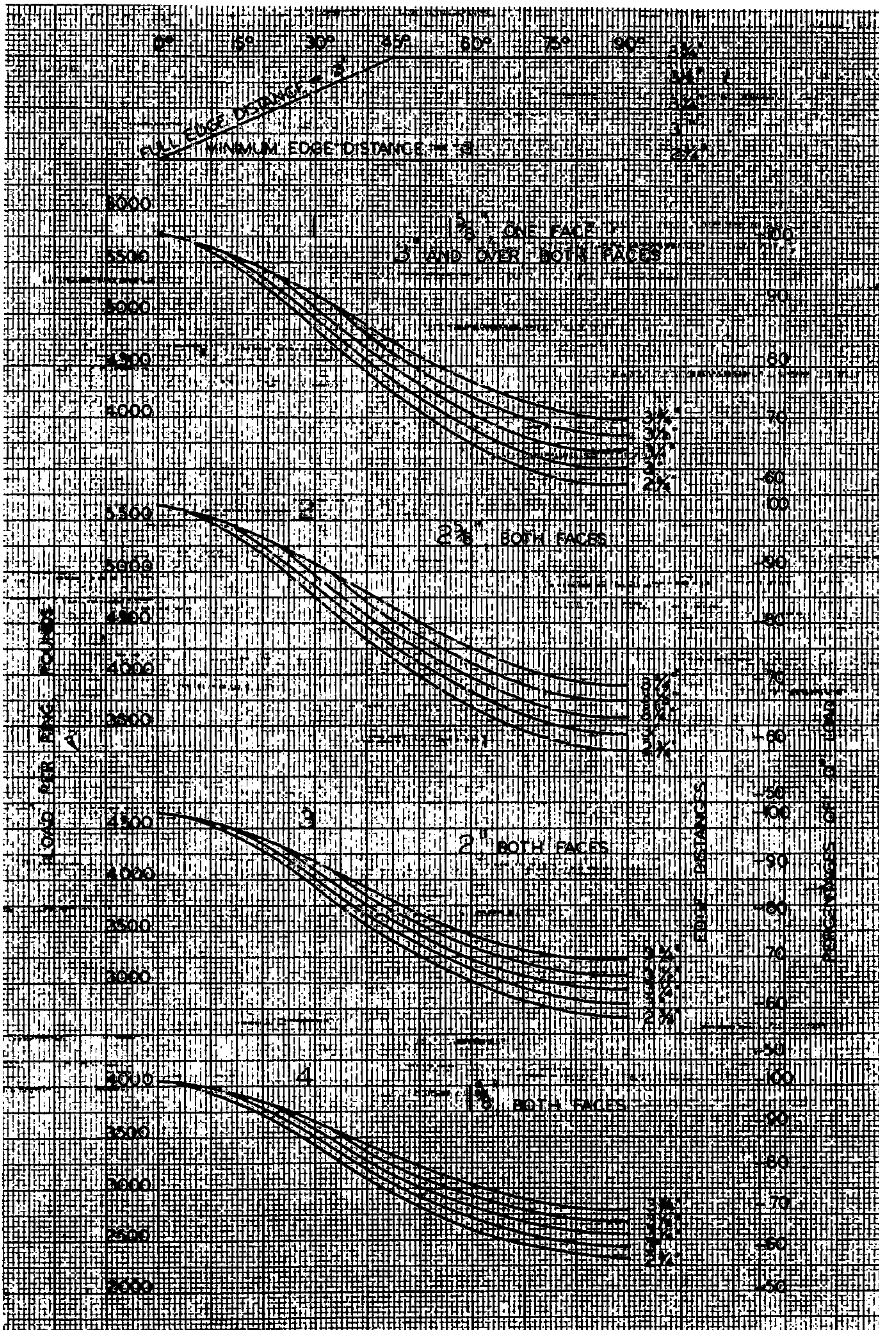


FIG. 4.—CHARTS OF ALLOWABLE LOADS ON 4-INCH SPLIT RING TIMBER CONNECTORS IN GROUP B SPECIES, AIR-DRY IN OUTER THREE-QUARTERS INCH OF THICKNESS AT TIME OF FABRICATION, IN STRUCTURES CONTINUOUSLY LOADED FOR MORE THAN THREE MONTHS, IN LOCATIONS PERMITTING TIMBERS TO REMAIN IN AN AVERAGE AIR-DRY CONDITION. CHARTS ARE SOLUTIONS OF EQUATION (1), FOR FULL, MINIMUM, AND INTERMEDIATE EDGE DISTANCES, AND FOR TIMBERS OF DIFFERENT THICKNESSES WITH RINGS IN ONE OR BOTH FACES.

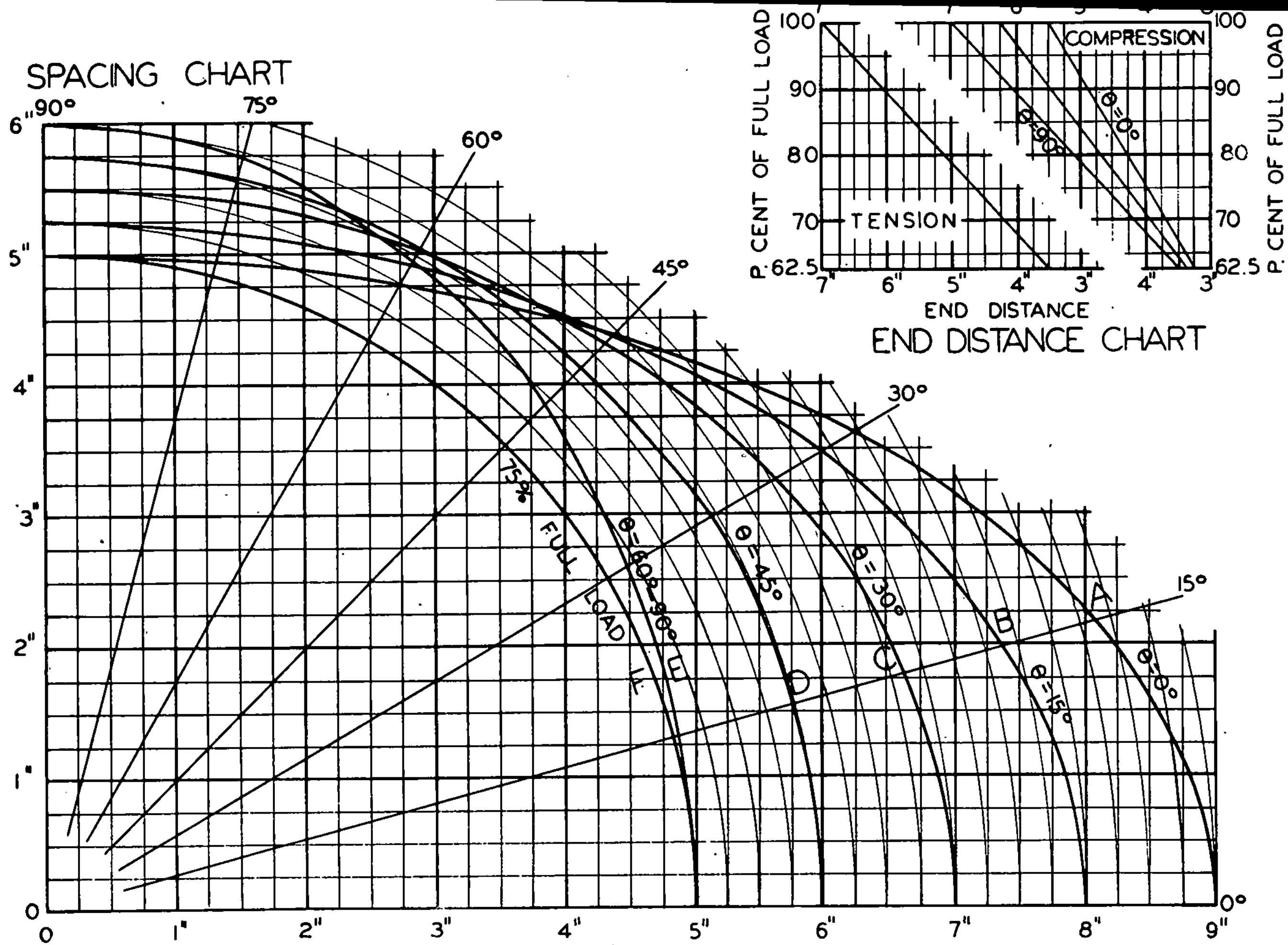

SPACING CHART
END DISTANCE CHART
COMPRESSION
TENSION
P. CENT OF FULL LOAD
END DISTANCE
75% FULL LOAD
θ=60°-90°
θ=45°
θ=30°
θ=15°
θ=0°
θ=90°
A
B
C
D
E
F

FIG. 5.

made with respect to edge and end distances still apply, but, in addition, the center-to-center distances, or spacings, of adjacent rings must be great enough to develop the rated load-carrying capacity of the rings. Spacings depend upon the angle of load to grain and upon the angle formed by the ring axis, or line joining the centers of ring-pairs, with the direction of grain.

1. *Load Parallel to Grain.* Figs. 3(a), (b), (c).

Figs. 3(a), (b), (c) illustrate the three cases of ring-pairs loaded parallel to the grain. The spacing *d,* ring-axis parallel to grain, is greater than spacing *e*, ring-axis perpendicular to grain because in the first instance the rings tend to shear out along the same line. If the ring-axis forms an angle ϕ which is neither 0° nor 90°, as shown in Fig. 3(c), the spacing *f* is found from the equation of an ellipse

$$f = \frac{d\,e}{\sqrt{d^2 \sin^2 \phi + e^2 \cos^2 \phi}} \qquad (2)$$

For a 4-in. split-ring, the ellipse for loading parallel to the grain is curve *A*, Fig. 5. Spacing *d* is 9 in., spacing *e* is 5 in., and for ϕ equal to 30°, for example, *f* is 7¼ in.

2. *Load Perpendicular to Grain.* Figs. 3(d), (e), (f).

In Fig. 3(d), the vertical member is loaded parallel to grain, ϕ is 90°, and spacing is, therefore, *e*. The horizontal member is loaded perpendicular to the grain, ϕ is 0°, and spacing is therefore *d*. In the horizontal member the angle of load to grain is 90°, and *d* can be less than for 0° loading. For a 4-in. split ring (Fig. 5), spacing *e*, curve *A* is required for the vertical member. Spacing *d*, curve *E*, angle of load to grain 90°, is required for the horizontal member. Both spacings are 5 inches.

In Fig. 3(e), the horizontal member is loaded perpendicular to the grain ($\theta = 90°$) and the ring axis ϕ is also 90°. Curve *E*, spacing *e*, is therefore required and is found to be 6 in. Vertical member is loaded parallel to grain ($\theta = 0°$) and the ring axis ϕ is also 0°. Curve *A*, spacing *d* is therefore wanted, but must be modified because the load *Q* is less than the full allowable *P* parallel to grain. Inasmuch as *Q* is 69.5 per cent of *P* (Fig. 4) and therefore less than 75 per cent of *P*, curve *F* comes into the picture and the spacing can be 5 in. in the vertical member. Final spacing, therefore, is the 6 in. required in the horizontal member.

In Fig. 3(f), the ring axis forms an angle ϕ_1 with the grain of the horizontal member and ϕ_2 with that of the vertical. If ϕ_1 is 30°, for instance, the spacing f in the horizontal member is found, from curve E, angle 30°, to be 5 3/16 in. Since 5 in. is sufficient for the vertical member, the final spacing f is 5 3/16 inches.

3. *Load Inclined to Grain.* Figs. 3(g), (h), (i).

In 3(g), rings in inclined member are loaded parallel to the grain, θ is 0°, but the ring axis forms an angle ϕ with the grain of the inclined member. Spacing f is governed by the allowable load per ring and by angle ϕ. For example. if θ is 30°, the allowable load per ring, P_θ, from equation (1) or Fig. 4, is $0.9P$. In the inclined member the distance f (Fig. 5, 30° line, curve A) is 7¼ in. for full allowable load P. Inasmuch as the actual load P_θ is $0.9P$, the corrected spacing f is found by direct interpolation along the 30° line between curve A (100% P) and curve F (75% P). Corrected spacing f is found to be 6.35 in. or 6⅜ in. Rings in the horizontal member are loaded to capacity ($P_\theta = 0.9P$) at θ equal to 30° and ϕ equal to 0°. Intersection of the 0° line and curve C gives the spacing d as 7 in. Final spacing, therefore, is 7 in. controlled by the horizontal member.

In 3(h), if θ is 30°, P_θ is $0.9P$. In the inclined member θ and ϕ are both 0°. Curve A and 0° line show spacing for full load to be 9 in., but P_θ actually is $0.9P$. Interpolation along line 0° between curves A and F indicate that the required spacing in the inclined member is 7.4, or 7 7/16 in. In the horizontal member θ and ϕ are both 30°. Intersection of the 30° line and curve C yields 6½ in. required spacing f in the horizontal member. Final spacing, therefore, is 7 7/16 in., controlled by the inclined member.

In 3(j), suppose θ is 30°, ϕ_1 is 20°, and ϕ_2 is 10°. In the inclined member, f for full allowable load P is 8⅝ in. (intersection of 10° line and curve A). Interpolating between this point and curve F, spacing f for $P_\theta = 0.9P$ is found to be 7¼ in. In the horizontal member full allowable load is $0.9P$. Spacing f, therefore, is the intersection of the 20° line and curve C, or 6¾ in. Final spacing, therefore, is 7¼ in., controlled by the inclined member.

End and edge distances for all the cases illustrated in Fig. 3 are found as previously described. In Figs. 3(g), (h), (j), for example, a is 2¾ in., a' is 3 7/16 in., and c is 7 in. because the direction of P_θ is such as to tend to push the end ring out through the end of the side member. If P_θ were reversed in direction, c would be 6 in., as found by linear interpolation between 5½ and 7 in.,

$$c = 5\tfrac{1}{2} + \frac{30}{90}(7 - 5\tfrac{1}{2}) = 6 \text{ in.}$$

in Fig. 5. Since P_θ is only $0.9P$, end distance b is $3\tfrac{1}{4} + 0.9(5\tfrac{1}{2} - 3\tfrac{1}{4}) = 5\tfrac{1}{4}$ in. When the end of a compression or tension member is cut on a bias, as in Figs. 3(g), and 3(j), the end distance b is measured from the midpoint of the radius of the ring normal to the center line of the member.

Illustrative Example

The foregoing observations may be illustrated by designing the heel and peak joints in the Belgian truss shown in Fig. 6. Without going into an extended analysis of possible combinations of members, it will be decided to use two-member chords, single-member compression web diagonals placed between chord members, and two-member tension web diagonals placed outside the chords. Material selected will be Group 2 softwood,

$$\begin{aligned} E &= 1{,}600{,}000\ \#/\text{p.s.i.} \\ f &= 1{,}700\ \#/\text{p.s.i.} \\ c_{\parallel} &= 1{,}325\ \#/\text{p.s.i.} \\ c_{\perp} &= 455\ \#/\text{p.s.i.} \\ s &= 145\ \#/\text{p.s.i.} \end{aligned}$$

as specified by W.P.B. Directive 29.

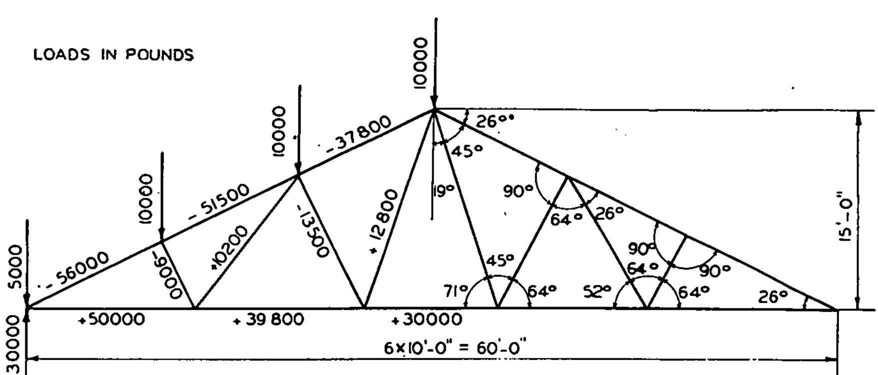


Fig. 6.

Allowable loads on connectors for Group 2 species will be those given in Fig. 4.

The top chord is a spaced column whose laterally unrestrained length between purlin points is 11.2 ft. For 4 in. nominal thickness, L/d is $\dfrac{11.2 \times 12}{3.63} = 36.8$. Allowable compressive stress for this spaced Euler column is 820 p.s.i.* The heaviest chord stress is 56,000 lb., and 68.5 sq. in. of cross-section are required. Two $4'' \times 10''$ (nominal) are sufficient. The second compression diagonal is a simple column having the same L/d. It is found that a nominal $4'' \times 12''$ will carry the load. Consequently, all compression diagonals will be 3⅝ in. thick, as will all internal splices. Top chord sizes usually are determined by their maximum compressive stresses, sizes of other members often depend upon the details at the joints.

1. *Heel* (Fig. 7)

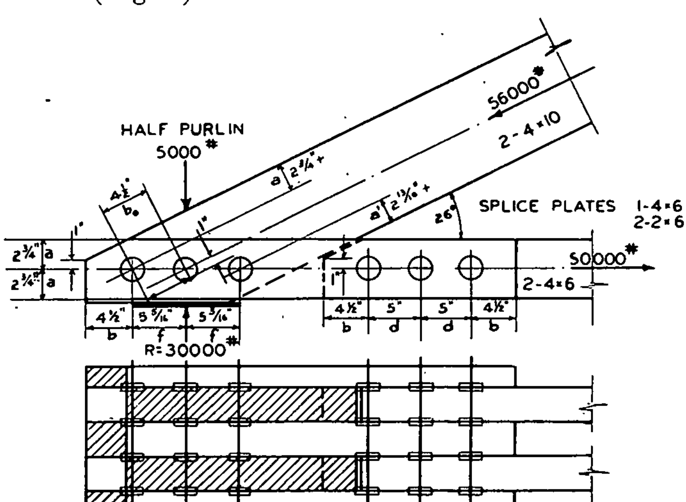


Fig. 7.

Since web members are to lap over the chords, upper and lower chords must lie in the same plane. At the heel, therefore, lower chord members are cut off underneath upper chords, and connection is made by one internal and two external splice plates. Top chords are

*See W.P.B. Directive 29 or "Wood-Columns, Safe Loads," Supplement No. 4 to Wood Structural Design Data, National Lumber Manufacturers Association, Washington, D. C.

allowed to project below the splice plates and to rest directly on bearing plates, so that the total vertical load is carried directly into the reaction. Rings transmit only the horizontal component, or lower chord stress.

Computations are made to determine number of rings, edge distances, end distances and spacing. In all of these computations, requirements for chords and splice plates must be considered separately. The final spacing of rings in chords and splices is the largest required by either.

After the joint has been detailed, it is checked for net section of timber remaining at the critical points after grooves and bolt holes are subtracted. In the lower chord this occurs at the right-hand ring in the lower-chord-splice joint, where total tension is transmitted. The net area of timber remaining, multiplied by the constants in Table 2, gives the allowable tensile stress in the timber. In the upper chord the critical section occurs at the right-hand ring in the upper-chord-splice joint, where total compression is transmitted. Net section is multiplied by the allowable compressive stress intensity to find the total allowable compressive load. Although the net section check in compression members is usually omitted, conservative practice includes it.

TABLE 1.—SIZES AND CROSS-SECTIONS OF TIMBERS, ILLUSTRATIVE EXAMPLE

Size	Dimensions in.	Cross-Section sq. in.
2×6	1⅝×5⅝	9.14
2×8	1⅝×7½	12.19
4×6	3⅝×5⅝	20.39
4×10	3⅝×9½	34.44
4×12	3⅝×11½	41.69

Projected Area of Connectors and Bolts, Square Inches

4-in. Split Ring
¾-in. Bolt

Rings	Thickness of Timber 1⅝″	2⅝″	3⅝″
One Face	3.09	3.84	4.59
Two Faces	4.97	5.72	6.47

TABLE 2.—CONSTANTS FOR DETERMINING NET CROSS-SECTIONAL AREA REQUIRED IN TENSION

Type of Loading	Thickness of Wood	Group B Species
Permanent	4″ or less	0.00047
	over 4″	0.00059
Snow	4″ or less	0.00041
	over 4″	0.00051
Wind or Earthquake	4″ or less	0.00031
	over 4″	0.00039

Computations are as follows:

Allowable load per ring (Fig. 4)

$\theta = 0°$, $P = 5735\#$

$\theta = 26°$, $P_\theta = 5250\#$

Number of rings required,

$50{,}000\#/5250\# = 9.5$. *Use 12 rings*

at 79% capacity in upper chord ($\theta = 26°$)

at 73% capacity in splice and lower chord ($\theta = 0°$)

Upper Chord Design

Edge distances (Fig. 4)

$a = 2\frac{3}{4}''$

$a' = 2\ 13/16''$ (Compression, $\theta = 26°$)

End distance (Fig. 5)

$b_\theta = 4\frac{1}{2}''$ (Compression, $\theta = 26°$)

(measured from point 1″ out on radius of ring)

Spacing, $\theta = \phi = 26°$ (Fig. 5)

100% capacity, $f_{100} = 6\frac{3}{4}''$

75% capacity, $f_{75} = 5''$

$$79\% \text{ capacity, } f = 5 + \frac{4}{25}(6\tfrac{3}{4} - 5) = 5\ 5/16''$$

Splice Plate Design

Connection to upper or lower chord.

Edge distance, $a = 2\frac{3}{4}''$ (Fig. 4)

End distance, tension, 73%, $b = 4\frac{1}{2}''$ (Fig. 5)

(measured from point 1″ out on radius on ring)

Spacing, $\theta = \phi = 0^\circ$ (Fig. 5)
73% load, $d = 5''$

Final Ring Spacing
$f = 5\ 5/16''$, upper chord to splice plate.
$d = 5''$, lower chord to splice plate.

Net Sections
Top Chord
At critical point, 2 ring grooves and bolt hole are cut out.
Projected area (Table 1) is 6.47 sq. in. per chord member
Net cross sectional area of top chord is 55.94 sq. in.
Allowable compressive stress intensity is 1325 p.s.i.

Actual compressive stress intensity is $\dfrac{56000}{55.94} = 1000$ p.s.i.

Section is adequate
Bottom Chord
At critical point,
Net cross-section area remaining in bottom chord is 27.84 sq. in.
Net cross-sectional area remaining in 2-2×6 and 1-4×6 splice is 26.02 sq. in.
Required cross-sectional area (Table 2) is $.00047 \times 50{,}000 = 23.5$ sq. in.
Sections are adequate.

Bearing Plate
Width = 10⅝″ if centered on 30,000# reaction under intersection of 30,000#, 56,000#, and 50,000#.
Allowable bearing on ends of upper chords, $\theta = 64^\circ$

$$C_\theta = \frac{1325 \text{ x } 455}{1325(0.8 + 455(0.2)} = 525\#/\text{p.s.i. [equation (1)]}$$

$$\text{Actual bearing} = \frac{30{,}000}{2 \times 3.63 \times 10.63} \doteq 390\#/\text{p.s.i.}$$

Plate could be made only 8″ wide, but must be large enough to spread load on support.

2. *Peak* (Fig. 8)

The arrangement calls for diagonals outside of the chords, and a splice plate inside. Diagonals transmit 12,800 pounds at 45° to the grain of the chord, splice plate transmits 30,000 pounds at 26° to the grain of the chord. Loads in diagonals and splice are necessarily parallel to the grain.

Center lines *n* and *m* of diagonal and chord are first drawn (Fig. 8), and edges of chord are drawn. Gage line a_1' and a_2' are drawn. (See computations below.) Rings 1 and 2 must lie within these lines. Spacing f_3 cannot be maintained if rings 1 and 2 are on center line *n*. The rings are therefore placed ¾ in. off center as shown, and distance b_1 is thereby also satisfied. The small angle ϕ_1 makes no essential difference in spacing 1-2. Diagonals must consequently be 2″×8″. minimum. Final location of 1 and 2 is therefore as shown, if ring 1 is on gage line a_1'. End distance c_2 fixes the end of the chord. Spacing f_5 and distance b_2 locate ring 3 and the end of the splice plate. Splice plate must be 4″×12″ to satisfy edge distances for rings 1 and 2.

Computations are as follows:

Allowable load per ring (Fig. 4)

$\theta = 0^\circ \quad P = 5735\#$

$\theta = 26^\circ \quad P_\theta = 5250$

$\theta = 45^\circ \quad P_\theta = 4720$

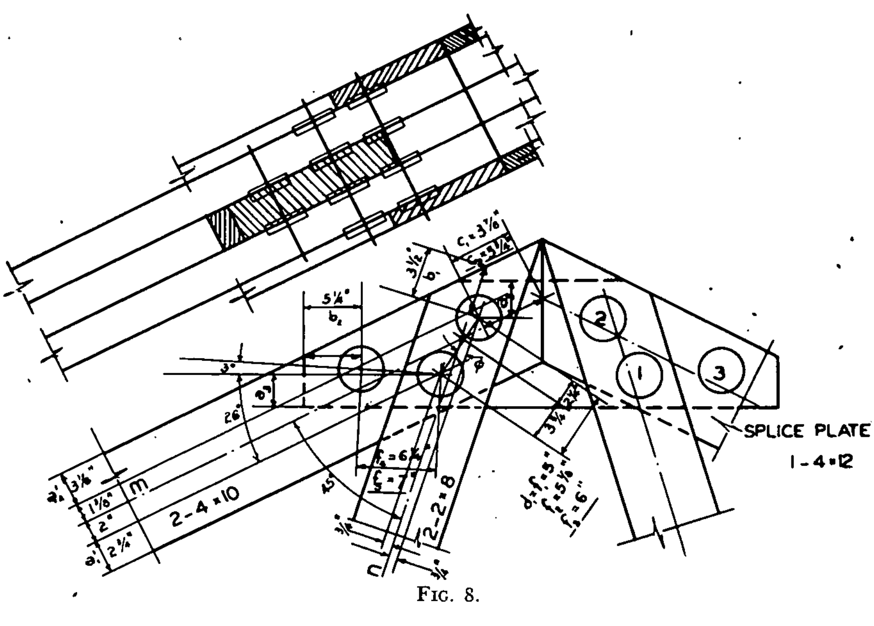


FIG. 8.

Diagonal to Chord

Stress = 12,800#, $\theta = 45°$
Number of rings = 12,800#/4720# = 2.7
Use 4, at 68% capacity in chord ($\theta = 45°$)
at 56% capacity in diagonal ($\theta = 0°$)
Edge distances (Fig. 4)
Diagonal, $a = 2\frac{3}{4}''$
Chord, $a_1' = 2\frac{3}{4}''$ (Compression, $\theta = 45°$, Load = 68%)
End distances (Fig. 5)
Diagonal, $b_1 = 3\frac{1}{2}''$ (Tension, Load = 56%)
(measured from point 1″ out on radius of ring)
Chord, $c_1 = 3\frac{7}{8}''$ (Compression, Load = 68%)
(measured from point 1″ out on radius of ring)
Spacings, Rings 1-2, Load less than 75% capacity
Diagonal and chord, $d_1 = f_1 = 5''$

Splice Plate to Chord

Stress = 30,000#, $\theta = 26°$
Number of rings = 30,000/5250 = 5.7
Use 6, at 95% capacity in chord ($\theta = 26°$)
at 87% capacity in splice plate ($\theta = 0°$)
Edge distances (Fig. 4)
Splice plate, $a = 2\frac{3}{4}''$
Chord, $a_2' = 3\frac{1}{8}''$ (Compression, $\theta = 26°$, Load = 95%)
End distances (Fig. 5)
Splice plate, $b_2 = 5\frac{1}{4}''$ (Compression, $\theta = 0°$, Load 87%)
(measured from point 1″ out on radius of ring)
Chord, $c_2 = 5\frac{3}{4}''$ (Compression, $\theta = 26°$, Load 95%)
Controls

Spacing (Fig. 5)
Rings 1-2
Splice plate, $\theta = 0°$, $\phi = 71°$
71° line and Curve A, f (100%) = 5 5/16″
f_2 (87%) = $5\frac{1}{8}''$
Chord, $\theta = 26°$, $\phi = 45°$
45° line and curve 26° (interpolated)
f (100%) = $6\frac{1}{8}''$
f_3 (95%) = 6″ *Controls*

Rings 1-3, Trial and error, positions shown on sketch are found:
Chord, $\theta = 26°$; $\phi = 29°$
29° line and 26° curve, f (100%) = $6\frac{5}{8}''$
f_4 (95%) = $6\frac{1}{4}''$
Splice plate, $\theta = 0°$, $\phi = 3°$
3° line and 0° curve, f (100%) = 9″
f_5 (87%) = 7″ *Controls*

Ring 3 is placed to conform with requirements $f_5 = 7''$ and $b_2 = 5\frac{1}{4}''$.
Spacing 2-3, by measurement, = 11″ and is easily satisfactory.
Edge distances a_3 in splice plate, checked by measurement, are more than $2\frac{3}{4}''$, and are satisfactory, if splice plate is 4″×12″.

Net Sections

Chord. Same net section as at heel, load less, therefore satisfactory.

Diagonal. Each diagonal has one ring and bolt removed at critical section (Ring 1). Net area is 18.20 sq. in. (Table 1)
Required cross-sectional area (Table 2) is .00047×12,800 = 6.05 sq. in.
Two 2 x 8 are satisfactory.

Splice Plate.
Critical section is at rings 2. Two ring grooves and one bolt removed.
Net section is 35.22 sq. in.

$$\text{Required cross-sectional area} = \frac{30{,}000}{1325} = 22.6 \text{ sq. in.}$$

Splice plate is adequate.

Working drawings would require all bolt holes to be located by measurements from ends and edges of individual pieces. These supplementary dimensions have been omitted to avoid confusion.

The same general procedures are followed at all other joints and splices. It is entirely probable that the second lower chord joint will require the 12,800 diagonals to be enlarged to 2″×12″ in order to find space for enough rings. Such an increase would not affect the peak joint. Other joints might call for other changes in sizes, but would not necessarily affect the joints already designed.

A PRACTICAL FORMULA FOR THE FLOW OF WATER IN PIPES

By William F. Covil, Member*

Presented at a meeting of the Hydraulics Section of the Boston Society of Civil Engineers held on November 1, 1944.)

Many of the complicated exponential formulae for calculating the lost head for the flow of water in pipe lines can be reduced to some constant, times the quantity flowing raised to some power

$$h_f = \text{constant } Q^x$$

In a previous paper†[1] presented to this society, the writer has reduced all of the well-known exponential formulae and solved them for the exponent x. These values are repeated in Table 1, for convenience of ready reference.

With the above general relationship in mind, the writer set out to derive a formula which would contain the least number of terms to satisfy the fundamental requirements of: water to be delivered, pipe to carry it, and energy to get it there.

It was desired to make the formula as practical as possible from the standpoint of use and of ease in applying test results, and without resorting to complicated theory and mathematical derivation.

The following new formula is proposed for the flow of water in the turbulent range as given by Equation 1 and its corollary Equation 8, based on the fundamental equation as given above, in terms as previously defined.

$$h_f = k_p Q^x \tag{1}$$

where

> h_f is the head loss in feet per thousand feet of pipe, k_p is the friction characteristic for reasonably straight pipe and is the head loss in feet per thousand for a flow of 1 c.f.s.
> Q is the quantity actually flowing in the pipe line in cubic feet per second.

---

*Senior Hydraulic Engineer, Metropolitan District Water Supply Commission, 20 Somerset Street, Boston, Massachusetts.

†Numbered references listed at the end of the paper.

TABLE 1.—VALUES OF x IN EQUATION $h_f = kQ^x$

Originator of Formula or Experimenter	Cast Iron	New Cast Iron	Old Cast Iron	Asphalted	New Asphalt Coated	Old Asphalt Coated	Riveted Steel and Analogous	Concrete	Wood Stave and Analogous	All Kinds
Chezy										2.00
Lampe	1.80									
Fanning	2.00									
Reynolds		2.00	1.85							
Unwin		1.95	2.00	1.85			1.87			
Manning										2.00
Flamant										1.75
Tutton	1.96	1.96	1.96		1.81	1.96	1.96		1.96	
Saph-Schoder										1.74
Williams-Hazen										1.85
Williams										1.87
Lea		1.93	2.00	1.78			2.00	2.00	1.80	
Moritz							1.80			
Biegeleisen	1.90						1.80			
Barnes		1.95			1.89				1.73*	
Wegmann-Aeryns	1.86									
Scobey							1.90	2.00	1.80	
Average	1.90	1.96	1.95	1.81	1.85	1.96	1.89	2.00	1.82	1.87

*Average value.

The term Q best represents the water, the terms k_p and x represent the pipe to carry it and h_f represents the energy necessary to deliver it.

The following relationships have been established:

1. The term k_p varies with the diameter of pipe, but is constant for a given diameter and unaffected by quantity.
2. The exponent x varies with the type of pipe and is, therefore, affected somewhat by the condition of the interior surface and by jointing in a pipe line but for the same type of new pipe is unaffected by diameter over a practical range of quantities.

In the derivation of the new formula and in order to substantiate these relationships use is made of the Darcy equation, which is believed to be fundamental, for a starting point.

In 1857, Darcy[2] expressed the Chezy formula for the flow of water in pipe lines.

$$h_f = \frac{fL}{D} \frac{V^2}{2g}$$

This formula has appeared in nearly all textbooks on hydraulics from that time on and has generally been accepted as fundamental for the flow of water in pipe lines. To the writer's way of thinking, it is based on simple, common sense as so ably expressed by Mansfield Merriman[3] in 1889, in recommending the Darcy formula, where he states that the five fundamental laws of flow are as follows:

1. The loss of head in friction is directly proportional to the length of the pipe.
2. It is inversely proportional to the diameter of the pipe.
3. It increases nearly as the square of the velocity.
4. It is independent of the pressure of the water.
5. It increases with the roughness of the interior surface.

To this we can now add:

6. It increases with viscosity, and therefore inversely with temperature.

This formula fell into general disuse in the practical field of hydraulics because it was found that the friction factor f not only varied with the type of pipe and the diameter but also with the velocity and consequently with Q.

This had the effect of discrediting to some extent Darcy's original determination of the friction factor f. The net result was that different hydraulicians as for example Hazen-Williams, Kutter and others were encouraged to experiment with exponential formulae.

With the advent of dimensional analyses and Reynolds' Number, in recent years the Darcy equation was again held to be valid but the "bugaboo" of Reynolds' Number arose to haunt practical hydraulicians. With one assumption as far as theory is concerned, namely, that the temperature of the water remains constant at 55° and a disregard of temperature in test results, Reynolds' Number can be eliminated. This is not an unusual procedure since no other wholly practical formula ever attempted to include the effect of temperature, as far as water for domestic use is concerned.

ALIGNMENT CHART

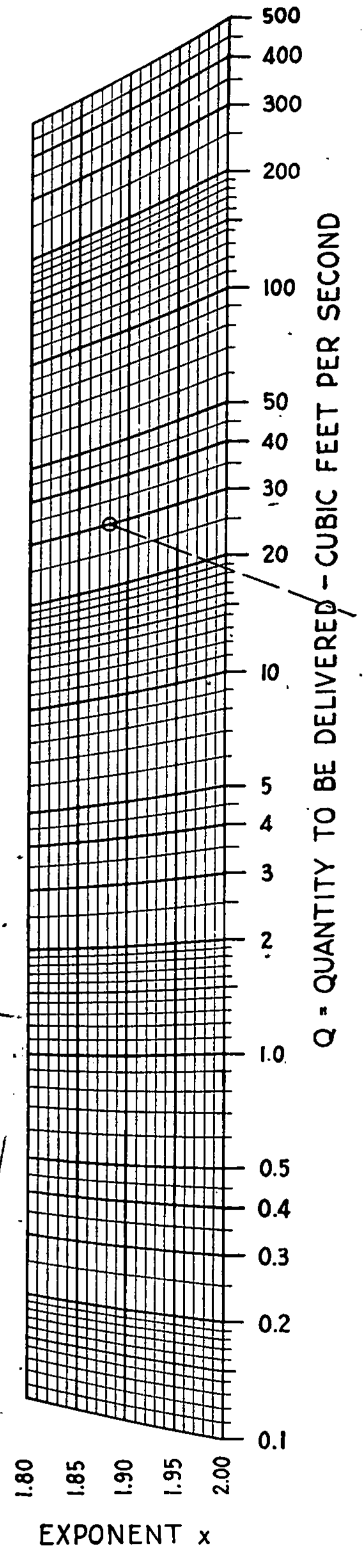
FOR

SELECTION OF PIPE DIAMETER REQUIRED TO TRANSPORT WATER

FROM

COVIL FORMULA

$$h_f = k_p Q^x$$



Example Shown

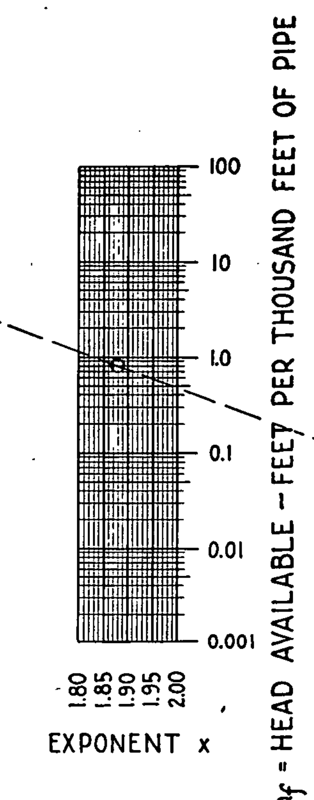
$Q = 30$ c.f.s.

$h_f = 0.8'$ per $1000'$

$x = 1.88$ for average cast-iron pipe

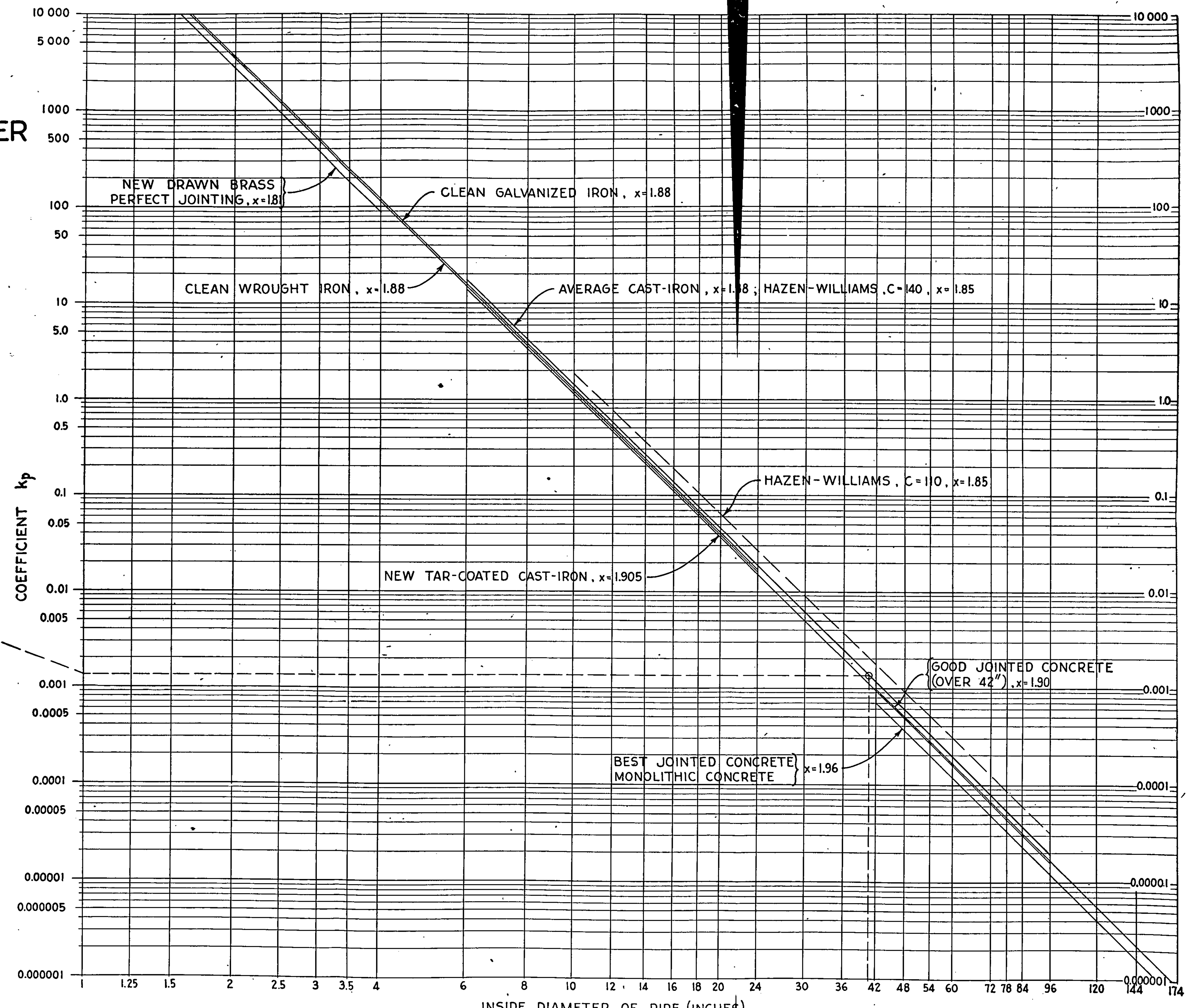
(Note: It is not necessary to know k_p)

Ans: 42" diam. pipe



Note:

The diameter given is for reasonably straight pipe with a normal small percentage of minor losses. If the proposed pipe line will have excessive minor losses due to bends, valves, transitions etc., a percentage should be deducted from the available head to allow for this.



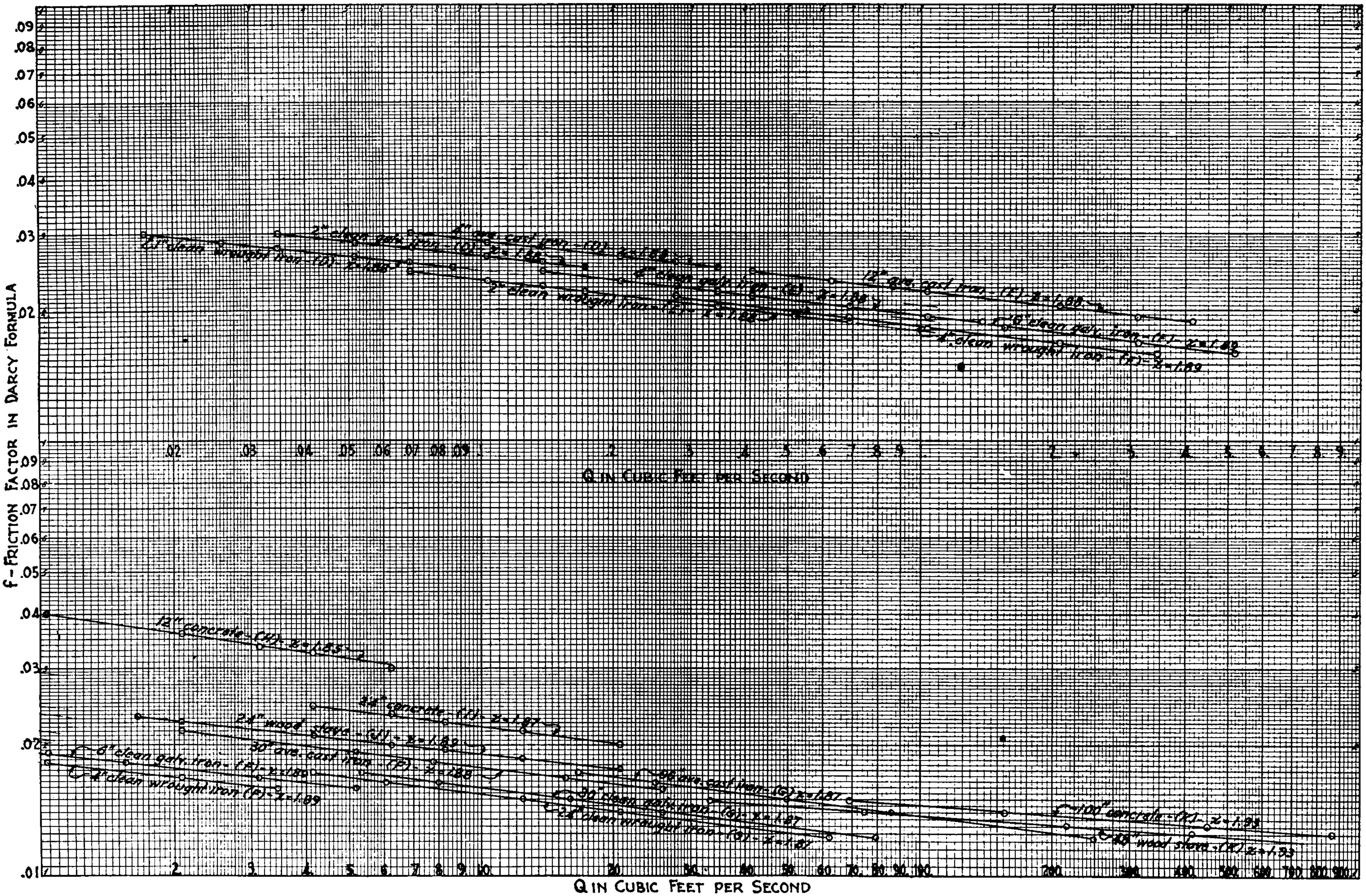
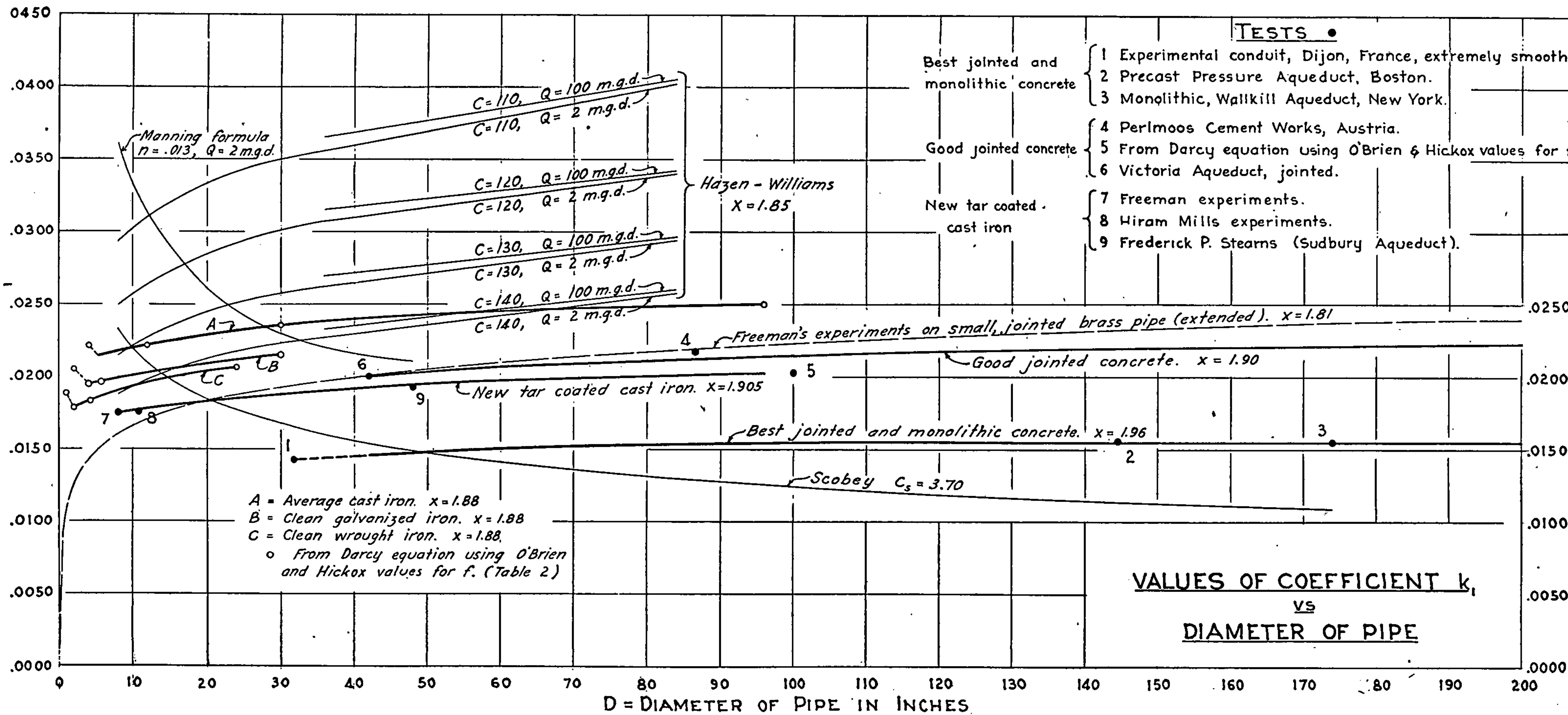

f - Friction Factor in Darcy Formula
Q in Cubic Feet per Second
2" clean galv. iron - (D) - x = 1.88
4" ave. cast iron - (D) - x = 1.88
2" clean wrought iron - (D) - x = 1.88
2" clean wrought iron - (D) - x = 1.88
12" ave. cast iron - (F) - x = 1.88
10" clean galv. iron - (F) - x = 1.89
4" clean wrought iron - (F) - x = 1.89
12" concrete - (H) - x = 1.85
24" concrete - (J) - x = 1.87
24" wood stave - (J) - x = 1.89
30" ave. cast iron - (P) - x = 1.88
6" clean galv. iron - (F) - x = 1.88
4" clean wrought iron (P) - x = 1.89
36" ave. cast iron - (G) x = 1.87
30" clean galv. iron - (G) - x = 1.87
24" clean wrought iron - (G) - x = 1.87
100" concrete - (K) - x = 1.93
48" wood stave - (K) x = 1.93

Fig. 1.



TESTS •
Best jointed and monolithic concrete
1 Experimental conduit, Dijon, France, extremely smooth.
2 Precast Pressure Aqueduct, Boston.
3 Monolithic, Wallkill Aqueduct, New York.
Good jointed concrete
4 Perlmoos Cement Works, Austria.
5 From Darcy equation using O'Brien & Hickox values for f.
6 Victoria Aqueduct, jointed.
New tar coated cast iron
7 Freeman experiments.
8 Hiram Mills experiments.
9 Frederick P. Stearns (Sudbury Aqueduct).
Manning formula n = .013, Q = 2 m.g.d.
C = 110, Q = 100 m.g.d.
C = 110, Q = 2 m.g.d.
C = 120, Q = 100 m.g.d.
C = 120, Q = 2 m.g.d.
C = 130, Q = 100 m.g.d.
C = 130, Q = 2 m.g.d.
C = 140, Q = 100 m.g.d.
C = 140, Q = 2 m.g.d.
Hazen - Williams X = 1.85
Freeman's experiments on small, jointed brass pipe (extended). X = 1.81
Good jointed concrete. X = 1.90
New tar coated cast iron. X = 1.905
Best jointed and monolithic concrete. X = 1.96
Scobey Cs = 3.70
A = Average cast iron. X = 1.88
B = Clean galvanized iron. X = 1.88
C = Clean wrought iron. X = 1.88
o From Darcy equation using O'Brien and Hickox values for f. (Table 2)
VALUES OF COEFFICIENT k1 VS DIAMETER OF PIPE
D = DIAMETER OF PIPE IN INCHES

FIG. 2.

The Darcy formula may be reduced by the substitution of k for the constants to the expression

$$h_f = kfQ^2 \qquad (2)$$

It will be noted that k is used in this instance instead of C for the coefficient as in the writer's previous paper before this society, so as to avoid any possible confusion with the C in the Hazen-Williams formula.

Dimensional analysis has shown that f in the Darcy Equation is a function of the Reynolds' Number which is dimensionless in any consistent set of units.

$$R_e = \frac{4Q}{\pi D v}$$

Since the term Q appears in Reynolds' Number and therefore affects the friction factor f, it is apparent that we cannot separate f from Q in Equation 2 without acknowledging that we have somewhat changed the exponent of Q. In fact without some assumption it is impossible to legitimately separate f and Q at all.

If we consider that the temperature of the water, and therefore kinematic viscosity, remains constant then f is the function of some constant k_1 and Q to some power. It does not follow that this is the first power of Q as in the Reynolds' Number since f is merely a function of the Reynolds' Number. Since f decreases with increases in Reynolds' Number, the exponent of Q would have a minus sign.

$$f \neq k_1 Q^{-a} \qquad (3)$$

or

$$f \neq \frac{k_1}{Q^a} \qquad (3A)$$

The friction factor f plotted against Q on logarithmic paper plots as a straight line verifying the above relationship. This is clearly demonstrated by Fig. 1.

In the Darcy Equation f is a dimensionless number. In Equation 3A, it appears that f is given dimension by the fact that Q ostensibly has dimension. In order to make the left and right side of Equation 3A equal to each other, I am assuming that $\frac{1}{Q^a}$ in Equation 3A is merely a numerical friction equivalent of the effect of turbulence due to the quantity flowing, and Q is not in the dimensional terms of the Q in the Darcy formula. Therefore, in order to modify the Q in the Darcy formula by this value of Q^a in a legitimate manner, it must be shown that Q^a is constant for any given Q and therefore dimensionless, for a given type of new pipe *irrespective of diameter*. From an analysis of actual experimental tests the writer has verified the fact that Q^a for a given Q is approximately constant for any diameter of a given type of new pipe as will be shown later.

It will be noted that the Reynolds' Number, and therefore f, is also a function of diameter and since the exponent "a" does not vary with diameter the coefficient k_1 assumes the function of diameter in Equation 3A. This is important because it indicates that k_1 theoretically is a real measure of the skin friction due to the pipe walls.

k_1 is a dimensionless coefficient varying approximately constantly with diameter and increasing with the rougher types of pipe. This is shown on Figs. 2 and 3. It is obviously not a measure of the total friction in a pipe line but since the influence of quantity and therefore turbulence has been removed in the main by separating out $\frac{1}{Q^a}$ in Equation 3A, the writer contends that it is a better measure

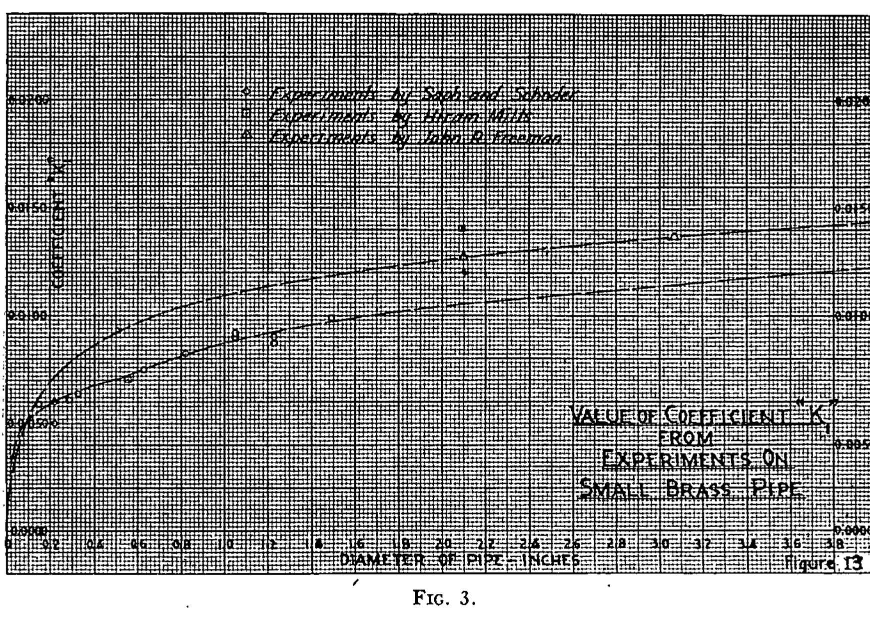


FIG. 3.

of the friction contributed by the pipe walls than the friction factor f. The writer believes that this analysis accomplishes the separating out of the factors which originally threw the Darcy formula into disuse as previously mentioned.

Substituting Equation 3A in Equation 2

$$h_f = \frac{k.k_1 .Q^2}{Q^a}$$

Combining exponents

$$h_f = k.k_1\, Q^{2-a} \qquad (4)$$

Let the exponent $\quad 2—a = x$

Then $$h_f = kk_1\, Q^x \qquad (5)$$

which is in the general form to which all hydraulic formulae for flow of water in pipes may be reduced, as noted previously. Expressing Equation 3A in the logarithmic form

$$\log f = \log k_1 — a \log Q$$

this will be recognized as the equation of the straight line

$$y = mx + b \text{ where } a \log Q = mx$$

Taking the friction factor f, as plotted by O'Brien and Hickox[4] against Reynolds' Number for various types of pipe and by figuring the Q which goes with the Reynolds' Number, with temperatures of water held constant at 55°, f has been plotted against Q on log-log paper as shown on Fig. 1.

The slope of the lines as shown on this figure give the value of the exponent "a" in Equation 3A.

This slope may be easily determined by measuring the rise and run of the line in inches with an ordinary scale.

$$a = \frac{\text{rise in inches}}{\text{run in inches}}$$

Where the lines slope downward from left to right, as they all do on this chart, the sign of the slope is minus and the sign of the exponent "a" is minus as given in Equation 3.

The point where these curves projected, intercept the value of $Q = 1$, is the y intercept and gives the value of the constant k_1.

Values of a and k_1 are given in Table 2 along with the values of the exponent x in Equation 5, as determined from $x = 2—a$. These values of k_1 are plotted on Fig. 2. The values for average cast-iron pipe fall on a very flat curve. Subsequent investigation indicates that this line has the exponent of x equal to 1.88 which is the value of the exponents for all but the 96" pipe which has the exponent 1.87.

TABLE 2

Curve Designation	Type and Size of Pipe	Exponents of Q a	x	Values of k_1
D	1" clean wrought iron	0.12	1.88	0.0189
D	2" clean galv. iron	0.12	1.88	0.0205
D	4" ave. cast iron	0.12	1.88	0.0221
E	2" clean wrought iron	0.12	1.88	0.0179
E	4" clean galv. iron	0.12	1.88	0.0195
E	12" ave. cast iron	0.12	1.88	0.0221
F	4" clean wrought iron	0.11	1.89	0.0183
F	6" clean galv. iron	0.11	1.89	0.0192
F	30" ave. cast iron	0.12	1.88	0.0235
G	24" clean wrought iron	0.13	1.87	0.0207
G	30" clean galv. iron	0.13	1.87	0.0215
G	96" ave. cast iron	0.13	1.87	0.0249
H	12" concrete	0.15	1.85	0.0401
I	24" concrete	0.13	1.87	0.0293
J	24" wood stave	0.11	1.89	0.0245
K	48" wood stave	0.07	1.93	0.0190
K	100" concrete	0.07	1.93	0.0202

Since by finding the exponent for Q in Equation 3A the water has figuratively been removed from the pipe, the constant k_1 might reasonably be expected to be a function of constant factors; diameter and type of pipe. The type of pipe when new defines the average roughness of the interior surface in contact with the outermost layer of water. The area of this surface for unit length is πD. It would be common sense then to suppose that k_1 from tests as well as from theory is approximately a function of the diameter to the first power, and the figure indicates that this is so for all practical purposes and the line may be considered to be straight over limited ranges of diameter above 6".

In order to see if this relationship holds true for any of the more generally accepted exponential formulae, value for k_1 were figured from the Hazen-Williams formula for values of C from 110 to 140 for quantities of 2 and 100 m.g.d. respectively and plotted on Fig. 2. Above 30" diameter the plot is substantially a straight line.

and the values of k_1 are approximately constant for the wide variation in quantity. The curves in general seem to conform to the proper shape. In the writer's opinion the values of k_1 are too high but this is compensated by a lower value for the exponent x. The curves tend to dip more sharply than they should near the X axis as shown by points not plotted and this is probably why the Hazen-Williams formula has not proven practical for small diameters. The values of k_1 for clean, wrought iron and galvanized pipe of small diameter as obtained previously from the Darcy Equation indicate that the flat curve also holds good below the 30″ diameter down to say 4″ or 6″. It is reasonable to suppose that this type of curve also holds true for older and more corroded pipe. From plotting test results, the writer finds that corrosion of the pipe increases the skin friction and turbulence and therefore increases the coefficient k_1 and the exponent x, as would be supposed if the writer's general theory is correct.

At the bottom of Fig. 2 are plotted the values of k_1 obtained from Scobey's formula for concrete pipe of the smoothest type, using his coefficient $C_s = .370$ and with the exponent $x = 2$. The result is a flat curve in the opposite direction approaching a straight line as the diameter increases above 30″. This curve is the same regardless of quantity. A curve based on the Manning formula is also shown on Fig. 2 for $n = .012$ and $Q = 2$ m.g.d. This is the same general type of curve as for the Scobey formula.

The writer does not wish to cast any aspersions on the Hazen-Williams, the Scobey or the Manning formula since from his experience all of these formulas will give excellent results with use based on a knowledge of their limitations. The curves on Fig. 2 do show however that the only formula which approximates what the writer considers to be the fundamental relationship between friction and diameter is the Hazen-Williams formula.

Below say 4″ or 6″ diameter the points obtained from consideration of the Darcy formula have a tendency to rise above the curve. This is also true from the results obtained from experimental tests on small diameter commercial pipe. In the writer's opinion, the reason for this is that below say 6″ diameter it is not possible to obtain the same comparative smoothness of internal pipe surface, and these points represent another curve for a rougher pipe.

Going back to the Darcy Equation, we can solve for the value of the constant k in Equation 2, 4 and 5.

$$k = \frac{.0252\ L}{D^5}$$

and since $L = 1000'$ in Equation 1

$$k = \frac{25.2}{D^5}$$

TABLE 3

Size of Pipe Inches	log k	Size of Pipe Inches	log k
1	6.796839	30	9.411232-10
1½	5.916382	36	9.015325-10
2	5.291688	42	8.680592-10
2½	4.807142	48	8.390632-10
3	4.411232	54	8.134869-10
3½	4.076495	60	7.906082-10
4	3.786540	72	7.510175-10
6	2.906082	78	7.336365-10
8	2.281390	96	6.885482-10
10	1.796839	102	6.753837-10
12	1.400932	108	6.629719-10
14	1.066210	120	6.400932-10
16	.776243	138	6.097443-10
18	.520475	144	6.005026-10
20	.291697	174	5.594092-10
24	9.895782-10		

The logarithmic values of k are shown in Table 3 for various diameters of pipe for ready reference in making computations. This coefficient has the function of providing for the constant factors, length and gravity; and of dividing out the factor D in the coefficient k_1 and the factor of area squared or $\frac{1}{D^4}$ in Q^2, thus keeping the equation dimensionally correct. Let the two constants k_1 and k in Equation 5 equal k_p and Equation 5 becomes Equation 1, the new equation

$$k_p = k\ k_1$$

and

$$k_p = \frac{25.2\ k_1}{D^5} \tag{6}$$

Effect of Minor Losses

If there are no appreciable minor losses in a pipe line due to sharp bends, valves, transitions, intakes and outlets, etc., Equation 1 times the length L in thousands of feet gives the head loss for the line as a whole.

$$H_f = k_p LQ^x \qquad (7)$$

where H_f is the total head loss.

It will be noted that k_pL is k_f or the friction characteristic of the line as a whole as defined in the previous paper before this society. It is the total head loss for a flow of 1 c.f.s.

$$k_f = k_pL$$

where L is the length of line in thousands of feet.

and

$$H_f = k_fQ^x \qquad (8)$$

If there are important minor losses k_f is equal to the sum of all losses.

$$k_f = k_pL + k_{\text{valves}} + k_{\text{bends}} + \text{etc.}$$

The most satisfactory way of estimating minor losses is on the basis of some coefficient times the velocity head, or differences in velocity head, and data on these coefficients may be obtained from all hydraulic textbooks.

When these losses are obtained they must be reduced to the head loss for $Q = 1$ c.f.s. and then added together as shown in the previous equation. These losses are usually a small enough part of the total loss so that the error in reducing them to a loss of $Q = 1$ c.f.s. on the basis of the quantities squared is negligible and this may be easily accomplished on the slide rule. Figure the head loss for the average Q

then

$$k_{\text{valve, etc.}} = \frac{\text{Head loss}}{Q^2}$$

Where the conditions of the test are not known first hand the writer is reluctant to accept old tests on other than experimental pipe lines. Values for k_p and for the exponent x are valuable only when they represent results for reasonably straight pipe. This is a very important point to my mind and should not be casually brushed aside because there are no two pipe lines that are ever identical, and to intimate, for example, that the Hazen-Williams tables will give the head loss for a line which has a rather high percentage of minor losses would be shear folly. The most you can say when the actual losses prove to be larger is that the coefficient was not selected properly and should have been lower. Tests are usually conducted for reasonably straight lengths but if this is not possible, the losses through valves, venturi meters, bends, transitions, intakes and outlets, etc., should be deducted from the total loss so far as practicable. The designer of a new pipe line is thus able to add any combination of the above minor loss factors into the head loss obtained from Equation 1 to obtain the loss for the line as a whole as given by Equation 8.

How to Obtain the Exponent x and the Constant k_1 from Tests

Assume that tests have been carefully conducted on a pipe of a given diameter and head losses in feet per thousand have been obtained for several different quantities in cubic feet per second flowing. A careful estimate should be made if possible of any minor losses which will have increased these head losses beyond the loss for reasonably straight pipe and these losses subtracted from the total loss for each quantity.

Plot the head loss H_f against the quantity Q on log-log paper. A straight line should result if the values are without error. A well conducted test by Arthur T. Safford in 1905 on 12" Tar Coated Cast-Iron Pipe is illustrated on Fig. 7. The slope of this straight line is obtained by dividing the rise of the line measured in inches by the run measured in inches, and this slope is the value of the exponent x.

$$x = \frac{\text{rise in inches}}{\text{run in inches}}$$

It is the writer's opinion that if the exponent x comes out greater than 2, the minor losses have not been subtracted or there is an error in the head losses or quantities.

The value of the head loss H_f where this straight line, projected in the proper direction touches $Q = 1$ is the value of k_f. It is not always possible to conveniently find k_f in this manner and perhaps the better way is to select a plotted point which definitely comes exactly on the straight line. Using the actual values of H_f and its corresponding Q, solve for k_f using the value of x just obtained

$$k_f = \frac{H_f}{Q^x}$$

The value of k_p is obtained by dividing k_f by the length of the line in thousands of feet

$$k_p = \frac{k_f}{L}$$

The value of k_1 is then obtained from Equation 6 and becomes another point to be plotted against diameter.

A refinement of the above method is to obtain the percentage deviation of the calculated head losses from the observed head losses, using the value of k_p and x just obtained. Adjust the value of x slightly to "straighten out" the positive and negative deviations. Finally adjust the value of k_1 slightly to move all the deviations one way or the other so that the maximum positive and negative deviations are about the same.

Variation of k_1 with Diameter for Small Commercial Size Pipe

Test results from experiments by Freeman and Hiram Mills[6] on tar coated cast-iron pipe below 6″ diameter seem to verify what was indicated by plotting k_1 for small galvanized and wrought iron pipe on Fig. 2; namely that the value of k_1 increases from the flat curve for pipe sizes below 6″ or 4″ diameter. Mills noted, however, that the surface of some of the smaller pipes were not comparable in smoothness with that of the larger pipes. Darcy made tests on new 4″ cast-iron pipe of "extreme smoothness" but unfortunately doubt is cast on his manometer measurements; the writer therefore turned to tests on small brass pipe to substantiate his theories.

Variation of k_1 with Diameter for Small Brass Pipes

The values of k_1 and x were carefully figured from tests by Hiram Mills,[6] Saph and Schoder and John R. Freeman on small brass pipe. The results of the computations for k_1 are shown on Fig. 3 and for x on Fig. 4. Practically all of the tests plot as straight lines on logarithmic paper showing that they were carefully conducted.

The method employed to figure the exponent x was to calculate the slope of the logarithmic line taking the extreme pair of values within the turbulent range and then the next pair. The pairs were then interchanged taking the top and next to the bottom and then the bottom and next to the top and so on. Ordinarily three of the

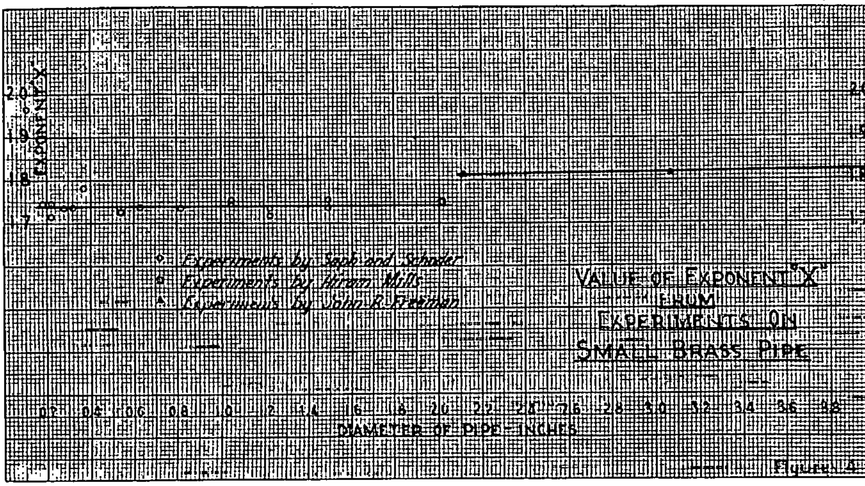


FIG. 4.

first four results would give almost identical values for x showing that three of the points were on the same straight line. The value of k_1 was obtained using one of the good points and the slope just obtained.

The results obtained from the tests by John R. Freeman were the most consistent and the writer therefore gave them special attention for further study. These experiments were conducted over unusual ranges in velocity.

It will be noted that the Freeman experiments indicate rougher pipes, and Hiram Mills[6] states that the difference in frictional resistance between Freeman's experiments and the Saph and Schoder experiments is undoubtedly due to the difference in character of the surfaces of the larger pipes used by Freeman.

The value of x for the 4.00″ pipe came slightly greater than for the 2″ and 3″ pipes. To test whether this was more apparent than real a value of $x = 1.81$ was assumed for all three sizes of pipe and the head losses computed from Equation 1 over practically the entire range of velocities by cut-and-try using different values of k_1, until the percent departure of these computed losses from the observed losses was approximately balanced with reference to the maximum plus and minus departure. The results are shown in Table 4.

TABLE 4

Velocity Ft./Sec.	Quantity c.f.s.	Observed Head Loss	Computed Head Loss from Eq. 1	Percent Departure from Observed
Departure of head losses from actual losses using $x = 1.81$ and $k_1 = .01275$ (log $k_p = 3.283017$) for Freeman's Experiments on 2.108″ brass pipe.				
2.782	.067425	14.88	14.56	−2.20
3.7695	.091358	25.51	25.23	−1.11
5.9264	.143632	56.80	57.23	−0.76
8.2439	.19980	102.68	104.01	+1.19
10.3063	.24978	153.47	155.81	+1.52
12.5766	.304806	219.33	223.40	+1.86
14.6647	.35541	288.61	295.01	+2.21
15.0190	.36400	301.50	308.04	+2.17
17.8913	.43361	415.46	422.83	+1.77
20.7570	.503067	544.78	553.30	+1.56
23.5645	.57111	687.46	696.11	+1.26
24.0894	.58383	713.50	724.43	+1.53
26.593	.64451	861.37	867.84	+0.75
Departure of head losses from actual losses using $x = 1.81$ and $k_1 = .01369$ (log $k_p = 2.499955$) for Freeman's Experiments on 3.067″ brass pipe.				
4.4737	0.22952	22.06	22.03	− .14
6.0017	0.307914	37.27	37.50	+ .62
7.4029	0.379801	54.54	54.82	+ .51
9.1029	0.46702	79.09	79.69	+ .76
10.0673	0.51650	94.86	95.63	+ .81
12.3309	0.63263	137.14	138.05	+ .66
14.1207	0.72445	174.88	176.43	+ .89
17.1880	0.88182	249.36	251.82	+ .98
18.4642	0.94729	288.25	286.67	− .55
20.5784	1.05576	348.87	348.85	− .006
22.0712	1.13235	396.82	395.94	− .22
23.7325	1.21758	450.21	451.24	+ .23
26.3539	1.35207	545.70	545.86	+ .03
27.979	1.43545	613.42	608.24	− .85
29.4534	1.511089	672.61	667.54	− .75
30.8502	1.58275	729.20	725.88	− .45
Departure of head losses from actual losses using $x = 1.81$ and $k_1 = .01437$ (log $k_p = 1.944019$) for Freeman's Experiments on 4.00″ brass pipe.				
3.5731	.311806	10.63	10.66	+0.30
5.8364	.509312	25.61	25.92	+1.21
7.565	.660159	41.29	41.46	+0.41
7.5695	.660552	41.04	41.50	+1.12
9.0007	.785445	56.13	56.77	+1.14
9.5759	.835640	62.81	63.51	+1.11

TABLE 4 (*Continued*)

Velocity Ft./Sec.	Quantity c.f.s.	Observed Head Loss	Computed Head Loss from Eq. 1	Percent Departure from Observed
11.7276	1.023408	89.48	91.66	+2.44
11.8374	1.032990	92.16	93.23	+1.16
13.7759	1.202153	121.11	122.68	+1.28
15.201	1.32651	144.69	146.59	+1.31
16.9851	1.48226	175.57	179.22	+2.08
18.3543	1.60169	204.35	206.21	+ .91
19.6892	1.718176	233.14	234.15	+ .43
22.1662	1.93433	289.48	290.15	+ .23
22.8205	1.99143	304.85	305.78	+ .30
24.6249	2.14889	351.10	351.02	− .23
25.5533	2.22816	382.53	374.81	−2.02
26.7065	2.33054	408.44	406.54	−0.46
28.0598	2.44864	446.07	444.59	−0.33
28.739	2.50791	473.94	464.27	−2.09

Other values of x were tried, slightly greater and slightly less than 1.81, and as long as the exponent was kept about constant for all three pipes the results were quite consistent.

The maximum deviation was plus and minus 2.2% except for one value where the test head loss or quantity is open to question. The values of k_1 obtained are as follows:

Inside Diameter	k_1
2.108″	.01275
3.067″	.01369
4.00″	.01437

These points plot on semi-logarithmic paper against diameter as a precise straight line as shown on Fig. 5 indicating that k_1 varies as a simple exponential curve which becomes asymptotic to the X axis as the diameter increases and to the Y axis as the diameter becomes very small.

This exponential curve is extended to the left on Fig. 3 and to the right on Fig. 2 as a dashed line. It is not shown on Fig. 2 to indicate precise results but to illustrate the trend of the curve for the larger pipe sizes. It will be noted that the shape conforms very well to the Hazen-Williams curves but is somewhat higher at the outer

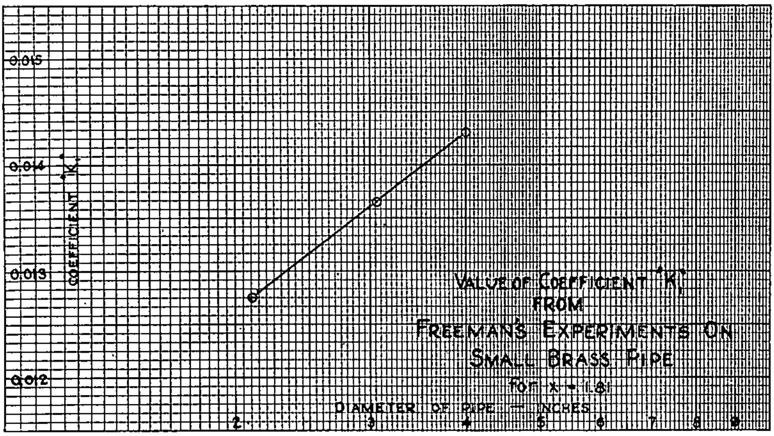


FIG. 5.

end than data obtained from tests of large diameter concrete pipe would indicate should be the case. It will require more good test runs on large diameter pipe to definitely fix the exact position of the outer end of this curve.

A semi-logarithmic plot of the values of k_1 from the Saph and Schoder experiments is shown on Fig. 6. The results of experiments on pipe above .54″ diameter indicate a straight line approximately paralleling the line extended from the Freeman experiments. Below this diameter, the results are inconsistent indicating a varying character of internal pipe surface.

EXPONENT X CONSTANT WITH DIAMETER

As shown previously the test results for small brass pipe indicate a constant value of x against diameter for pipes of the same internal surface and jointing. Experimental tests on tar coated cast-iron pipe confirms this within the limits of accuracy to which these determinations may be made. The results of three tests on different diameter pipe by three different experimenters are given below. These tests were selected because they plotted as perfect straight lines on log-log paper, and because considerable confidence could be placed in the experimenters.

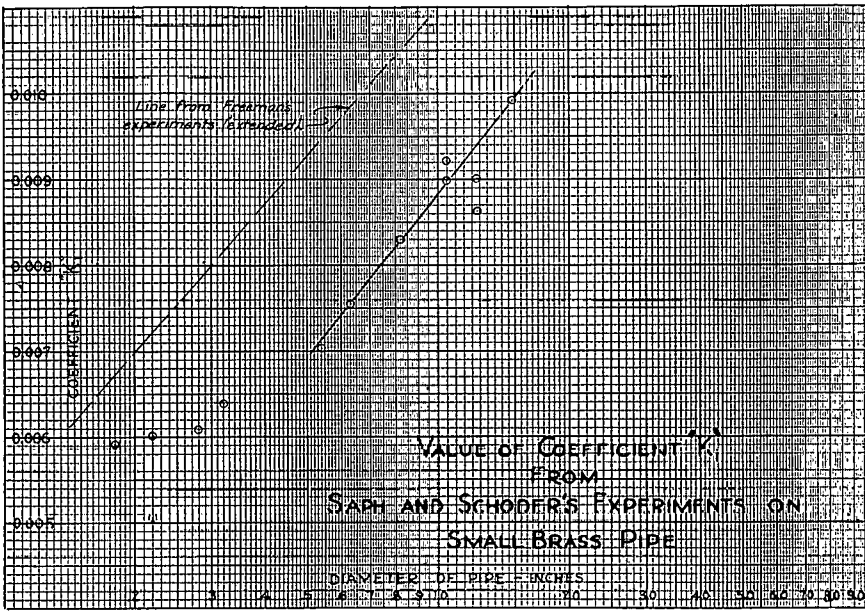


FIG. 6.

Size of Pipe	Experimenter	Exponent x	Coefficient k_1
8″	John R. Freeman	1.909	.0178
12″	Hiram Mills	1.906	.0176
48″	Frederick P. Stearns	1.900	.0192

It will be noted here that the exponent x seems to decrease slightly with increase in diameter while for small brass pipe the opposite was indicated. In my opinion this is more apparent than real. It would be interesting to conduct an experiment on small and large diameter pipe of identical internal smoothness and jointing for the purpose of establishing this relationship definitely.

TEST RESULTS FOR LARGE AQUEDUCTS

Estimates of the value of k_1 and x were made for numerous larger aqueducts, of which many tests were discarded for various reasons. Reliable reference data is definitely lacking in the field of large sizes. Tests in which it is felt some degree of confidence can be placed are given in Table 5 and are shown on Fig. 2. They form the basis for the lines drawn on Fig. 2 for concrete pipe. It will be found that the results obtained from the use of either line are not too widely separated.

TABLE 5

Name of Aqueduct	Designation on Fig. 2	D Inches	x	k_1	Comments
Victoria Aqueduct, B. C., Canada	6	42	1.88	.0208	Jointed concrete pipe reinforced. Test results obtained from Reference 4. Points plotted fairly well.
Perlmoos Cement Works, Austria	4	86.6	1.91	.0218	Gentle curves in alignment on continuous down grade. Test results obtained from Reference 4. Points plotted on perfect straight line, with exception of point which was obviously in error.
	5	100	1.93	.0202	Obtained from Table 2.
Pressure Aqueduct, Boston, Mass.	2	various (weighted ave. 144.5")	2.03	.0155	Test results obtained from Reference 1, with an additional value for test of June 2, 1942, $Q = 123$ m.g.d. for $H_f = 4.28'$. Points plotted on perfect straight line.
Walkhill Tunnel Catskill Aqueduct, New York	3	174	1.96	.0155	Monolithic lining with steel forms. Points plotted only fairly well.
Dijon, France	1	31.5	1.96	.0143	Short experimental conduit perfect joints, exceedingly smooth, points plotted perfectly.

EFFECT OF AGE ON PIPE

An attempt was made to estimate the effect of age on pipe with but indifferent success; due primarily to the dearth of dependable data. As previously mentioned it can be demonstrated that both k_1 and x increase with age as was to be expected from all other indications.

From experiments on tar coated pipe it was determined that the upper value of k_1 was .0430 by holding the exponent x constant at 1.905 as though it were new pipe. This value was reached in 14 years by one 12″ pipe and in 37 years by a different 12″ pipe. A 48″ pipe reached a maximum value of .0322 in 16.7 years.

Effect of Temperature Negligible for Domestic Water Supply

As previously noted the writer has assumed that the temperature of water was 55° F. when solving for k_1 from the friction factor f of the Darcy formula, and has disregarded temperature entirely when obtaining k_1 from tests.

That this is justified is aptly illustrated by tests made by Desmond Fitzgerald in 1894 and 1895 on the 48″ Tar Coated Cast-Iron Sudbury Aqueduct. The results of these experiments are plotted on Fig. 7. The five lower points were obtained from tests in Sept. and Oct. 1894 at temperatures ranging from a minimum of 61.8° F. to a maximum of 70.3° F. The three upper points were obtained from tests made in Jan. 1895 at temperatures ranging from a minimum of 34.9° F. to a maximum of 35.5° F. It would be possible to pass a straight line through the lower five points, the top of which would pass to the left of the upper three points. This would indicate decreasing head loss for lower temperature of the upper three points which is contrary to known hydraulic law regarding temperature. The writer concluded, therefore, that the straight line should pass through the upper three points giving a value of $x = 2.00$ and $k_1 = .0214$, which is consistent with the 16.7 years use of the line without cleaning. This serves to illustrate that the effect of temperature variations as regards water for domestic use may be disregarded.

Practical Application of Formula

The coefficient k_p is the product of two coefficients, k and k_1

$$k_p = kk_1$$

Since the coefficient k varies as D^{-5} and the coefficient k_1 varies nearly as D^1 the combination varies very nearly as D^{-4}. A plot of k_p against diameter results in a straight line on log-log paper as closely as can be plotted with reasonable scales both ways.

This is taken advantage of by an alignment chart presented herewith, for determining the proper size pipe to carry a given quantity of water for the available head loss.

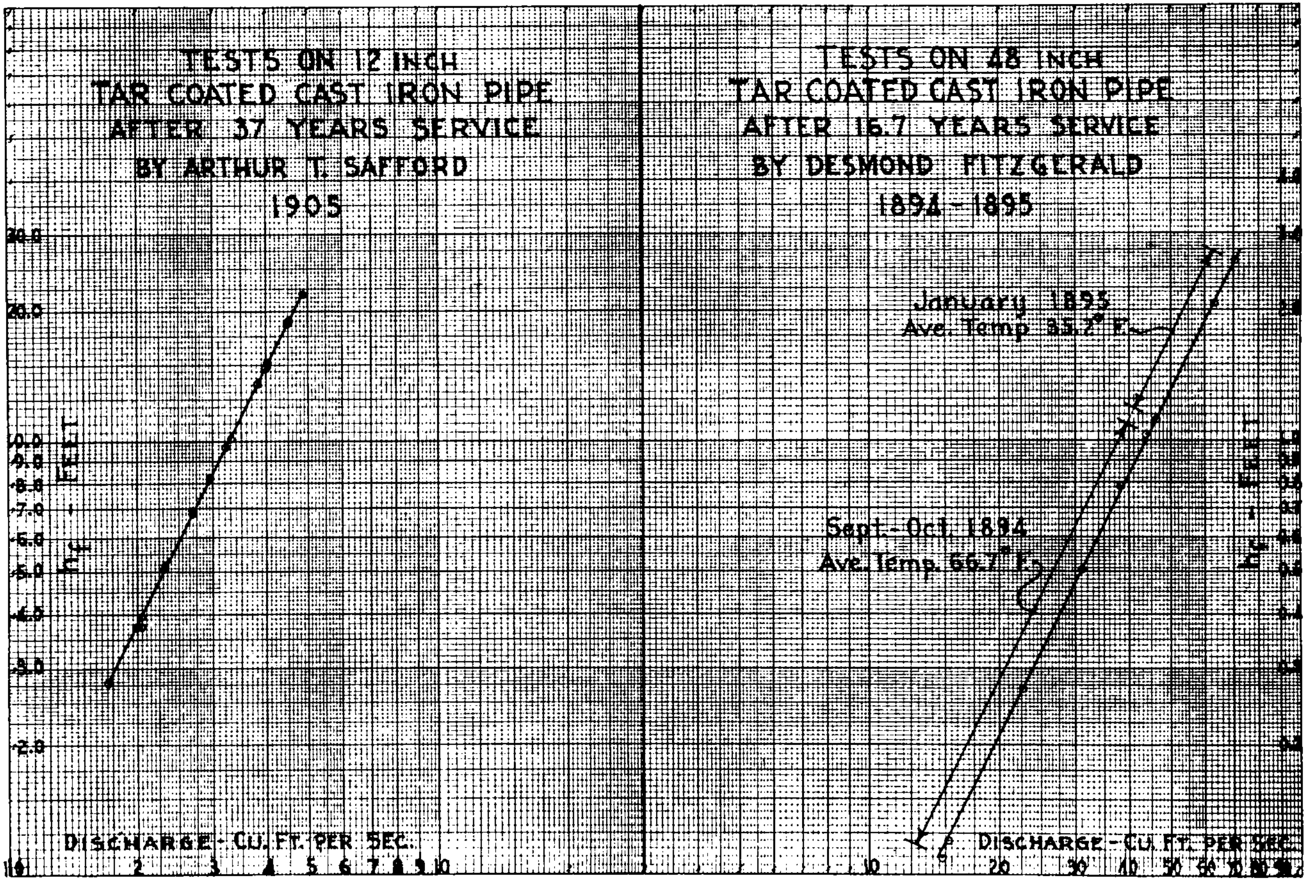

TESTS ON 12 INCH
TAR COATED CAST IRON PIPE
AFTER 37 YEARS SERVICE
BY ARTHUR T. SAFFORD
1905
TESTS ON 48 INCH
TAR COATED CAST IRON PIPE
AFTER 16.7 YEARS SERVICE
BY DESMOND FITZGERALD
1894 - 1895
January 1895
Ave. Temp 35.2° F.
Sept.-Oct. 1894
Ave. Temp. 66.7° F.
DISCHARGE - CU. FT. PER SEC.
DISCHARGE - CU. FT. PER SEC.

Fig. 7.

The left hand side gives the solution of Equation 1 for k_p and the right hand side is a plot of k_p against diameter. It is therefore never necessary to actually figure a value for k_p when using this diagram and for all purposes other than academic it drops out of consideration. It will also be noted that practical considerations such as the next stock size of pipe often governs the proper selection of diameter, and head losses merely act as an intelligent guide.

An average of the Hazen-Williams lines for $C = 110$ from Fig. 2 has been borrowed and shown to indicate the effect of age for those who are most familiar with that formula. The average Hazen-Williams line for $C = 140$ merges so closely with the line for average cast-iron that it has been left out.

The farther the lines are to the right the rougher the condition of the interior surface of the pipe. Allowance for age may be made at the users discretion by noting the amount of shift to the right from Hazen-Williams $C = 140$ to $C = 110$, and estimating a corresponding shift for the desired age and type of pipe. It should be noted that the Hazen-Williams age factor varies with diameter, and that the carrying capacity of a large size concrete aqueduct does not decrease with age at the same rate or to the same extent as cast-iron pipe in certain localities.

The example shown makes the use of the diagram self-explanatory but it should always be kept in mind that the exponent x for the particular type of pipe used should always be employed in the left hand side of the chart for determining k_p.

Solving for Lost Head h_f

For any pipe size the alignment chart will give an approximate value for the lost head h_f directly for ordinary purposes. If a closer determination is desired, it should be done mathematically. This is best accomplished by logarithms using a table of log k_p against diameter, such as Table 6. The value of log k was obtained from Table 3 above 6″ diameter and of k_1 from Fig. 2 and Fig. 3.

$$\log k_p = \log k + \log k_1$$

Converting Equation 1 into its logarithmic equivalent

$$\log h_f = \log k_p + x \log Q$$

With log k_p given the solution of this equation becomes very

Diameter Inches	New Drawn Brass Perfect Jointing	Clean Wrought Iron	Clean Galvanized Iron	
	$x = 1.81$	$x = 1.88$	$x = 1.88$	
1	4.838232	5.039877	5.069840	
1½	3.991929	4.164355	4.192844	
2	3.381593	3.542108	3.572721	
2½	2.927716	3.062415	3.090443	
3	2.544771	2.671303	2.696789	
3½	2.222623	2.337758	2.364297	
4	1.943997	2.048991	2.076575	
	New Tar-Coated Cast-Iron			Average Cast-Iron
	$x = 1.905$	$x = 1.88$	$x = 1.88$	$x = 1.88$
6	1.141610	1.177924	1.200548	1.238521
8	0.524428	0.560144	0.578055	0.619847
10	0.044812	0.082396	0.100035	0.139262
12	9.651352-10	9.693188-10	9.708428-10	9.747285-10
14	9.321482-10	9.362875-10	9.377964-10	9.416458-10
16	9.033922-10	9.077273-10	9.090110-10	9.130351-10
18	8.780546-10	8.827971-10	8.838538-10	8.876501-10
20	8.554148-10	8.601327-10	8.611843-10	8.651533-10
24	8.162954-10	8.211752-10	8.222118-10	8.261270-10
30	7.685390-10		7.743671-10	7.784144-10
36	7.294079-10			7.391902-10
		Best Jointed and Monolithic Concrete	Good Jointed Concrete	
	$x = 1.905$	$x = 1.96$	$x = 1.90$	$x = 1.88$
42	6.963893-10	6.841960-10	6.981622-10	7.062609-10
48	6.680667-10	6.557949-10	6.695983-10	6.774447-10
54	6.427125-10	6.308055-10	6.446623-10	6.522259-10
60	6.200548-10	6.082173-10	6.222052-10	6.295248-10
72	5.809028-10	5.693445-10	5.830321-10	5.902872-10
78	5.637395-10	5.521056-10	5.658584-10	5.730817-10
96	5.192978-10	5.073003-10	5.215896-10	5.283422-10
102		4.944169-10	5.086276-10	
108		4.820051-10	4.964173-10	
120		4.591264-10	4.739388-10	
138		4.287775-10	4.437887-10	
144		4.195358-10	4.347449-10	
174		3.784424-10	3.940445-10	

simple. For example, to find the actual head loss for a flow of 30 c.f.s. in a 42″ cast-iron pipe:

log k_p for 42″			$\longrightarrow$	7.062609-10	(from Table 6 for ave. cast-iron)
$\log Q = \log 30$	$\longrightarrow$	1.477121			
times exponent x		$\times 1.88$			
		2.776987	$\longrightarrow$	2.776987	
$h_f = 0.69' \ /1000'$			$\longleftarrow$	9.839596-10	

Additional Data

The writer would welcome additional data on good tests which could be used to fix the position of the outer end of the lines on Fig. 2, that is, for large diameters and it should be realized that these curves do not necessarily represent the final word as yet.

Conclusion

The writer believes that the basic idea presented here represents a real advancement in the practical appreciation of the factors involved in the flow of water in pipes, and results in a simple formula which can become a practical tool in the hands of the hydraulic engineer.

List of References

1. W. F. Covil, "Flow Characteristics of Pipe Lines," B.S.C.E., January, 1942.
2. M. H. Darcy, "Recherches Experimentales Relative au Mouvement de l'eau dans les Tuyaux," Paris, 1857.
3. Mansfield Merriman, "Treatise on Hydraulics," 1889.
4. O'Brien and Hickox, "Applied Fluid Mechanics," McGraw-Hill Book Co.
5. Fred C. Scobey, "Flow of Water in Concrete Pipes," Agricultural Bulletin No. 852.
6. Hiram F. Mills, "'Flow of Water in Pipes," Memoirs of the American Academy of Arts and Sciences, Vol. XV, No. II, 1924.

OF GENERAL INTEREST

PROCEEDINGS OF THE SOCIETY

MINUTES OF MEETING

Boston Society of Civil Engineers

OCTOBER 18, 1944.—A regular meeting of the Boston Society of Civil Engineers was held this evening in Lecture Hall, Room 228, New Building, Northeastern University, and was called to order by President Harry P. Burden. Fifty members and guests attended the meeting and dinner.

President Burden announced that the November meeting is to be a Joint Meeting with the Designers Section, and will be held at the 20th Century Association, 3 Joy Street, Boston. The speaker will be Mr. J. Stuart Crandall, President and Chief Engineer, Crandall Dry Dock Engineers, Cambridge, Mass., who will give a talk on "Recent Timber Floating Dry Docks".

President Burden introduced the speaker of the evening, Mr. J. S. Macdonald, General Manager of the Walsh-Kaiser Shipyard, Providence, R. I., who gave a very interesting paper on "The Construction of the Walsh-Kaiser Shipyard at Providence and the Building of Ships". The talk was followed by a question and answer period and many excellent photographs of the construction of the plant and ships being built were circulated.

The speaker was given a rising vote of thanks. Adjourned at 9:00 P.M.

EVERETT N. HUTCHINS, *Secretary*

NOVEMBER 15, 1944.—A regular meeting of the Boston Society of Civil Engineers was held this evening at the 20th Century Association, 3 Joy Street, Boston, Mass., and was called to order by President Harry P. Burden at 7:00 P.M. This was a Joint Meeting with the Designers Section B.S.C.E. Sixty-five members and guests attended the meeting, and fifty members and guests attended the dinner.

President Burden announced the death of the following member:

> James L. Crandall, who was elected a member November 19, 1924, and who died October 18, 1944. A brief outline of Mr. Crandall's career as a member of the firm, Crandall Dry Dock Engineers and his consulting practice was given by the President.

President Burden announced that the December meeting would be held at the Twentieth Century Association, speaker to be announced when obtained, the expected speaker having found it impossible to be at the December meeting.

President Burden then turned the meeting over to Mr. Lawrence M. Gentleman, Chairman, Designers Section, to conduct any business matters for that Section.

The President then introduced the speaker of the evening, Mr. J. Stuart Crandall, President and Chief Engineer, Crandall Dry Dock Engineers, Cambridge, Mass., who gave a very interesting paper on "Recent Timber Floating Dry Docks". The talk was illustrated with lantern slides. A question period followed the talk.

The meeting adjourned at 8:20 P.M.

EVERETT N. HUTCHINS, *Secretary*

DECEMBER 20, 1944.—A regular meeting of the Boston Society of Civil Engineers was held this evening at the 20th Century Association, 3 Joy Street, Boston, Mass., and was called to order by President Harry P. Burden, at 7:00 P.M. This was a joint meeting with the Highway Section BSCE. Thirty-eight members and guests attended the meeting and thirty-four members and guests attended the dinner preceding the meeting.

President Burdent asked members to rise and announced the death of the following members:—

Alexander L. Kidd, who was elected a member January 1, 1885 and who died August 21, 1944.

Herbert B. Allen, who was elected a member September 15, 1920 and who died November 30, 1944.

Herbert L. Ripley, who was elected a member May 19, 1897 and who died December 12, 1944.

The Secretary announced that the following had been elected to membership at the November 15, 1944, meeting.

Grade of Member:—Russell C. Chase, Charles W. Bowen, *Walter A. Ford.

Grade of Junior:—†Lawrence I. Piper.

The President announced that the January meeting would be held at the 20th Century Association. The speaker to be Lt. Commander J. E. Larsen, USNR., who will give a talk on "Construction with the Seabees in Iceland."

President Burden called upon Prof. Charles O. Baird, Chairman of the Highway Section to carry on any necessary business for that Section.

President Burden then introduced the speaker of the evening, Capt. J. D. Boylan, U. S. War Dept., Corps of Engineers, who gave a talk on "Highway Construction in Persia." The talk was illustrated by lantern slides shown by Capt. J. H. Aiken who accompanied the speaker.

The speaker was given a rising vote of thanks.

Adjourned at 8:40 p. m.

EVERETT N. HUTCHINS, *Secretary*

*Transfer from Grade of Junior.
†Transfer from Grade of Student.

SANITARY SECTION

JUNE 7, 1944.—A meeting of the Sanitary Section was held this evening at the Society Rooms at 7 p. m., following an informal dinner gathering at Patten's Restaurant. Twenty-three persons attended the meeting with seventeen at the dinner.

Chairman Gibbs introduced the speaker of the evening, M. E. Sherman Chase, member of the firm of Metcalf & Eddy, who gave an interesting talk on "The Proposed Method of Sewage Treatment for Los Angeles, Cal." Mr. Chase described the conditions which led to an investigation of the sewage treatment problem of Los Angeles—namely, the pollution of ocean bathing beaches in and near Los Angeles by sewage from that city and neighboring municipalities. In order to remedy these conditions, it is proposed to treat the sewage by screening, grit removal, preliminary sedimentation, short-period aeration, final sedimentation and post-chlorination, with dispersion of the effluent into the ocean through multiple outlets, a mile off shore. It is proposed to treat the sludge by separate digestion, elutriation, mechanical dewatering and drying, the dried sludge to be either used as a fertilizer or incinerated.

After a considerable discussion, the

speaker was given a rising vote of thanks and the meeting adjourned about 8:40 p. m.

GEORGE C. HOUSER, *Clerk*

DESIGNERS' SECTION

OCTOBER 11, 1944.—A meeting of the Designers Section was held in the society rooms on October 11, 1944, following an informal dinner at the Ambassador Restaurant. The meeting started at 6:45 P.M. with Chairman Lawrence M. Gentleman presiding. The report of the previous meeting was approved as read.

The speakers of the evening were Professors Walter C. Voss and Dean Peabody, Jr., of the Massachusetts Institute of Technology, who spoke on the subject, "Concentrated Loads on Thin Shelled Spherical Domes." Professor Voss described the construction and testing of a plaster of Paris model about 8 feet in diameter with a ¼-inch shell thickness. The tests described included loadings concentrated on a small area and uniform loadings over one-eighth and one-quarter segments of the dome. Professor Peabody described the mathematical analyses made and the application of the test data to design. Both papers were illustrated by slides. Because of further development anticipated by the speakers they requested that no steps be taken to publish the papers at this time.

The papers were followed by informal discussion by members and guests. There was an attendance of 37 members and guests and the meeting adjourned at 8:30 P.M.

FRANK L. LINCOLN, *Clerk*

NOVEMBER 15, 1944.—A joint meeting of the Boston Society of Civil Engineers and the Designers Section was held at the Twentieth Century Association, 3 Joy Street, Boston. The meeting started at 7:00 P.M. following a dinner with President Harry P. Burden presiding, assisted by Lawrence M. Gentleman, Chairman of the Designers Section.

The speaker for the evening was Mr. J. Stuart Crandall, President and Chief Engineer of the Crandall Dry Dock Engineers, who spoke on the subject, "Recent Timber Floating Dry Docks." Mr. Crandall discussed the design and construction of timber dry docks in considerable detail and his talk was illustrated by slides showing design details and construction photographs. There was an attendance of sixty-five members and guests.

The meeting adjourned at 8:15 P.M.

FRANK L. LINCOLN, *Clerk*

DECEMBER 13, 1944—A meeting of the Designers' Section of the Boston Society of Civil Engineers was held at the Society Rooms, 715 Tremont Temple, Boston, at 6:45 p. m., following an informal luncheon at the Ambassador Restaurant. Chairman Lawrence M. Gentleman presided.

The report of the previous meeting was approved as read.

The speaker for the evening was Professor George G. Marvin of the Massachusetts Institute of Technology, who spoke on the subject, "Methods for the Prevention of Corrosion." Professor Marvin reviewed the causes and the methods of prevention of corrosion in general and discussed more particularly the methods of retarding corrosion of ferrous metals. A number of specimens showing advanced corrosion from various causes were displayed. The formal paper was followed by an enthusiastic discussion by members and guests. There was an attendance of 28 members and guests.

The meeting adjourned at 8:45 p. m.

FRANK L. LINCOLN, *Clerk*

HIGHWAY SECTION

April 26, 1944.—The Highway Section of the Boston Society of Civil Engineers held a regular meeting at Northeastern University on this date. An Executive Meeting was scheduled at 5:00 p. m. Three members were present at this meeting and an informal discussion was held on the tentative program for the coming year.

At 7:15 p. m. the Chairman, Professor Charles O. Baird, Jr. introduced Mr. Votaw of the Portland Cement Association who gave a very interesting illustrated talk on "Soils Cement." Mr. Votaw related the eleven steps which must be followed rigidly in order to obtain a stable surface. He also told of the tremendous increase in the use of Soils Cement, particularly during this war emergency.

On motion of Professor Baird, a rising vote of thanks was given to the speaker for his courtesy in presenting this helpful lecture.

Members and guests present 46.

Adjourned at 9:30 p. m.

George W. Hankinson, *Clerk*

September 27, 1944.—A joint meeting of the American Society of Civil Engineers, the Boston Society of Civil Engineers and the Highway Section was held September 27, 1944 at Northeastern University. A caterer served dinner in the University Commons preceding the meeting of the evening.

The meeting was held in room 300 Richards Hall, Dean Burden of Tufts College as President of B. S. C. E., presiding. The speaker, Professor Charles B. Breed, Professor of Civil Engineering, Massachusetts Institute of Technology gave an illustrated talk on "Land and Air Transport after the War." The future outcome of the three chief transportation facilities, airlines, railroads and motor vehicles, was the chief topic. A short period at the end of the talk was allowed in which the members and guests asked questions of the speaker.

The meeting was well attended by members and guests from both societies.

George W. Hankinson, *Clerk.*

HYDRAULICS SECTION

November 1, 1944.—A meeting of the Hydraulics Section was held in the society rooms. During a brief business meeting the chairman, Allen J. Burdoin, was authorized to appoint a nominating committee for the purpose of nominating officers for the coming year. The chairman appointed William F. Covil, Stanley M. Dore, and Scott Keith to be members of the nominating committee.

A paper entitled "A Practical Formula for the Flow of Water in Pipes" was presented by Mr. William F. Covil, Senior Hydraulic Engineer, Metropolitan District Water Supply Commission. The speaker's treatment of the problem was based upon his extensive experience with the design and testing of large conduits for the Metropolitan District Water Supply Commission. The general interest in the method presented was evidenced in the discussion following the presentation of the paper.

Thirty-five members and guests attended the meeting.

Harold A. Thomas, *Clerk*

NORTHEASTERN UNIVERSITY SECTION

May 10, 1944.—An evening meeting of the Northeastern University Section of the Boston Society of Civil Engineers was held in room 228 N., Northeastern University, Boston, Mass.

Dinner was held at the Cafe De Paris at 6:00 p. m. Seventeen persons were present including guests and faculty.

The business meeting was opened at 7:30 p. m. by Vice-President Peter Mouldore who introduced the speaker for the evening, Mr. Herman Dresser. Mr. Dresser gave a very enlightening talk on the subject "Sanitary Engineering Problems."

Mr. Dresser described some of the problems with which he had been confronted in the past. He pointed out unforeseen problems that developed in the construction of sewers and drains, including rock tunnels. Court and evaluation cases were described, and the peculiarities that arise in these cases. The three different types of wells; the shallow well, the developed well, and the gravel packed well were discussed in detail.

Slides were shown of wells and sewage treatment plants.

The meeting adjourned at 8:30 p. m.

PHILIP A. FRIZZELL, *Secretary*

JUNE 20, 1944.—A business meeting of the Northeastern University Section of the Boston Society of Civil Engineers was held in room 106 South Building, Northeastern University. The meeting was opened at 10:00 a. m. by the Vice-President Joseph J. Bulba. Business for the day was the election of officers to replace those leaving for the service. The election was held under the supervision of Professor C. O. Baird, Chapter Adviser. The results of the election were:

Joseph J. Bulba, *President*
George W. Laakso, *Vice-President*
Robert J. Markell, *Treasurer*

The meeting was adjourned at 10:30. Twelve members were in attendance.

ARTHUR HEBERT, *Secretary*

AUGUST 2, 1944.—An evening meeting of the Northeastern University Section of the Boston Society of Civil Engineers was held in room 300 Richards Hall, Northeastern University.

Dinner was served at the Cafe De Paris at 6:00 p. m. Twenty-six persons were present including members and guests.

The meeting was opened at 8:00 p. m. by President Joseph J. Bulba, who introduced the speaker for the evening, Major Zavin Malkasian, of the Boston Office of the United States Engineering Department. Major Malkasian gave an illustrated lecture on "Sonic Sounding Devices."

The Major outlined various methods employed in the past and their faults, then gave the historical development of the present device. Plaques and drawings were passed through the audience portraying the various requirements, errors, flaws and their cure. Movies were presented which showed the operation of such devices and the auxiliary equipment required for smooth and efficient work. A movie of scenic beauty but with adverse conditions for the operation of the sonic sounding devices was shown; this comprised a trip by boat up the Kennebec River to Bath, Maine. The meeting was informal.

The meeting was adjourned at 9:00 p. m. Thirty-four persons were in attendance.

ARTHUR HEBERT, *Secretary*

AUGUST 9, 1944.—A noon meeting of the Northeastern Section of the Boston Society of Civil Engineers was held in Room 202 South Building, Northeastern University. The meeting was called to order by Joseph J. Bulba, President, at 1:00 p. m.

The main feature for the day was the presentation of the movie "The Inside of Arc Welding." The pictures were presented by the General Electric Welding Laboratories. Questions were forwarded to Professor Lawrence Cleveland of the Electrical Engineering Department whose attendance was in an advisory manner.

The meeting was adjourned at 2:00 p. m. Sixteen members and guests were present.

ARTHUR HEBERT, *Secretary*

SEPTEMBER 27, 1944.—Annual Student Night sponsored by the Boston Society of Civil Engineers and the Northeastern Section, American Society of Civil Engineers and Highway Section B.S.C.E. was held at Northeastern University, Huntington Avenue, Boston.

Dinner was served in the University Commons at 6:00 p. m. Members of both Societies, guests and students totaling 150 attended the dinner.

The meeting was opened at 7:20 p.m. by Professor Harry P. Burden, President of the Boston Society of Civil Engineers. A period of silent tribute was observed by the gathering for those members who have departed from the Society in the past year.

Presentation of Student Guests in order of Colleges then followed. Students from Massachusetts Institute of Technology, Harvard, Tufts, Rhode Island State, Worcester Polytechnic Institute, University of Maine, and Northeastern were present.

Mr. Kingsbury, President of the American Society of Civil Engineers, joined Prof. Burden in extending a welcome to the students and other invited guests.

President Burden then introduced the speaker for the evening, Professor Charles B. Breed, of M.I.T., who spoke on the subject "Land and Air Transportation in the Post-War Period." Professor Breed opened his lecture with the historical background and development of transportation and transportation engineering.

He then presented with the aid of lantern slides the statistical side of rail, highway, and air transport and the recent development in equipment offered by each.

After comparing the various modes of transportation, he then presented his prophecy of post-war conditions. Particular emphasis was placed on air transport as regards to both freight and passenger service.

Professor Breed then explained the function of C.A.A. and C.A.B. and their effects upon future developments in air transport.

A short question period followed in which various points were discussed and clarified.

The meeting was adjourned at 9:30 p. m. Two hundred members and guests were in attendance.

Respectfully submitted,
ARTHUR HEBERT, *Secretary*

OCTOBER 9, 1944.—Inspection trip to the General Edward Lawrence Logan Airport, East Boston by the Northeastern University Section of the Boston Society of Civil Engineers. The members of the Section assembled at 2:30 p. m., at the Administration Building at the Airport. Under the guidance of Mr. Everett N. Hutchins, District Waterways Engineer of the Massachusetts Department of Public Works, in charge of the project, and Major Addison Crafts, Airport Manager, proceeded on the tour of the airport project.

The party proceeded to the roof of the Administration Building where a general view of existing and proposed conditions were explained by Mr. Hutchins. Here also were viewed the plane loadings, weather bureau equipment and the general handling of traffic of the port, as explained by the Major. Proceeding on the tour, the students inspected the various equipment used in Suction Dredging and the placing of Hydraulic Fill which is forming the foundation for the proposed runways.

An historical note was given the tour by a visit to Governors Island. Here the type of fortification produced by engineers in the period from 1840 to 1870 was inspected. The durability and completeness of this now out-moded type of construction was especially interesting.

Here also was a view of the airport project. Mr. Hutchins outlined the general plan of expansion of the airport and factors such as Glide and Minimum Take-Off Angles, and Clearance to Neighboring Structures and Topography.

Seventeen students, and also Professors, C. O. Baird, and E. L. Spencer and Mr. G. W. Hankinson were in attendance. The tour was completed at 4:30 p. m.

ARTHUR HEBERT, *Secretary*

OCTOBER 25, 1944.—A morning meeting of the Northeastern Section, Boston Society of Civil Engineers was held in room 104 South Building, Northeastern University. The meeting was opened by President Joseph J. Bulba, at 10:05 a. m.

The main feature for the day was the showing of films on Pile Driving and Equipment Used. Particular emphasis was placed on Poured-in Place Piles. The use of a driving shell to accommodate lengths longer than the leads of the driver was explained. An item of special note was the way in which the equipment was designed and used for the continuous operation of the driver and men tending the operation.

The meeting was adjourned at 10:50 a. m. Eleven members were in attendance.

ARTHUR HEBERT, *Secretary*

NOVEMBER 2, 1944.—A meeting of the Northeastern University Section of the Boston Society of Civil Engineers was held in room 104 South Building, Northeastern University. President Jos- J. Bulba opened the meeting at 1:15 p. m. President Joseph J. Bulba introduced the speaker, Mr. Oliver G. Julian of the Design Department, Jackson and Moreland Inc. Mr. Julian's subject for the day was "What I Expect of a Graduate."

The speaker opened his talk by giving a definition of the profession as, "the utilization of the forces of nature." He then proceeded to outline the various qualifications of an engineer. Of these qualifications there are two general types, the division line being Professional against Technical.

On the Professional side there are these basic requirements.

1. Ability to associate with any acquaintance, business or other.
2. Executive ability to handle anything within reason and direct to the best of one's ability.
3. Be able to consider all points and purposes involved in the situation and derive a complete conclusion.
4. The rate of pay cannot be evaluated on any hourly basis. This is due to the fact that a man may spend his lifetime evaluating something that can be expressed in five minutes. These qualifications are about 70 per cent of the successful engineer.

On the Technical side the following are present.

1. Ability to express one's self verbally, literally, and by the use of drawings.
2. The use of logic in making any decision.
3. The knowledge in the basic problems of the engineer and not specialization in the early stages of practice.

The speaker then compared the principles of the profession to the basic laws of science and nature.

A brief question period followed the talk and both students and faculty forwarded questions.

The meeting was adjourned at 2:30 p. m. Seventeen students and guests were in attendance.

ARTHUR HEBERT, *Secretary*

NOVEMBER 9, 1944.—A meeting of the Northeastern University Section of the Boston Society of Civil Engineers was held in room 104 South Building and opened by the President Joseph J. Bulba at 1:15 p. m. President Bulba then introduced the speaker for the day, Mr. E. C. Houdlette of the Massachusetts Geodetic Survey.

Mr. Houdlette's subject was "Geodetic Control and Its Use in the State." With the aid of lantern slides, Mr. Houdlette showed the set-up and fallacy of the old system of control and the variation in observed data. He then proceeded to explain the general type of system now used along with the difficulty encountered in setting up the system. He then showed equipment used in triangulation and precise leveling which gives accurate horizontal and vertical control. He then discussed the various systems used in other states and the ties to our state system.

A period followed where questions were forwarded to the speaker and the use of the system in aerial mapping was explained.

The meeting was adjourned at 3:00 p. m. Twenty students and faculty were in attendance.

ARTHUR HEBERT, *Secretary*

NOVEMBER 17, 1944.—A meeting of the Northeastern University Section of the Boston Society of Civil Engineers was held in room 104 South Building, Northeastern University. The meeting was opened at 3:00 p. m., by the President, Joseph J. Bulba.

The immediate business presented by the Nominating Committee of the section was the election of officers for the coming semester. The nominations were approved by those present and the election held. The results of the election were:

President—Arthur Hebert
V-President—Roy Wooldridge
Secretary—Gordon Searles
Treasurer—John Sikora

These officers will start their term as of December 11, 1944.

The main feature of the meeting then followed. This consisted of films presented through the aid of the American Society of Civil Engineers. Film and lantern slides on the failure of the Tacoma Narrows Bridge and a lecture given by one of the student body was the subject. The actual failure of the bridge along with films on the laboratory studies of the effect of wind forces on such a structure were presented.

ARTHUR HEBERT, *Secretary*

APPLICATIONS FOR MEMBERSHIP

[January 20, 1945]

The By-Laws provide that the Board of Government shall consider applications for membership with reference to the eligibility of each candidate for admission and shall determine the proper grade of membership to which he is entitled.

The Board must depend largely upon the members of the Society for the information which will enable it to arrive at a just conclusion. Every member is therefore urged to communicate promptly any facts in relation to the personal character or professional reputation and experience of the candidates which will assist the Board in its consideration. Communications relating to applicants are considered by the Board as strictly confidential.

The fact that applicants give the names of certain members as reference does not necessarily mean that such members endorse the candidate.

The Board of Government will not consider applications until the expiration of fifteen (15) days from the date given.

For Admission

Leonard B. Cornish, Winthrop, Mass. (b. November 14, 1902, Springfield, Mass.) 1st Lt., Capt. and Major, Corps of Engineers from September 16, 1940 to date. Post Engineer Harbor Defenses of Boston, Fort Banks, Mass. Construction Officer (S-4) A.A.A. School, Camp Davis, N. C. Operations Officer (S-3) 211th Engineer Port Construction and Repair Group, Camp Gordon Johnston, Florida. Employed in Civilian life by Boston Edison Company from 1927 to date. At present on Military leave since September 1940 from that organization. Am a member of the Society of American Military Engineers.

Albert E. Cummings, New York, N. Y. (b. March 29, 1894, St. Louis, Missouri). Attended Washington University in St. Louis, Missouri in 1911-1912. Attended the University of Wisconsin at Madison from 1912-1915. Received B.S. degree in Civil Engineering and also the professional degree of Civil Engineer, both from the University of Wisconsin. Experience, August, 1915 to March, 1916, with the New York, New Haven and Hartford Railroad, as rodman on valuation survey; March 1916, with the Raymon Concrete Pile Company, first as a timekeeper and then as Superintendent of Construction, was transferred to the Chicago Office in the Spring of 1920 and was District Manager there until January 1, 1943, when I was transferred to the Company's home office in New York as Research Engineer. Refers to A. Casagrande, J. S. Crandall, F. A. Marston, H. A. Mohr, K. Terzaghi.

Frank A. Cundari, South Boston, Mass. (b. July 17, 1899, Messina, Italy). Graduated from Northeastern University in 1921, receiving a degree of C. E. Experience, special graduate work on both concrete and steel design and the design of concrete mixtures. Am a member of the American Concrete Institute. Since 1922, have operated my own engineering and construction business under the name of Cundari Construction Company which was later superseded by the Old Colony Construction Corporation of which I had complete control, and since January 1, 1944, it has been superseded by the Old Colony Construction Company. During this entire period I did the engineering design work on many of the projects which were built by us. Have also done structural design work for some architects in Boston, as well as the estimating for my own business and general supervision of the construction work done by us. At present Engineer, estimator and treasurer of the "Old Colony Construction Company." Refers to *E. F. Allbright, M. N. Clair, C. S. Ell, C. J. Ginder, A. E. Harding, T. F. Sullivan.*

James F. Cunniff, Holyoke, Mass. (b. July 26, 1896, Holyoke, Mass.) Graduate (1925) Massachusetts Institute of Technology, S.B. in Civil Engineering. Experience, nineteen years with Casper Ranger Construction Company, Holyoke, Mass.; General Contractors, rising to Chief Engineer, which post I filled for ten years. Seven years with J. F. Cunnigg Company, Engineers and Contractors. Two years officer in charge U. S. Naval Construction Battalion overseas. Ten years experience teaching Mechanical Drawing, Holyoke Public Evening High School. At present Officer in Charge 78th U. S. Naval Construction Battalion. Refers to *J. B. Babcock, C. B. Breed, J. D. Mitsch, G. E. Russell, C. M. Spofford.*

Byron O. McCoy, Wellesley, Mass. (b. March 27, 1912, New London, Conn.) June, 1933, Dartmouth College, A.B.; May, 1934, Thayer School of Civil Engineering, C. E. Experience, June, 1934—January, 1935, Computer, New Hampshire Highway Department; January, 1935—January, 1937, Truck trailer locator, U. S. Forest Service, White and Green Mountain National Forests; February, 1937—August, 1942, Hydraulic Engineer, William P. Creager, Buffalo, New York, assistant on design of large earth and concrete dams and auxiliary structures, including flood control, water supply, hydraulic design, suitability of materials, stability, etc., hydraulic design of pumping stations, estimates of cost of several hydro-electric developments, and research on dam design details and general hydraulic problems; August, 1942- February, 1943, Hydraulic Engineer, Chas. T. Main, Inc., Boston, Mass., design of 250,000 g.p.m. pumping station, water hammer studies, and stream flow studies; March, 1943- September, 1943, Hydraulic Engineer, Malcolm Pirnie, New York. On leave of absence from Chas. T. Main to assist in design of two dams, one concrete, the other earth, for the water supply system of the city of San Juan, Puerto Rico. October, 1943 to date, Hydraulic Engineer, Chas. T. Main, Inc., Boston, Mass., Hydro-electric developments, design studies and cost estimates. Refers to *W. F. Covil, W. C. Custer, L. G. Ropes, H. A. Thomas, Jr., W. F. Uhl.*

Charles F. Peoples. Medford, Mass. (b. October 11, 1911, Somerville, Mass.) Graduated from Northeastern University in 1935, B.S. degree in Civil Engineering. Attended Northeastern University School of Law for five semesters in evening in study of law. Experience, 1931-1936. in office of City Engineer, City of Medford, from rodman to assistant city engineer. U.S.E.D. 1936-1937—Flood Control preliminary survey in State of Maine, Chief of party; 1937-1937. in office of City Engineer, City of Medford. as chief inspector on contract construction; 1939- six months, Metcalf & Eddy, chief of party on preliminary survey of layout for main trunk line sewer; 1940-1941, 10 months, Stone & Webster, design of concrete, etc.; March 1941- July 1941, Pvt. 101st Eng. (C) Reg't; Aug. 1941- May 1942, instructor, Engineering School Ft. Belvoir, Va.; May- August 1942, O. Candidate; October 1942- April 1943, C. O. Hq. Co. 861 Eng. (Aun) Bn.; April 1943- September 1943, Bn. Motor Off.; September 1943- December 1943, Plt. Ldr. Co. A. 825 Eng. (Aun) Bn.; December 1943- July 1944, Assistant Engineer 9th Engineer Command—charge of construction and water supply; at present Capt. Corps of Engineers. Refers to *C. O. Baird, C. S. Ell, A. E. Everett, E. A. Gramstorff.*

HAROLD S. SCHIANO, Roslindale. Mass. (b. February 1. 1896, Roslindale, Mass.) Attended Mechanics Art High School. Berkeley Prep. School and Lawrence Scientific School. Experience. 12 months in 1924, Boston Transit Commission. rodman, transitman, East Boston Tunnel (construction) (Maverick Square) and Dorchester Rapid Transit (prelim. survey); 1925-1927, Commonwealth of Masachusetts Highway Division. senior engineering aide, finals department: 1927-1945 City of Boston sewer division, civil engineer grade IV on construction; 1914-1915, B. F. Sturtevant Company. draftsman; 1915-1916, American St. Gauge Valge Mfg. Company, draftsman: 1916-1917. American Sugar Refining Company, draftsfman; 1917-1919. U. S. Army A.E.F. At present employee of City of Boston sewer division. civil engineer. Refers to *G. F. Haskell, G. G. Hyland, W. T. Morrisey, S. Tomasello.*

HARRISON E. SHOCK, Boston, Mass. (b. June 10, 1893, Boston, Mass.) Graduate of Cooper Union in architectural construction, 1911-1915; attended Columbia University, courses in structural design 1916-1917. Experience, while attending school worked part time for D. E. Waid, architect for Metropolitan Life Insurance Co., New York, as junior draftsman; 1917-1925, with Walter Leslie Walker and Charles W. Leavitt, architects and engineers, New York, as draftsman and designer on industrial developments for Midvale Steel Co., Coatesville, Pa., Cambria Steel Co., Johnstown, Pa., Rockaway Rolling Mills in New Jersey and New York; 1925-1928, with Dennison & Hirons, architects and engineers, New York, as squad boss in the design of construction of bank and office buildings. Principal structures in charge of, were Erie Trust Co., Erie Pa., and Home Savings Bank, Albany, N. Y.; 1928-1931, with the associated constructors (Starrett Bros. & Eken, H. C. Severance) for Bank of Manhattan Co., Building, New York, third tallest structure in New York City, as specification writer, coordinator and expeditor; 1931-1939, in charge of rehabilitating foreclosed properties for several trusteeships and two savings banks in New York City. This work involved practically all phases of engineering, principally structural and sanitary in the alleviation of slum conditions, sanitation of and clearances of structures and alleys, fire prevention work and mechanical equipment; 1941-1944, with Shreve, Lamb & Harmon, Fay, Spofford & Thorndike, associated architects and engineers, Boston, as designer and assistant engineer in fire prevention, miscellaneous piping and plumbing. 1944 to date with Kilham, Hopkins & Greeley, Boston, in charge of building construction and engineering design. Refers to *J. F. Brittain, F. M. Cahaly, G. W. Coffin, L. M. Gentleman, M. H. Mellish.*

Edward N. Tashian, Watertown, Mass. (b. January 1, 1892, Harpoof, Armenia). Graduated from Massachusetts Institute of Technology in 1921, receiving B. S. degree as Mechanical Engineer. After graduating and up to July 1942, followed the construction line, designing, estimating and supervising buildings in and around Boston. From July, 1942, to March, 1943, worked for the Morton C. Tuttle Company and Lockwood Green, Engineers, at the Lowell Ordnance Plant, in the engineering department as an estimator. At present, and since March, 1943, with U. S. Army Engineers, at Park Square Building, Boston, on engineering estimates and transfer drawings. Refers to *C. O. Baird, E. F. Childs, A. E. Harding, E. L. Spencer.*

Transfer from Grade of Student

Francis Sattin, Malden, Mass. (b. May 14, 1919, Malden, Mass.) Graduate of Northeastern University in 1943, B.S. degree in Civil Engineering. Employed by U. S. Engineers, October, 1941 to July, 1942. Now serving with the Army as a communications officer in the Air Corps. Refers to *C. O. Baird, A. E. Everett, E. A. Gramstorff, C. S. Ell.*

ADDITIONS

Albert E. Abruzzese, 153 Cedar Street, Wellesley Hills, Mass.

Charles W. Bowne, 652 Prairie Avenue, Providence, R. I.

George S. Brush, 57 Main Street, Essex Jct. Vermont.

Russell C. Chase, 4 West Street, Stoneham, Mass.

Albert L. Coyne, 101 Fresh Pond Parkway, Cambridge, Mass.

George W. Hankinson, 360 Huntington Avenue, Boston, Mass.

CHARLES H. NORRIS, 1-239 Mass. Institute of Technology, Cambridge, Mass.

ERNEST L. SPENCER, Northeastern University, Boston, Mass.

WILLIAM E. STANLEY, 44 Hastings Road, Belmont, Mass.

DEATHS

HERBERT B. ALLEN, November 30, 1944.

MAYO T. COOK, April 11, 1944.

CHARLES G. CRAIB, April 29, 1944.

ALEXANDER L. KIDD, August 21, 1944.

HERBERT L. RIPLEY, December 1, 1944.

ADVERTISEMENTS

The advertising pages of the JOURNAL aim to acquaint readers with Professional and Contracting Services and Sources of Various Supplies and Materials. You would find it of advantage to be represented here.

Vol. XXXI OCTOBER, 1944 No. 4

BOSTON SOCIETY OF CIVIL ENGINEERS

FOUNDED 1848

INDEX TO ADVERTISERS

COMMITTEES

1944-1945

NOMINATING COMMITTEE

Past Presidents (Members of the Committee)

Karl R. Kennison
Gordon M. Fair
Arthur L. Shaw

George N. Bailey
Walter N. Fife
Frank L. Lincoln
(Term expires March, 1945)

Raymond W. Coburn
Lawrence M. Gentleman
Donald W. Taylor
(Term expires March, 1946)

SPECIAL COMMITTEES

Program

Harry P. Burden, *Chairman, ex officio*

Edward H. Cameron
William F. Covil
George H. Delano
Frank L. Flood
Everett N. Hutchins
Herman G. Protze
Truman H. Safford
Ralph M. Soule
Donald W. Taylor

Publication

Everett N. Hutchins, *Chairman*

J. Stuart Crandall
Gordon M. Fair
John B. Babcock

Library

Allen J. Burdoin, *Chairman*

Burtis S. Brown
Thomas C. Coleman
Eugene Mirabelli
J. Donald Mitsch
Ralph M. Soule
Frederic N. Weaver

Hospitality Committee

John H. Harding, *Chairman*

Edward S. Averell
Frederick S. Gibbs
Frederick M. Joy, Jr.
Edward Wright

Relations of Sections to Main Society

Frederick S. Gibbs, *Chairman*

Charles O. Baird
Allen J. Burdoin
Lawrence M. Gentleman

Welfare

Ralph W. Horne, *Chairman*

John R. Freeman Fund Committee

Howard M. Turner, *Chairman*

Charles M. Allen
William F. Uhl

Desmond Fitzgerald Award

Harold K. Barrows, *Chairman*

James E. Lawrence
Arthur L. Shaw

Sanitary and Hydraulics Section Award

Harold K. Barrows, *Chairman*

Harvey B. Kinnison
Thomas R. Camp

Designers Section Award

Arthur L. Shaw, *Chairman*

J. Donald Mitsch
Frederick N. Weaver

Highway Section Award

James E. Lawrence, *Chairman*

Alexander J. Bone
Parker Holbrook

Subsoils of Boston

Donald W. Taylor, *Chairman*

Miles N. Clair
Irving B. Crosby
Stanley M. Dore
Lawrence G. Ropes

Investment Committee

Chester J. Ginder, *Chairman*

Harry P. Burden
Carroll A. Farwell