MACHINERY'S DATA SHEETS

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No. 18

Beam Formulas and Structural Design

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CONTENTS

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MACHINERY'S DATA SHEET SERIES

COMPILED FROM MACHINERY'S MONTHLY DATA
SHEETS AND ARRANGED WITH
EXPLANATORY NOTES

No. 18

Beam Formulas and Structural Design

CONTENTS

In the following pages are compiled a number of diagrams and concise tables relating to the strength of beams and structural design, carefully selected from MACHINERY'S monthly Data Sheets, issued as supplements to the Engineering and Railway editions of MACHINERY since September, 1898.

In order to enhance the value of the tables and diagrams, brief explanatory notes have been provided. In many cases in these notes, references are made to articles which have appeared in MACHINERY, and to matter published in MACHINERY'S Reference Series, giving additional information on the subject. These references will be of considerable value to readers who wish to make a more thorough study of the subject. In a note at the foot of each table reference is made to the page on which the explanatory note relating to the table appears.

BEAM FORMULAS AND STRUCTURAL DESIGN

Formulas and Tables for Beam Calculations

On page 4 is given a collection of formulas for beams of rectangular or round cross-section, supported and loaded in various manners. The table has been arranged in the simplest possible manner, and any required formula can be found at a glance. [MACHINERY, December, 1903, Flexure Simplified; March and May, 1907, Fundamental Ideas on the Strength of Beams; MACHINERY'S Reference Series No. 19, Use of Formulas in Mechanics, Second Edition, Chapter V, The First Principles of the Strength of Beams.]

On page 5 are given constants used in beam calculations for various cross-sections of beam. The formulas for maximum bending moment and maximum deflection for beams loaded in various ways are also given on the same page. [MACHINERY, June, 1909, The Relation of Depth to Span of a Girder; January, 1910, To Calculate the Deflection of a Special Steel Section; February, 1910, Deflection of Beam Uniformly Loaded for Part of its Length; June, 1910, Limitations of the Common Theory of Flexure.]

On pages 6 and 7 tables are given of section moduli and weights per foot of beams of round, square and rectangular section, as well as of I-beams, channels and angles. These tables will be found particularly convenient for quickly determining the sizes of beams for supporting given loads. [MACHINERY, December, 1904, Strength of Beams with Ribbed Sections; June, 1905, Notes on the Strength of Beams, Plates and Columns; September, 1905, Beam Formulas; May, 1906, Sections of Cast-iron Beams.]

On pages 8 and 9 are given two beam charts by means of which the proper section to support a given load with a given length of beam may be found. The directions for the use of these charts are given on page 7.

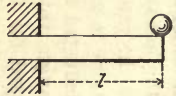
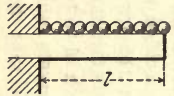
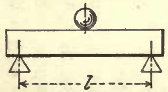
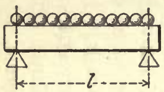
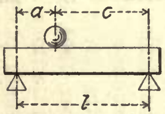
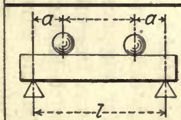
Areas for Small Rectangles—Net Areas of Structural Angles

On pages 11, 12 and 13 are given tables for the areas of rectangles, the sides of which are given in fractions of an inch. These tables will be found especially convenient when calculating the moment of inertia and section modulus of built-up structural shapes. [MACHINERY, January, 1910, To Calculate the Deflection of a Special Steel Section.]

On pages 14 to 17, inclusive, are given tables of the weight and areas of structural angles, together with the net area of the section with holes for rivets deducted. When using these tables, the lengths of the legs of the angles are added together, and the sum of the lengths is first found in the left-hand column of the tables. Then the thickness of the angle is found opposite this sum in the second column; the third and fourth columns give the weight in pounds per foot, and the cross-sectional area in square inches. The remaining columns give the net area after having deducted for one or two rivets of sizes as specified at the head of the columns.

At the foot of the table on page 17 a supplementary table is given of the area which is to be deducted for various sizes of rivets and angle thicknesses. This table may be used for determining the net area of angles of dimensions not given in the table, or for rivet sizes not specified.

FORMULAS FOR ROUND AND RECTANGULAR SOLID BEAMS

Style of Loading and Support	Rectangular Solid Beams. b=breadth of beam in inches	h=height of beam in inches	f=stress per sq. in. in extreme fibers of beam	l=length of beam in inches	W=load in pounds	Round Solid Beams.	d=diameter of beam in inches	f=stress per sq. in. in extreme fibers of beam	l=length of beam in inches	W=load in pounds
	b	h	f	l	W		d	f	l	W
	Beam fixed at one end, loaded at the other.					Beam fixed at one end, loaded at the other.				
	$\frac{6lW}{fh^2}=b$	$\sqrt{\frac{6lW}{bf}}=h$	$\frac{6lW}{bh^2}=f$	$\frac{bfh^2}{6W}=l$	$\frac{bfh^2}{6l}=W$		$\sqrt[3]{\frac{10.18lW}{f}}=d$	$\frac{10.18lW}{d^3}=f$	$\frac{d^3f}{10.18W}=l$	$\frac{d^3f}{10.18l}=W$
	Beam fixed at one end, uniformly loaded.					Beam fixed at one end, uniformly loaded.				
	$\frac{3lW}{fh^2}=b$	$\sqrt{\frac{3lW}{bf}}=h$	$\frac{3lW}{bh^2}=f$	$\frac{bfh^2}{3W}=l$	$\frac{bfh^2}{3l}=W$		$\sqrt[3]{\frac{5.092Wl}{f}}=d$	$\frac{5.092Wl}{d^3}=f$	$\frac{d^3f}{5.092W}=l$	$\frac{d^3f}{5.092l}=W$
	Beam supported at both ends, single load in middle.					Beam supported at both ends, single load in middle.				
	$\frac{3lW}{2fh^2}=b$	$\sqrt{\frac{3lW}{2bf}}=h$	$\frac{3lW}{2bh^2}=f$	$\frac{2bfh^2}{3W}=l$	$\frac{2bfh^2}{3l}=W$		$\sqrt[3]{\frac{2.546Wl}{f}}=d$	$\frac{2.546Wl}{d^3}=f$	$\frac{d^3f}{2.546W}=l$	$\frac{d^3f}{2.546l}=W$
	Beam supported at both ends, uniformly loaded.					Beam supported at both ends, uniformly loaded.				
	$\frac{3lW}{4fh^2}=b$	$\sqrt{\frac{3lW}{4bf}}=h$	$\frac{3lW}{4bh^2}=f$	$\frac{4bfh^2}{3W}=l$	$\frac{4bfh^2}{3l}=W$		$\sqrt[3]{\frac{1.273Wl}{f}}=d$	$\frac{1.273Wl}{d^3}=f$	$\frac{d^3f}{1.273W}=l$	$\frac{d^3f}{1.273l}=W$
	Beam supported at both ends, single unsymmetrical load.					Beam supported at both ends, single unsymmetrical load.				
	$\frac{6Wac}{fh^2l}=b$	$\sqrt{\frac{6Wac}{bfl}}=h$	$\frac{6Wac}{bh^2l}=f$	$a+c=l$	$\frac{bh^2fl}{6ac}=W$		$\sqrt[3]{\frac{10.18Wac}{fl}}=d$	$\frac{10.18Wac}{d^3l}=f$	$a+c=l$	$\frac{d^3fl}{10.18ac}=W$
	Beam supported at both ends, two symmetrical loads.					Beam supported at both ends, two symmetrical loads.				
	$\frac{3Wa}{fh^2}=b$	$\sqrt{\frac{3Wa}{bf}}=h$	$\frac{3Wa}{bh^2}=f$	l, any length $\frac{bh^2f}{3W}=a$	$\frac{bh^2f}{3a}=W$	$\frac{d^3f}{5.092W}=a$	$\sqrt[3]{\frac{5.092Wa}{f}}=d$	$\frac{5.092Wa}{d^3}=f$	l may be any length	$\frac{d^3f}{5.092a}=W$

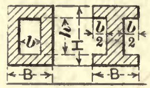
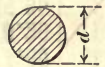
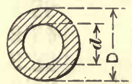
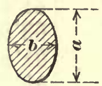
Contributed by B. M. Brigman, MACHINERY'S Data Sheet No. 97. Explanatory note: Page 3.

FORMULAS FOR CALCULATING THE STRENGTH OF BEAMS

FORMULAS FOR LOADED BEAMS

Beams of Uniform Cross-section	Maximum Moment, M	Maximum Deflection
Cantilever, load at end..	Wl	$\frac{Wl^3}{3EI}$
Cantilever, uniform load	$\frac{Wl}{2}$	$\frac{Wl^3}{8EI}$
Simple beam, load at middle...............	$\frac{Wl}{4}$	$\frac{Wl^3}{48EI}$
Simple beam, uniform load..................	$\frac{Wl}{8}$	$\frac{5Wl^3}{384EI}$
Beam fixed at one end, supported at other, load at middle............	$\frac{3Wl}{16}$	$\frac{0.0093Wl^3}{EI}$
Beam fixed at one end, supported at other, uniform load	$\frac{Wl}{8}$	$\frac{0.0054Wl^3}{EI}$
Beam fixed at both ends, load at middle.........	$\frac{Wl}{8}$	$\frac{Wl^3}{192EI}$
Beam fixed at both ends, uniform load..........	$\frac{Wl}{12}$	$\frac{Wl^3}{384EI}$
Beam fixed at both ends, load at one end (pulley arm).................	$\frac{Wl}{2}$	$\frac{Wl^3}{12EI}$

CONSTANTS OF CROSS-SECTION

Cross-section and Notation	Area, A	Square of Radius of Gyration, r^2	Moment of Inertia, $I = Ar^2$	Section Modulus, $\frac{I}{c}$	Polar Moment of Inertia, J	Torsion Modulus, $\frac{J}{c}$
	bh	$\frac{h^2}{12}$	$\frac{bh^3}{12}$	$\frac{bh^2}{6}$	$\frac{bh^3+b^3h}{12}$	$\frac{bh^3+b^3h}{6\sqrt{b^2+h^2}}$
	d^2	$\frac{d^2}{12}$	$\frac{d^4}{12}$	$\frac{d^3}{6}$	$\frac{d^4}{6}$	$\frac{d^3}{4.24}$
	$BH-hb$	$\frac{BH^3-bh^3}{12(BH-bh)}$	$\frac{BH^3-bh^3}{12}$	$\frac{BH^3-bh^3}{6H}$		
	$\frac{\pi}{4}d^2$	$\frac{d^2}{16}$	$\frac{\pi d^4}{64}$	$\frac{d^3}{10.2}$	$\frac{\pi d^4}{32}$	$\frac{d^3}{5.1}$
	$\frac{\pi}{4}(D^2-d^2)$	$\frac{D^2+d^2}{16}$	$\frac{\pi(D^4-d^4)}{64}$	$\frac{D^4-d^4}{10.2d}$	$\frac{\pi(D^4-d^4)}{32}$	$\frac{D^4-d^4}{5.1D}$
	$\frac{\pi}{4}ab$	$\frac{a^2}{16}$	$\frac{\pi ba^3}{64}$	$\frac{ba^2}{10.2}$	$\frac{\pi(ba^3+ab^3)}{64}$	$\frac{ba^3+ab^3}{10.2a}$

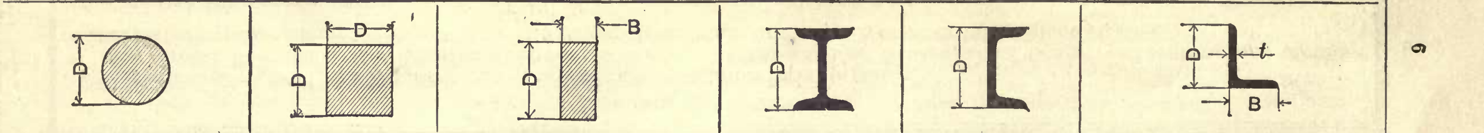
Values of I and J for more complicated sections can be worked out from those in table.

NOMENCLATURE

All dimensions are in inches, stresses in pounds and moments in inch-pounds.

S = stress; W = load; M = bending moment; A = area of cross-section; l = length of beam; I = rectangular moment of inertia; J = polar moment of inertia; c = half depth of beam or shaft; E = modulus of elasticity.

TABLE OF SECTIONAL MODULI AND WEIGHTS PER FOOT OF BEAMS OF VARIOUS SECTIONS.



D	W	S	W	S	D	B	W	S	D	W	S	D	W	S	D	B	t	W	S
1	2.67	.10	3.40	.17	2	¼	1.70	.17	3	5½	1.7	3	4	1.1	¾	¾	⅛	.6	.02
1⅛	3.38	.14	4.30	.24	2	½	3.40	.33	3	6½	1.8	3	5	1.2	¾	¾	3/16	.8	.02
1¼	4.17	.19	5.31	.33	2	¾	5.10	.50	3	7½	1.9	3	6	1.4	1	1	⅛	.8	.03
1⅜	5.05	.26	6.43	.43	2	1	6.80	.67	4	7½	3.0	4	5¼	1.9	1	1	¼	1.5	.06
1½	6.00	.33	7.65	.56	2½	¼	2.12	.26	4	8½	3.2	4	6¼	2.1	1¼	1¼	⅛	1.0	.05
1⅝	7.05	.42	8.98	.71	2½	½	4.25	.52	4	9½	3.4	4	7¼	2.3	1¼	1¼	5/16	2.4	.11
1¾	8.18	.53	10.41	.89	2½	¾	6.38	.78	4	10½	3.6	5	6½	3.0	1½	1½	3/16	1.8	.10
1⅞	9.39	.65	11.95	1.10	2½	1	8.50	.04	5	9¾	4.8	5	9	3.5	1½	1½	⅜	3.4	.19
2	10.68	.79	13.60	1.33	3	¼	2.55	.38	5	12¼	5.4	5	11½	4.2	1¾	1¾	3/16	2.1	.14
2⅛	12.06	.94	15.35	1.60	3	½	5.10	.75	5	14¾	6.1	6	8	4.3	1¾	1¾	7/16	4.6	.30
2¼	13.52	1.12	17.22	1.90	3	¾	7.65	1.13	6	12¼	7.3	6	10½	5.0	2	2	3/16	2.5	.19
2⅜	15.07	1.32	19.18	2.23	3	1	10.20	1.50	6	14¾	8.0	6	13	5.8	2	2	7/16	5.3	.40
2½	16.69	1.53	21.25	2.60	3½	½	5.95	1.02	6	17¼	8.7	6	15½	6.5	2½	2	3/16	2.8	.29
2⅝	18.40	1.77	23.43	3.00	3½	¾	8.93	1.53	7	15	10.4	7	9¾	6.0	2½	2	½	6.8	.70
2¾	20.20	2.04	25.00	3.46	3½	1	11.90	2.04	7	17½	11.2	7	12¼	6.9	2½	2½	¼	4.1	.40
2⅞	22.07	2.33	28.10	3.95	3½	1¼	14.87	2.55	7	20	12.1	7	14¾	7.8	2½	2½	½	7.7	.73
3	24.03	2.65	30.60	4.50	3½	1½	17.85	3.06	8	18	14.2	7	17¼	8.6	3	2½	¼	4.5	.56
3⅛	26.08	3.00	33.20	5.01	4	¾	10.20	2.00	8	20½	15.1	7	19¾	9.5	3	2½	9/16	9.5	1.15
3¼	28.20	3.37	35.92	5.72	4	1	13.60	2.67	8	23	16.1	8	11¼	8.1	3	3	¼	4.9	.58
3⅜	30.42	3.77	38.73	6.40	4	1¼	17.00	3.33	8	25½	17.1	8	13¾	9.0	3	3	5/16	6.0	.71
3½	32.71	4.21	41.65	7.14	4	1½	20.40	4.00	9	21	18.9	8	16¼	10.0	3	3	⅝	11.4	1.30
3⅝	35.09	4.68	44.68	7.94	4	2	27.20	5.33	9	25	20.4	8	18¾	11.0	3½	2½	¼	4.9	.75
3¾	37.56	5.18	47.82	8.79	5	1	17.00	4.16	9	30	22.6	8	21¼	11.9	3½	2½	5/16	6.0	.93
3⅞	40.10	5.71	51.05	9.70	5	1½	25.50	6.24	9	35	24.8	9	13¼	10.5	3½	2½	11/16	12.4	1.85
4	42.73	6.28	54.40	10.70	5	2	34.00	8.32	10	25	24.4	9	15	11.3	3½	3	5/16	6.6	.96
4¼	48.24	7.54	61.41	12.80	5	2½	42.50	10.40	10	30	26.8	9	20	13.5	3½	3	13/16	15.7	2.25
4½	54.07	8.94	68.85	15.20	5	3	51.00	12.50	10	35	29.3	9	25	15.7	3½	3½	5/16	7.1	.98
4¾	60.25	10.50	76.71	17.80	6	1	20.40	6.00	10	40	31.7	10	15	13.4	3½	3½	⅜	8.5	1.15
5	66.76	12.30	85.00	20.80	6	1½	30.60	9.00	12	31½	36.0	10	20	15.7	3½	3½	13/16	17.1	2.25
5¼	73.60	14.20	93.72	24.10	6	2	40.80	12.00	12	35	38.0	10	25	18.2	4	3	5/16	7.1	1.23
5½	80.77	16.30	102.80	27.70	6	2½	51.00	15.00	15	42	58.9	10	30	20.6	4	3	13/16	17.1	2.87

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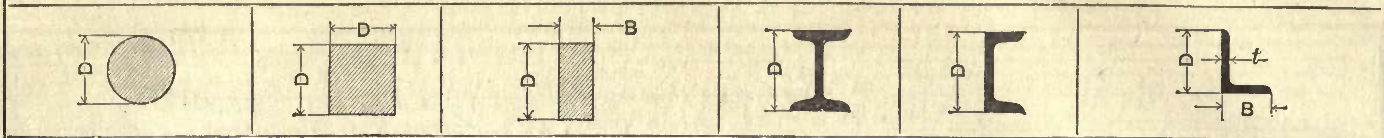
TABLE OF SECTIONAL MODULI AND WEIGHTS PER FOOT OF BEAMS OF VARIOUS SECTIONS (Continued).



D	W	S	W	S	D	B	W	S	D	W	S	D	W	S	D	B	t	W	S
5¾	88.29	18.7	112.4	31.6	6	3	61.2	18.0	15	45	60.8	10	35	23.1	4	4	5/16	8.2	1.29
6	96.14	21.2	122.4	36.0	6	3½	71.4	21.0	15	50	64.5	12	20½	21.4	4	4	3/8	9.7	1.52
6¼	104.3	24.0	132.8	40.6	6	4	81.6	24.0	15	55	68.1	12	25	24.0	4	4	13/16	19.9	3.01
6½	112.8	26.9	143.6	45.7	8	2	54.4	21.3	18	55	88.4	12	30	26.9	5	3	5/16	8.2	1.89
6¾	121.7	30.2	154.9	51.2	8	3	81.6	32.0	18	60	93.5	12	35	29.9	5	3	13/16	19.9	4.45
7	130.9	33.7	166.6	57.1	8	4	108.8	42.6	18	65	97.9	12	40	32.8	5	3½	3/8	10.4	2.29
7½	150.2	41.4	191.3	70.3	8	5	136.0	53.3	18	70	102.4	15	33	41.7	5	3½	7/8	22.7	4.88
8	171.0	50.2	217.6	85.3	8	6	163.2	64.0	20	65	117.0	15	35	42.7	6	3½	3/8	11.7	3.25
8½	193.0	60.3	245.6	102.3	9	3	91.8	40.5	20	70	122.0	15	40	46.3	6	3½	7/8	25.7	6.98
9	216.3	72.8	275.4	121.5	9	6	183.6	81.0	20	75	126.9	15	45	50.0	6	4	3/8	12.3	3.32
9½	241.0	84.1	306.8	142.7	10	4	136.0	66.7	24	80	174.0	15	50	53.7	6	4	7/8	27.2	7.15
10	267.0	98.2	340.0	166.7	10	6	204.0	100.0	24	85	180.7	15	55	57.4	6	6	7/16	17.2	4.07
10½	294.4	113.6	374.9	192.7	10	8	272.0	133.3	24	90	186.6	..	..	...	6	6	7/8	33.1	7.64
11	323.1	130.7	411.4	221.7	12	6	244.8	144.0	24	95	192.5	..	..	...	8	8	1/2	26.4	8.37
11½	353.1	149.2	449.6	253.5	12	8	326.4	192.0	24	100	198.4	..	..	...	8	8	1 1/8	58.3	18.40
12	384.5	169.5	489.6	288.0	12	10	408.0	240.0	..	..	...	..	..	...	..	..	..	...	...

DIRECTIONS FOR USING THE BEAM CHARTS.

To find a proper section to support a given load with a given length of beam:

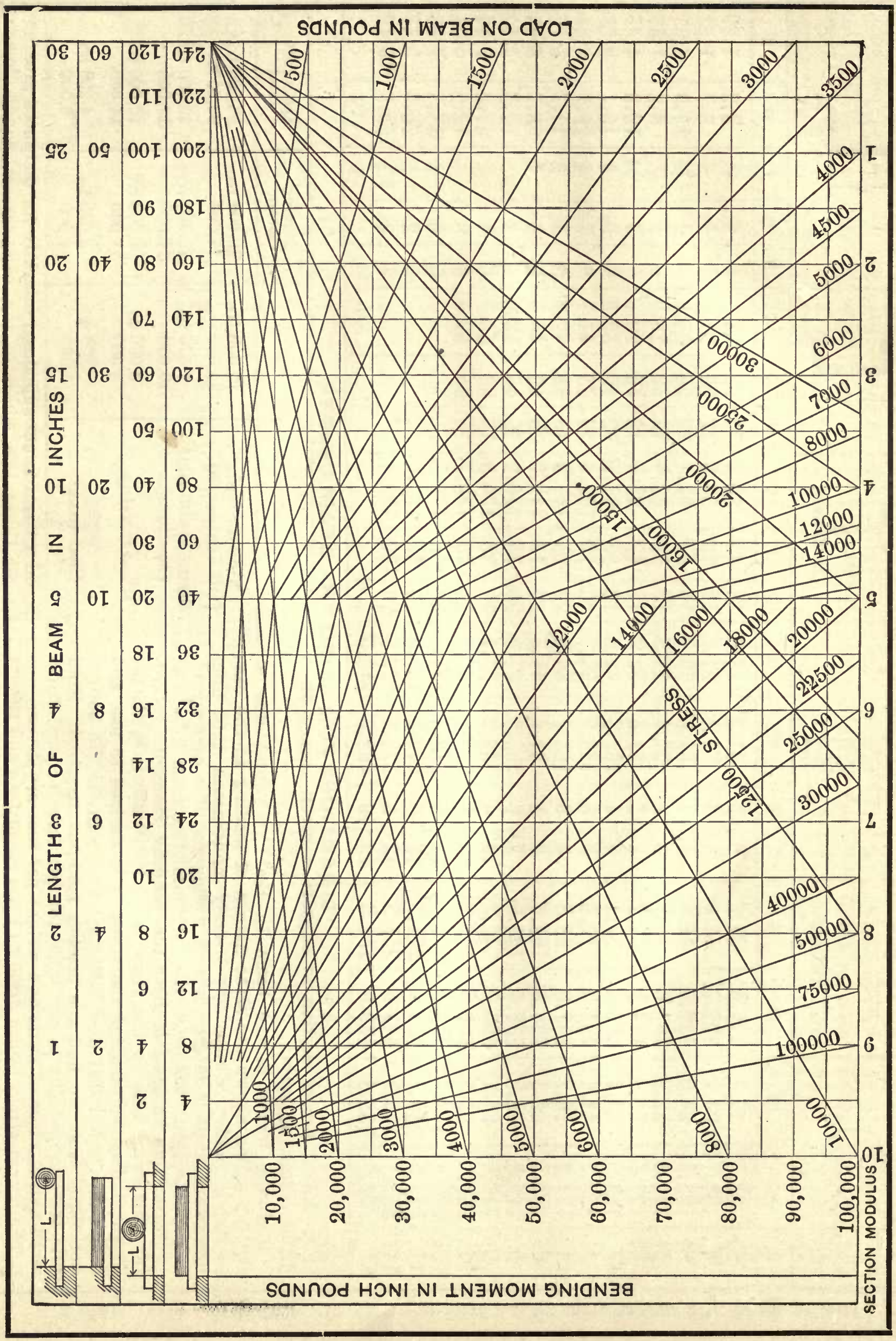
Find the length of the beam in that horizontal line at the top which shows the same nature of loading as the case in hand; follow vertical line directly underneath this line, downward until it intersects with a diagonal line corresponding to the load; following the horizontal line from this point to the column on the left gives the bending moment; following this same line to the right until it intersects with the diagonal line representing the stress it is desired to use, and following the vertical line from this new point to the bottom horizontal line, we find the section modulus required. Find this section modulus in the table for the form of section desired and the size of beam and weight per foot are given.

The proper stress to use depends upon conditions and should be selected to suit the case in hand. The following values may be used:

	Shock.	Moving Load.	Quiescent Load.
Nickel Steel (Oil Tempered).	15,000 to 20,000	20,000 to 25,000	25,000 to 30,000
Structural Steel (Medium).	7,500 to 10,000	12,500 to 14,000	16,000 to 17,000
Steel Casting.	6,000 to 8,000	8,000 to 11,000	10,000 to 14,000
Cast Iron.	1,000 to 2,000	2,000 to 4,000	4,000 to 6,000

When a beam is not supported laterally for distances greater than 20 times the width of the compression flange, lower stresses must be used. Short beams heavily loaded may fail by crippling of the web.

Contributed by J. S. Myers, MACHINERY'S Data Sheet No. 27. Explanatory note: Page 3



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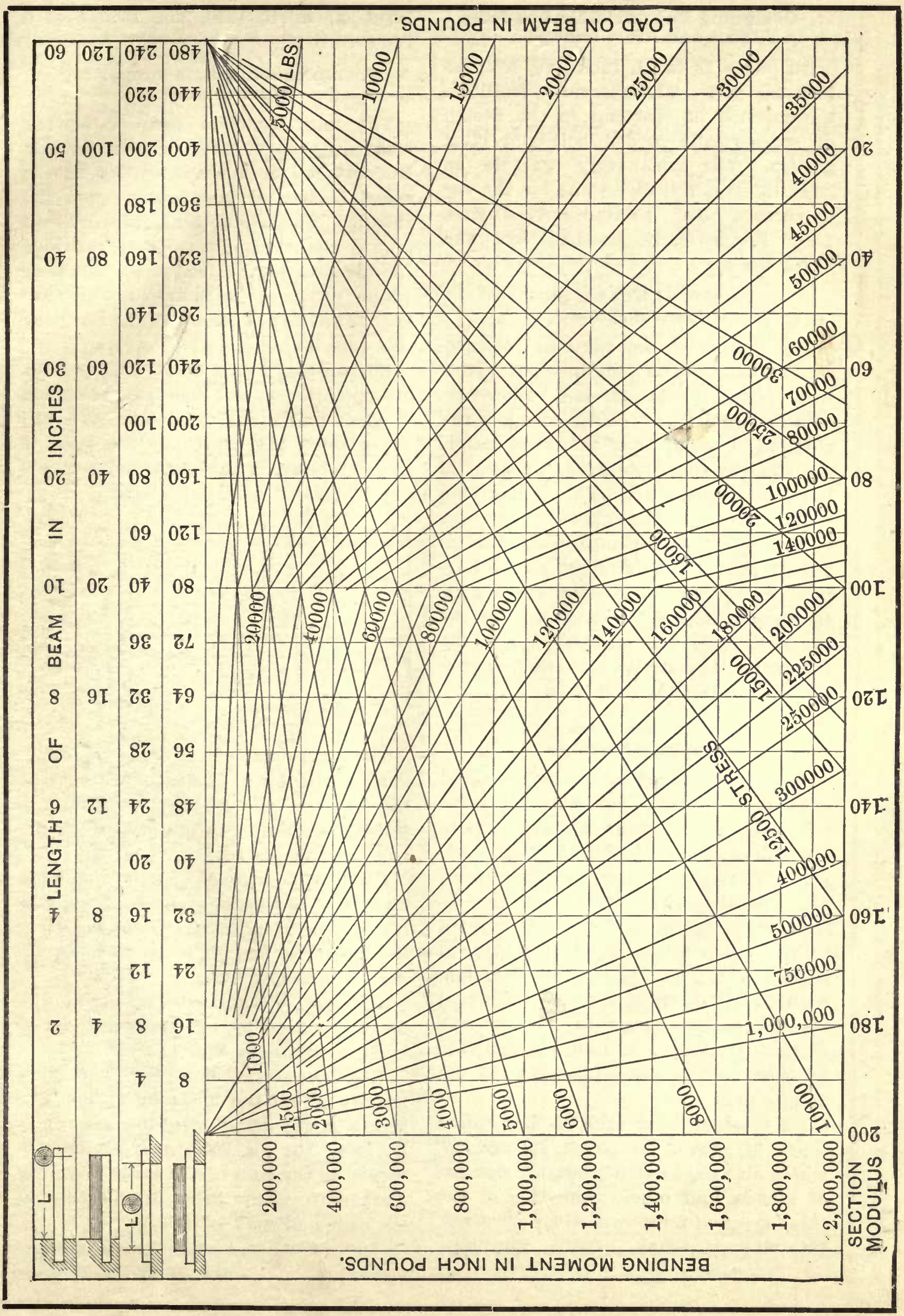
BEAM CHART—II



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Designing Eccentrically Loaded Bolt and Rivet Groups

On pages 18 to 21, inclusive, four tables are given which greatly facilitate the solution of problems in the design of eccentrically loaded bolt and rivet groups. The explanatory example on page 18 gives full directions for the use of these tables. [MACHINERY, August, 1910, Eccentrically Loaded Bolt and Rivet Groups.]

Angles of Hopper Side Intersections

The finding of the angle of intersection between the various inclined planes in a rectangular hopper is a rather perplexing problem. In order to make the solution of problems of this kind easier, the diagrams on pages 22, 24 and 25 have been prepared. These diagrams permit the required angle of intersection to be read off at a glance, when the inclinations of the side planes of the hopper are known. The descriptive matter on page 22 and the directions for the use of the diagrams on page 23, give the necessary information for their application to practical problems.

Sections for Crane and Telpher Runways

In the design of crane, telpher and similar runways, suitable provision should be made for the lateral strength. The three types of section most commonly used for the purposes mentioned above consist of: 1. An I-beam for vertical strength with a channel riveted to the compression flange for lateral stiffness. 2. The same construction, with the addition of a smaller channel to the tension flange to increase the vertical strength. 3. Two I-beams side by side, with a cover plate on the top flanges only.

An illustration of each of these three types is shown on pages 26 and 27, where also the section modulus, moment of inertia and other properties of the three types of built-up sections are given. [MACHINERY, May, 1908, Maximum Stresses; April, 1910, The Design of a Plate Girder.]

Formulas for Beams Supporting Moving Loads

The most common case of moving loads is that of two wheels equally loaded, such as a crane trolley on the crane bridge, or the bridge upon the runway. There is nothing difficult about finding the maximum moment, provided the location of the load upon the span which produces the maximum moment is known. The general rule covering this case is:

For moving loads, when all the loads are upon the span at once, the maximum moment under any particular load will occur when the center of the span is midway between this load and the center of gravity of all the loads.

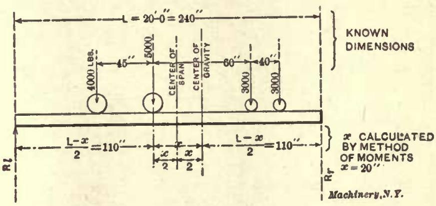

Fig. 1

The load which produces the maximum moment will in nearly all cases be the heaviest one of the two loads adjoining the center of gravity, hence the rule may be stated:

Place the center of gravity of all the loads and the heaviest load adjacent to the center of gravity equidistant from the supports, and find the moment under the heaviest load.

Example.—What is the maximum moment produced by the system of wheel loading shown in Fig. 1?

Solution.—First find the center of gravity of all the loads by taking moments about some point of reference. Dividing the algebraic sum of the moments by the sum of the loads gives the distance from the point of reference to the center of gravity, thus:

(Continued on page 46.)

AREAS OF SMALL RECTANGLES—I

The fraction giving the altitude of the rectangle is found at top of the columns, the base in the left-hand column, and the area in the body of the table.

	1/32	1/16	3/32	1/8	5/32	3/16	7/32	1/4
1/32	0.000977							
1/16	.001953	0.003906						
3/32	.002930	.005859	0.008789					
1/8	.003906	.007812	.011719	0.015625				
5/32	.004883	.009766	.014648	.019531	0.024414			
3/16	.005859	.011719	.017578	.023437	.029297	0.035156		
7/32	.006836	.013672	.020508	.027344	.034180	.041016	0.047852	
1/4	.007812	.015625	.023437	.03125	.039062	.046875	.054687	0.0625
9/32	.008789	.017578	.026367	.035156	.043945	.052734	.061523	.070312
5/16	.009766	.019531	.029297	.039062	.048828	.058594	.068359	.078125
11/32	.010742	.021484	.032227	.042969	.053711	.064453	.075195	.085937
3/8	.011719	.023437	.035156	.046875	.058594	.070312	.082031	.09375
13/32	.012695	.025391	.038086	.050781	.063477	.076172	.088867	.101562
7/16	.013672	.027344	.041016	.054687	.068359	.082031	.095703	.109375
15/32	.014648	.029297	.043945	.058594	.073242	.087891	.102539	.117187
1/2	.015625	.03125	.046875	.0625	.078125	.09375	.109375	.125
17/32	.016602	.033203	.049805	.066406	.083008	.099609	.116211	.132812
9/16	.017578	.035156	.052734	.070312	.087891	.105469	.123047	.140625
19/32	.018555	.037109	.055664	.074219	.092773	.111328	.129883	.148437
5/8	.019531	.039062	.058594	.078125	.097656	.117187	.136719	.15625
21/32	.020508	.041016	.061523	.082031	.102539	.123047	.143555	.164062
11/16	.021484	.042969	.064453	.085937	.107422	.128906	.150390	.171875
23/32	.022461	.044922	.067383	.089844	.112305	.134766	.157227	.179687
3/4	.023437	.046875	.070312	.09375	.117187	.140625	.164062	.1875
25/32	.024414	.048828	.073242	.097656	.122070	.146484	.170898	.195312
13/16	.025391	.050781	.076172	.101562	.126953	.152344	.177734	.203125
27/32	.026367	.052734	.079102	.105469	.131836	.158203	.184570	.210937
7/8	.027344	.054687	.082031	.109375	.136719	.164062	.191406	.21875
29/32	.028320	.056641	.084961	.113281	.141602	.169922	.198242	.226562
15/16	.029297	.058594	.087891	.117187	.146484	.175781	.205078	.234375
31/32	.030273	.060547	.090820	.121094	.151367	.181641	.211914	.242187
1"	.03125	.0625	.09375	.125	.15625	18.75	.21875	.25

The areas of intermediate rectangles varying by $\frac{1}{64}$ can be found by interpolation as the following examples show:

One side given in 64 ths.

$$\frac{3}{32} \times \frac{5}{64} = (\text{next smaller area} + \text{next larger area}) \div 2$$

$$\text{next smaller area} = \frac{3}{32} \times \frac{1}{16} = 0.005859$$

$$+ \text{ next larger area} = \frac{3}{32} \times \frac{3}{32} = 0.008789$$

$$\frac{0.014648}{2} = 0.007324$$

(Continued on Sheet No. 2.)

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AREAS OF SMALL RECTANGLES—II

	9/32	5/16	11/32	3/8	13/32	7/16	15/32	1/2
9/32	0.079102							
5/16	.087891	0.097656						
11/32	.096680	.107422	0.118164					
3/8	.105469	.117187	.128906	0.140625				
13/32	.114258	.126953	.139648	.152344	0.165039			
7/16	.123047	.136719	.150391	.164062	.177734	0.191406		
15/32	.131836	.146484	.161133	.175781	.190430	.205078	0.219727	
1/2	.140625	.15625	.171875	.1875	.203125	.21875	.234375	0.25
17/32	.149414	.166016	.182617	.199219	.215820	.232422	.249023	.265625
9/16	.158203	.175781	.193359	.210937	.228516	.246094	.263672	.28125
19/32	.166992	.185547	.204102	.222656	.241211	.259766	.278320	.296875
5/8	.175781	.195312	.214844	.234375	.253906	.273437	.292969	.3125
21/32	.184570	.205078	.225586	.246094	.266602	.287109	.307617	.328125
11/16	.193359	.214844	.236328	.257812	.279297	.300781	.322266	.34375
23/32	.202148	.224609	.247070	.269531	.291992	.314453	.336914	.359375
3/4	.210937	.234375	.257812	.28125	.304687	.328125	.351562	.375
25/32	.219727	.244141	.268555	.292969	.317383	.341797	.366211	.390625
13/16	.228516	.253906	.279297	.304687	.330078	.355469	.380859	.40625
27/32	.237305	.263672	.290039	.316406	.342773	.369141	.395508	.421875
7/8	.246094	.273437	.300781	.328125	.355469	.382812	.410156	.4375
29/32	.254883	.283203	.311523	.339844	.368164	.396484	.424805	.453125
15/16	.263672	.292969	.322266	.351562	.380859	.410156	.439453	.46875
31/32	.272461	.302734	.333008	.363281	.393555	.423828	.454102	.484375
1"	.28125	.3125	.34375	.375	.40625	.4375	.46875	.5

Interpolation (continued)

$$\text{Example: } \frac{3}{64} \times \frac{7}{64} = \frac{\text{next smaller area} + \text{next larger area}}{2} - \left(\frac{1}{64}\right)^2$$

Both sides given in 64ths.

$$\text{next smaller area} = \frac{1}{32} \times \frac{3}{32} = 0.002930$$

$$\text{next larger area} = \frac{1}{16} \times \frac{1}{8} = 0.007812$$

$$0.010742 \div 2 = 0.005371$$

$$\text{deduct } \left(\frac{1}{64}\right)^2 = 0.000244$$

$$0.005127$$

AREAS OF SMALL RECTANGLES—III

	17/32	9/16	19/32	5/8	21/32	11/16	23/32	3/4
17/32	0.282227							
9/16	.298828	0.316406						
19/32	.315430	.333984	0.352539					
5/8	.332031	.351562	.371094	0.390625				
21/32	.348633	.369141	.389648	.410156	0.430664			
11/16	.365234	.386719	.408203	.429687	.451172	0.472656		
23/32	.381836	.404297	.426758	.449219	.471680	.494141	0.516601	
3/4	.398437	.421875	.445312	.46875	.492187	.515625	.539062	0.5625
25/32	.415039	.439453	.463867	.488281	.512695	.537110	.561523	.585937
13/16	.431641	.457031	.482422	.507812	.533203	.558594	.583984	.609375
27/32	.448242	.474609	.500976	.527344	.553711	.580078	.606445	.632812
7/8	.464844	.492187	.519531	.546875	.574219	.601562	.628906	.65625
29/32	.481445	.509766	.538086	.566406	.594727	.623047	.651367	.679687
15/16	.498047	.527344	.556641	.585937	.615234	.644531	.673828	.703125
31/32	.514648	.544922	.575195	.605469	.635742	.666016	.696289	.726562
1	.53125	.5625	.59375	.625	.65625	.6875	.71875	.75

	25/32	13/16	27/32	7/8	29/32	15/16	31/32	1
25/32	0.610352							
13/16	.634766	0.660156						
27/32	.659180	.685547	0.711914					
7/8	.683594	.710937	.738281	0.765625				
29/32	.708008	.736328	.764648	.792969	0.821289			
15/16	.732422	.761719	.791016	.820312	.849609	0.878906		
31/32	.756836	.787109	.817383	.847656	.877930	.908203	0.938477	
1	.78125	.8125	.84375	.875	.90625	.9375	.96875	1.00000

Areas of rectangles larger than given in table:

Example: $\overset{a}{1}\overset{b}{\frac{11}{16}} \times \overset{c}{2}\overset{d}{\frac{3}{32}} = a \times c + b \times c + a \times d + b \times d$

$$a \times c = 1 \times 2 = 2.000000$$
$$b \times c = \frac{11}{16} \times 2 = 1.375000$$
$$a \times d = 1 \times \frac{3}{32} = 0.093750$$
$$b \times d = \frac{11}{16} \times \frac{3}{32} = \underline{0.064453}$$
$$\underline{3.533203}$$

NET AREAS OF STRUCTURAL ANGLES—I

Sum of Length of Legs	Thickness	Weight	Area	Area after Deducting for				
				One 5/8 Rivet	3/4 Rivets		7/8 Rivets	
					One	Two	One	Two
4"	3/16	2.5	0.72	0.58	—	—	—	—
	1/4	3.2	0.94	0.75	—	—	—	—
	5/16	4.0	1.15	0.92	—	—	—	—
	3/8	4.7	1.36	1.08	—	—	—	—
	7/16	5.3	1.56	1.23	—	—	—	—
4 1/2"	3/16	2.8	0.81	0.67	0.65	—	—	—
	1/4	3.7	1.06	0.87	0.84	0.62	0.81	0.56
	5/16	4.5	1.31	1.08	1.04	0.77	1.00	0.69
	3/8	5.3	1.55	1.27	1.22	0.89	1.17	0.79
	7/16	6.1	1.78	1.45	1.40	1.02	1.34	0.90
	1/2	6.8	2.00	1.62	1.56	1.12	1.50	1.00
5"	3/16	3.1	0.90	0.76	0.74	—	—	—
	1/4	4.1	1.19	1.00	0.97	0.75	0.94	0.69
	5/16	5.0	1.47	1.24	1.20	0.93	1.16	0.85
	3/8	5.9	1.73	1.45	1.40	1.07	1.35	0.97
	7/16	6.8	2.00	1.67	1.62	1.24	1.56	1.12
	1/2	7.7	2.25	1.87	1.81	1.37	1.75	1.25
5 1/2"	1/4	4.5	1.31	1.12	1.09	0.87	1.06	0.81
	5/16	5.5	1.62	1.39	1.35	1.08	1.31	1.00
	3/8	6.6	1.92	1.64	1.59	1.26	1.54	1.16
	7/16	7.6	2.22	1.89	1.84	1.46	1.78	1.34
	1/2	8.5	2.50	2.12	2.06	1.62	2.00	1.50
	9/16	9.5	2.78	2.36	2.29	1.80	2.22	1.66
6"	1/4	4.9	1.44	1.25	1.22	1.00	1.19	0.94
	5/16	6.1	1.78	1.55	1.51	1.24	1.47	1.16
	3/8	7.2	2.11	1.83	1.78	1.45	1.73	1.35
	7/16	8.3	2.43	2.10	2.05	1.67	1.99	1.55
	1/2	9.4	2.75	2.37	2.31	1.87	2.25	1.75
	9/16	10.4	3.06	2.64	2.57	2.08	2.50	1.94
	5/8	11.4	3.36	2.89	2.81	2.26	2.73	2.10
	11/16	12.4	3.65	3.13	3.03	2.43	2.96	2.27
6 1/2"	5/16	6.6	1.93	1.70	1.66	1.39	1.62	1.31
	3/8	7.8	2.30	2.02	1.97	1.64	1.92	1.54
	7/16	9.1	2.65	2.32	2.27	1.89	2.21	1.77
	1/2	10.2	3.00	2.63	2.56	2.12	2.50	2.00
	9/16	11.4	3.34	2.92	2.85	2.36	2.78	2.22
	5/8	12.5	3.67	3.20	3.12	2.57	3.04	2.41
	11/16	13.6	4.00	3.48	3.40	2.80	3.31	2.62
	3/4	14.7	4.31	3.75	3.65	2.99	3.56	2.81
	13/16	15.7	4.62	4.01	3.91	3.20	3.81	3.00

Note: The size of rivet holes is 1/8" larger than diameter of rivet.

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NET AREAS OF STRUCTURAL ANGLES—II

Sum of Length of Legs	Thickness	Weight	Area	Area after Deducting for ¾ Rivets		⅞ Rivets	
				One	Two	One	Two
7″	5/16	7.1	2.09	1.82	1.55	1.78	1.47
	3/8	8.5	2.48	2.15	1.82	2.10	1.72
	7/16	9.8	2.87	2.49	2.11	2.43	1.99
	1/2	11.1	3.25	2.81	2.37	2.75	2.25
	9/16	12.3	3.62	3.13	2.64	3.06	2.50
	5/8	13.6	3.98	3.43	2.88	3.35	2.72
	11/16	14.8	4.34	3.74	3.14	3.65	2.96
	3/4	16.0	4.69	4.03	3.37	3.94	3.19
	13/16	17.1	5.03	4.32	3.61	4.22	3.41
7½″	5/16	7.7	2.25	1.98	1.71	1.94	1.63
	3/8	9.1	2.67	2.34	2.01	2.29	1.91
	7/16	10.5	3.09	2.71	2.33	2.65	2.21
	1/2	11.9	3.50	3.06	2.62	3.00	2.50
	9/16	13.3	3.90	3.41	2.92	3.34	2.78
	5/8	14.6	4.30	3.75	3.20	3.67	3.04
	11/16	15.9	4.68	4.08	3.48	3.99	3.30
	3/4	17.2	5.06	4.40	3.74	4.31	3.56
	13/16	18.5	5.43	4.72	4.01	4.62	3.81
8″	5/16	8.2	2.40	2.13	1.86	2.09	1.78
	3/8	9.8	2.86	2.53	2.20	2.48	2.10
	7/16	11.3	3.31	2.93	2.55	2.87	2.43
	1/2	12.8	3.75	3.31	2.87	3.25	2.75
	9/16	14.2	4.18	3.69	3.20	3.62	3.06
	5/8	15.7	4.61	4.06	3.51	3.98	3.35
	11/16	17.1	5.03	4.43	3.83	4.34	3.65
	3/4	18.5	5.44	4.78	4.12	4.69	3.84
	13/16	19.9	5.84	5.13	4.41	5.03	4.22
8½″	5/16	8.7	2.56	2.29	2.02	2.25	1.94
	3/8	10.4	3.05	2.72	2.39	2.67	2.29
	7/16	12.0	3.53	3.15	2.77	3.09	2.65
	1/2	13.6	4.00	3.56	3.12	3.50	3.00
	9/16	15.2	4.47	3.98	3.49	3.91	3.35
	5/8	16.8	4.92	4.37	3.82	4.29	3.66
	11/16	18.3	5.37	4.77	4.17	4.68	3.99
	3/4	19.8	5.81	5.15	4.49	5.06	4.31
	13/16	21.3	6.25	5.54	4.83	5.44	4.63
	7/8	22.7	6.67	5.90	5.14	5.79	4.91

Note: The size of rivet holes is ⅛″ larger than diameter of rivet.

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NET AREAS OF STRUCTURAL ANGLES—III

Sum of Length of Leg	Thickness	Weight	Area	Area after Deducting for			
				3/4 Rivets		7/8 Rivets	
				One	Two	One	Two
9"	3/8	11.0	3.23	2.90	2.57	2.85	2.47
	7/16	12.8	3.75	3.35	2.99	3.31	2.87
	1/2	14.5	4.25	3.80	3.39	3.75	3.25
	9/16	16.2	4.75	4.26	3.77	4.19	3.63
	5/8	17.8	5.23	4.68	4.14	4.60	3.97
	11/16	19.5	5.72	5.12	4.52	5.03	4.34
	3/4	21.1	6.19	5.53	4.88	5.44	4.69
	13/16	22.7	6.65	5.94	5.23	5.84	5.03
	7/8	24.2	7.11	6.34	5.58	6.23	5.35
9 1/2"	3/8	11.7	3.42	3.09	2.76	3.04	2.66
	7/16	13.6	3.97	3.59	3.21	3.53	3.09
	1/2	15.3	4.50	4.06	3.62	4.00	3.50
	9/16	17.1	5.03	4.54	4.05	4.47	3.91
	5/8	18.9	5.55	5.00	4.45	4.92	4.29
	11/16	20.6	6.06	5.46	4.86	5.37	4.68
	3/4	22.3	6.56	5.90	5.24	5.81	5.06
	13/16	24.0	7.06	6.35	5.64	6.25	5.44
	7/8	25.7	7.55	6.78	6.02	6.67	5.79
	15/16	27.3	8.03	7.21	6.39	7.09	6.15
	1	28.9	8.50	7.63	6.75	7.50	6.50
10"	3/8	12.3	3.61	3.28	2.95	3.23	2.85
	7/16	14.3	4.18	3.80	3.42	3.74	3.30
	1/2	16.2	4.75	4.31	3.87	4.25	3.75
	9/16	18.1	5.31	4.82	4.33	4.75	4.19
	5/8	20.0	5.86	5.31	4.76	5.23	4.60
	11/16	21.8	6.41	5.81	5.21	5.72	5.03
	3/4	23.6	6.94	6.28	5.63	6.19	5.44
	13/16	25.4	7.47	6.76	6.05	6.66	5.85
	7/8	27.2	7.99	7.22	6.46	7.11	6.23
	15/16	28.9	8.50	7.68	6.86	7.56	6.62
	1	30.6	9.00	8.13	7.25	8.00	7.00
10 1/2"	7/16	15.0	4.40	4.02	3.64	3.96	3.53
	1/2	17.0	5.00	4.55	4.13	4.50	4.00
	9/16	19.1	5.59	5.10	4.61	5.03	4.47
	5/8	21.0	6.17	5.62	5.08	5.54	4.92
	11/16	23.0	6.75	6.15	5.55	6.06	5.37
	3/4	24.9	7.31	6.65	6.00	6.56	5.81
	13/16	26.8	7.87	7.16	6.45	7.06	6.25
	7/8	28.7	8.42	7.65	6.89	7.54	6.67
	15/16	30.5	8.97	8.15	7.33	8.03	7.10
	1	32.3	9.50	8.63	7.75	8.50	7.50

Note: The size of rivet holes is 1/8" larger than diameter of rivet.

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NET AREAS OF STRUCTURAL ANGLES—IV

Sum of Length of Legs	Thickness	Weight	Area	Area after Deducting for			
				3/4 Rivets		7/8 Rivets	
				One	Two	One	Two
12"	3/8	14.9	4.36	4.03	3.70	3.98	3.60
	7/16	17.2	5.06	4.68	4.30	4.62	4.18
	1/2	19.6	5.75	5.31	4.87	5.25	4.75
	9/16	21.9	6.43	5.94	5.45	5.87	5.31
	5/8	24.2	7.11	6.56	6.01	6.48	5.85
	11/16	26.5	7.78	7.18	6.58	7.09	6.40
	3/4	28.7	8.44	7.78	7.12	7.69	6.94
	13/16	31.0	9.09	8.38	7.67	8.28	7.47
	7/8	33.1	9.74	8.97	8.21	8.86	7.98
	15/16	35.3	10.37	9.55	8.73	9.43	8.49
	1	37.4	11.00	10.13	9.25	10.00	9.00
14"	1/2	23.0	6.76	6.31	5.89	6.26	5.76
	9/16	26.0	7.65	7.16	6.67	7.09	6.53
	5/8	28.7	8.44	7.89	7.35	7.82	7.19
	11/16	31.7	9.32	8.72	8.12	8.63	7.94
	3/4	33.8	9.94	9.28	8.63	9.19	8.44
	13/16	36.6	10.76	10.05	9.34	9.95	9.14
	7/8	39.5	11.62	10.85	10.09	10.74	9.87
	15/16	42.0	12.35	11.53	10.71	11.41	10.48
	1	44.4	13.06	12.19	11.31	12.06	11.06
16"	1/2	26.4	7.75	7.30	6.88	7.25	6.75
	9/16	29.6	8.69	8.20	7.71	8.13	7.57
	5/8	32.7	9.61	9.06	8.52	8.99	8.36
	11/16	35.8	10.53	9.93	9.33	9.84	9.15
	3/4	38.9	11.44	10.78	10.13	10.69	9.94
	13/16	42.0	12.34	11.63	10.93	11.52	10.72
	7/8	45.0	13.23	12.47	11.71	12.35	11.48
	15/16	48.1	14.12	13.31	12.49	13.18	12.24
	1	51.0	15.00	14.13	13.25	14.00	13.00
	1 1/16	54.0	15.87	14.95	14.01	14.81	13.75
	1 1/8	56.9	16.74	15.76	14.77	15.62	14.49

Area Deducted for Various Sizes of Rivets and Thickness of Angles.

No. of Rivets	Size of Rivets	Thickness															
		3/16	1/4	5/16	3/8	7/16	1/2	9/16	5/8	11/16	3/4	13/16	7/8	15/16	1	1 1/16	1 1/8
1	3/8	0.09	0.13	0.16	0.19	0.22	0.25	0.28	0.31	0.34	0.38	0.41	0.44	0.47	0.50	—	—
1	1/2	0.12	0.16	0.20	0.23	0.27	0.31	0.35	0.39	0.43	0.47	0.51	0.55	0.58	0.63	—	—
1	5/8	0.14	0.19	0.23	0.28	0.33	0.38	0.42	0.47	0.52	0.56	0.61	0.66	0.70	0.75	0.80	0.84
2	5/8	0.28	0.38	0.46	0.56	0.66	0.75	0.84	0.94	1.03	1.12	1.22	1.31	1.40	1.50	1.60	1.68
1	3/4	0.16	0.22	0.27	0.33	0.38	0.44	0.49	0.55	0.60	0.66	0.71	0.77	0.82	0.88	0.93	0.98
2	3/4	0.33	0.44	0.54	0.66	0.76	0.87	0.98	1.09	1.20	1.31	1.42	1.53	1.64	1.75	1.86	1.97
1	7/8	0.19	0.25	0.31	0.38	0.44	0.50	0.56	0.63	0.69	0.75	0.81	0.88	0.94	1.00	1.06	1.12
2	7/8	0.37	0.50	0.62	0.75	0.87	1.00	1.12	1.25	1.38	1.50	1.62	1.75	1.87	2.00	2.12	2.25
1	1	0.21	0.28	0.35	0.42	0.49	0.56	0.63	0.70	0.77	0.84	0.91	0.98	1.06	1.13	1.20	1.26

Note: The size of rivet holes is 1/8" larger than diameter of rivet.

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LOADS FOR ECCENTRICALLY LOADED RIVET GROUPS—I

Directions for Using Tables.

The following tables facilitate the finding of the number of rivets to support eccentric loads.

All the tables are calculated for a vertical spacing of rivets of three inches; size of rivets, 3/4-inch; and maximum stress per square inch, 10,000 pounds.

To use the tables, decide on the number of vertical rows of rivets, and the distance between the outside rows, if more than one row is used. Then, in the table for the number of rows adopted, find the number of rivets required for the given load.

Example:- Find number of rivets required for supporting a load of 5000 pounds applied 18 inches from the center of the rivet group. Three vertical rows of rivets will be used; distance between outside rows, 6 inches. (See illustration below).

In Table III, giving the number of rivets for three vertical rows, find the distance (18 inches) between the load and center of rivet group; then in the section headed "18 inches" and in the column headed "6 inches" (horizontal distance between the outside rivet rows), find the figure nearest to the given load. This figure is 5.6, which, being in thousands of pounds, is equivalent to a load of 5600 pounds. Now follow the horizontal line from 5.6 to the left where the number of rivets for the given case is found to be 9.

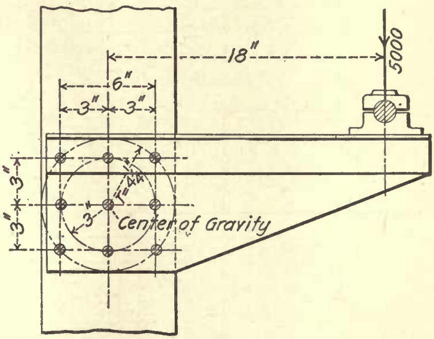

Table of Number of Rivets for Eccentric Loads
One Vertical Row of Rivets.

Body of Table Gives Total Load in Thousands of Pounds
Vertical Spacing of Rivets, 3"- Size of Rivets, 3/4".

Number of Rivets	Horizontal Distance between Load and Center of Rivet Group									
	0"	1½"	3"	6"	9"	12"	15"	18"	21"	24"
1	4.4	—	—	—	—	—	—	—	—	—
2	8.8	6.2	3.9	2.1	1.4	1.1	0.9	0.7	0.6	0.5
3	13	10	7.3	4.1	2.8	2.1	1.7	1.4	1.2	1.1
4	17	15	11	6.7	4.7	3.6	2.9	2.4	2.1	1.8
5	22	19	15	9.8	6.9	5.3	4.3	3.6	3.1	2.7
6	26	24	20	13	9.5	7.4	6.0	5.0	4.3	3.8
7	30	28	24	17	12	9.8	7.9	6.7	5.8	5.1
8	35	33	29	21	15	12	10	8.5	7.4	6.4
9	39	37	33	25	19	15	12	10	9.2	8.1
10	44	42	38	29	22	18	15	12	11	9.8
11	48	46	43	34	26	21	18	15	13	11
12	52	51	47	38	30	25	20	18	15	13

LOADS FOR ECCENTRICALLY LOADED RIVET GROUPS—II

Two Vertical Rows of Rivets.

Body of Table Gives Total Load in Thousands of Pounds
Vertical Spacing of Rivets, 3" – Size of Rivets, 3/4".

Horizontal Distance between Load and Center of Rivet Group / Horizontal Distance between Rivet Rows

Number of Rivets	0"	1½"					3"					6"				
	Any	3	6	9	12	15	3	6	9	12	15	3	6	9	12	15
2	8.8	4.4	5.8	6.6	7.1	7.3	2.9	4.4	5.2	5.8	6.3	1.7	2.9	3.7	4.4	4.9
4	17	11	12	13	14	14	7.9	9.5	10	11	12	4.9	6.5	7.5	9.1	9.9
6	26	19	19	20	21	22	13	15	16	18	19	8.6	10	12	14	15
8	35	27	27	28	29	29	20	22	23	24	25	13	15	17	19	20
10	44	37	36	36	37	37	29	29	30	31	32	19	20	22	24	26
12	52	46	44	44	44	45	38	37	38	39	40	25	26	28	30	32
14	61	55	53	53	54	54	46	45	46	46	47	31	33	34	36	38
16	70	64	61	61	62	62	56	54	54	55	56	39	40	41	42	44
18	79	73	71	71	71	71	65	63	63	63	63	48	48	49	50	51
20	88	82	80	80	80	80	74	72	72	72	72	57	56	56	57	59
22	96	92	88	88	88	88	83	80	80	80	81	65	64	64	65	66
24	105	101	97	97	97	97	93	89	89	89	89	75	73	73	73	74

Horizontal Distance between Load and Center of Rivet Group / Horizontal Distance between Rivet Rows

Number of Rivets	9"					12"					15"				
	3	6	9	12	15	3	6	9	12	15	3	6	9	12	15
2	1.2	2.2	2.9	3.5	4.0	1.0	1.7	2.4	2.9	3.4	0.8	1.4	2.0	2.5	2.9
4	3.5	4.8	6.1	7.2	8.1	2.7	3.9	5.0	6.0	6.9	2.2	3.2	4.3	5.2	5.9
6	6.2	8.0	9.5	10	12	4.8	6.3	7.9	9.2	10	3.9	5.3	6.6	7.9	9.1
8	9.6	11	13	15	16	7.4	9.1	10	12	14	6.0	7.6	9.2	10	12
10	14	15	17	19	21	11	12	14	16	18	9.0	10	12	14	16
12	19	20	22	24	26	15	16	18	20	22	12	13	15	17	19
14	24	25	27	29	31	19	20	22	24	26	15	17	18	20	23
16	30	31	32	35	37	24	25	27	29	31	20	21	23	25	27
18	37	37	39	41	43	30	30	32	34	36	24	25	27	29	31
20	44	44	45	47	49	36	36	37	39	42	29	30	31	33	36
22	52	51	52	53	55	42	42	43	45	47	35	35	37	39	41
24	60	59	59	60	62	49	49	50	51	53	41	41	42	44	46

Horizontal Distance between Load and Center of Rivet Group / Horizontal Distance between Rivet Rows

Number of Rivets	18"					21"					24"				
	3	6	9	12	15	3	6	9	12	15	3	6	9	12	15
2	0.7	1.2	1.7	2.2	2.6	0.6	1.1	1.5	1.9	2.3	0.5	1.0	1.4	1.7	2.1
4	1.9	2.8	3.7	4.5	5.3	1.6	2.4	3.3	4.0	4.7	1.4	2.1	2.9	3.6	4.2
6	3.3	4.5	5.7	6.9	8.1	2.9	3.9	5.0	6.2	7.2	2.5	3.5	4.5	5.6	6.5
8	5.1	6.5	8.0	9.4	10	4.4	5.6	7.0	8.3	9.7	3.9	5.0	6.3	7.5	8.8
10	7.6	8.8	10	12	14	6.6	7.6	9.1	10	12	5.8	6.8	8.1	9.7	11
12	10	11	13	15	17	9.1	10	11	13	15	8.0	8.9	10	11	13
14	13	14	16	18	20	11	12	14	16	18	10	11	12	14	16
16	17	18	19	21	23	14	15	17	19	21	13	13	15	17	19
18	21	21	23	25	27	18	18	20	22	24	16	16	18	20	22
20	25	26	27	29	31	22	23	24	26	28	20	20	21	23	25
22	30	30	32	34	36	26	26	28	30	32	23	23	25	27	29
24	35	35	36	38	40	31	31	32	34	36	27	27	28	30	33

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LOADS FOR ECCENTRICALLY LOADED RIVET GROUPS—III

Three Vertical Rows of Rivets.

Body of Table Gives Total Load in Thousands of Pounds
Vertical Spacing of Rivets, 3"—Size of Rivets, $\frac{3}{4}$".

Number of Rivets	Horizontal Distance between Load and Center of Rivet Group												
	0"	1½"				3"				6"			
	Horizontal Distance between Outside Rivet Rows												
	Any	6	8	10	12	6	8	10	12	6	8	10	12
3	13	7.5	8.4	9.1	9.6	5.7	6.2	6.9	7.5	3.3	4.0	4.7	5.3
6	26	16	17	18	19	12	13	14	15	7.8	9.0	10	11
9	39	28	28	29	30	20	21	23	24	13	14	16	17
12	52	39	40	40	41	30	31	32	33	20	21	23	24
15	66	52	52	53	53	41	42	43	44	28	29	30	32
18	79	66	66	66	66	53	53	54	55	37	38	39	40
21	97	79	79	79	79	66	66	67	67	47	48	49	50
24	105	92	92	92	92	79	79	79	79	58	58	59	60
27	118	106	106	106	106	92	92	92	92	69	69	70	71
30	132	119	119	119	119	106	106	106	106	82	82	82	83
33	145	132	132	132	132	119	119	119	119	94	94	94	95
36	158	146	146	146	146	133	133	133	133	107	107	107	107

Number of Rivets	Horizontal Distance between Load and Center of Rivet Group											
	9"				12"				15"			
	Horizontal Distance between Outside Rivet Rows											
	6	8	10	12	6	8	10	12	6	8	10	12
3	2.4	3.1	3.5	4.0	1.9	2.4	2.8	3.3	1.5	2.0	2.4	2.8
6	5.8	6.7	7.6	8.5	4.5	5.4	6.1	6.9	3.7	4.5	5.1	5.4
9	10	11	12	13	7.9	8.9	9.9	11	6.6	7.4	8.0	9.4
12	15	16	17	19	12	13	14	15	10	11	12	13
15	21	22	23	25	16	17	19	20	14	15	16	17
18	28	29	30	32	22	23	24	26	18	19	20	22
21	36	37	38	39	29	30	31	32	24	25	26	27
24	45	45	46	47	36	37	38	39	30	31	32	33
27	55	55	56	56	44	44	45	46	36	37	38	39
30	65	65	65	66	53	53	54	55	44	45	46	47
33	76	76	76	77	62	62	63	64	52	52	53	54
36	87	87	87	87	72	72	72	73	60	61	62	62

Number of Rivets	Horizontal Distance between Load and Center of Rivet Group											
	18"				21"				24"			
	Horizontal Distance between Outside Rivet Rows											
	6	8	10	12	6	8	10	12	6	8	10	12
3	1.3	1.7	2.0	2.4	1.1	1.5	1.8	2.1	1.0	1.3	1.6	1.9
6	3.2	3.8	4.4	5.0	2.8	3.3	3.9	4.4	2.5	3.0	3.4	3.9
9	5.6	6.3	7.2	7.9	4.9	5.5	6.3	7.0	4.3	4.9	5.6	6.2
12	8.4	9.3	10	11	7.2	8.1	9.0	10	6.5	7.2	8.0	8.9
15	11	12	13	14	10	11	12	13	9.1	9.9	10	11
18	16	17	18	19	14	14	15	16	12	13	14	15
21	20	21	22	23	17	18	19	20	15	16	17	18
24	25	26	27	28	22	23	24	25	19	20	21	22
27	31	32	33	34	27	28	29	30	24	25	26	27
30	38	38	39	40	33	34	35	36	29	30	31	32
33	45	45	46	47	39	39	40	41	35	35	36	37
36	52	53	54	54	46	46	47	48	40	41	42	42

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LOADS FOR ECCENTRICALLY LOADED RIVET GROUPS—IV

Four Vertical Rows of Rivets.

Body of Table Gives Total Load in Thousands of Pounds
Vertical Spacing of Rivets, 3″—Size of Rivets, ¾″.

Number of Rivets	Horizontal Distance between Load and Center of Rivet Group												
	0″	1½″				3″				6″			
	Horizontal Distance between Outside Rivet Rows												
	Any	9	12	15	18	9	12	15	18	9	12	15	18
4	17	11	1.2	13	13	8.0	9.2	10	11	5.2	6.3	7.2	8.0
8	35	23	25	26	27	17	19	21	22	11	13	15	16
12	52	37	35	40	43	28	30	32	34	18	21	23	25
16	70	52	54	55	56	41	43	45	46	28	30	32	34
20	88	69	70	71	72	55	57	58	60	38	40	42	45
24	105	86	86	87	88	71	72	73	74	50	52	54	56
28	123	104	104	104	105	87	87	88	89	63	65	66	68
32	140	122	122	122	122	104	104	105	105	77	78	79	80
36	158	139	139	139	139	122	122	122	122	92	93	94	95
40	176	157	157	157	157	139	139	139	139	108	108	109	110
44	193	175	175	175	175	156	156	156	156	124	124	124	125
48	211	193	193	193	193	174	174	174	174	140	140	140	141

Number of Rivets	Horizontal Distance between Load and Center of Rivet Group											
	9″				12″				15″			
	Horizontal Distance between Outside Rivet Rows											
	9	12	15	18	9	12	15	18	9	12	15	18
4	3.8	4.7	5.5	6.3	3.0	3.8	4.5	5.2	2.5	3.2	3.8	4.4
8	8.5	10	11	12	6.7	8.2	9.4	10	5.6	6.9	8.0	9.0
12	14	16	18	20	11	13	14	16	9.4	11	12	14
16	21	23	25	27	17	19	21	23	14	15	17	19
20	29	31	33	35	23	25	27	29	19	21	23	25
24	38	40	42	44	31	33	35	37	25	27	29	31
28	48	50	52	55	39	41	43	45	32	34	36	39
32	60	62	63	65	48	50	52	54	40	42	44	46
36	70	73	75	77	58	60	62	65	49	51	53	55
40	86	86	87	88	70	71	73	75	59	60	62	64
44	100	100	101	102	82	83	84	86	69	70	71	73
48	114	114	115	116	94	95	96	98	80	81	83	85

Number of Rivets	Horizontal Distance between Load and Center of Rivet Group											
	18″				21″				24″			
	Horizontal Distance between Outside Rivet Rows											
	9	12	15	18	9	12	15	18	9	12	15	18
4	2.1	2.7	3.3	3.8	1.9	2.4	2.9	3.4	1.7	2.1	2.6	3.0
8	4.8	5.9	6.9	7.9	4.2	5.2	6.1	7.0	3.7	4.6	5.4	6.2
12	8.0	9.1	10	12	7.0	8.3	9.6	10	6.2	7.4	8.5	9.7
16	12	13	15	17	10	12	13	15	9.4	10	12	13
20	16	18	20	22	14	16	17	19	13	14	16	17
24	22	24	25	27	19	20	22	24	17	18	20	22
28	28	30	32	34	24	26	28	30	21	23	25	27
32	34	36	38	40	30	32	34	36	27	29	30	32
36	42	44	46	48	37	39	41	43	33	35	36	38
40	51	52	54	56	44	46	48	50	40	41	43	45
44	60	61	62	64	51	53	55	57	48	49	50	52
48	69	71	72	74	61	63	64	66	55	56	57	59

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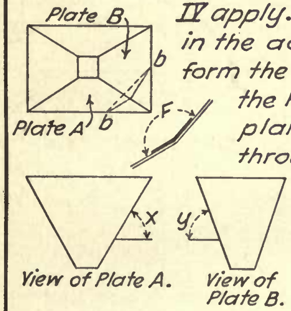
ANGLES OF HOPPER SIDE INTERSECTIONS—I

Usually there may be passed through an ordinary hopper or chute, a plane which will cut out a section having four straight sides and four right angles, and to these cases only do the curves on sheets I, III and IV apply. Let plates A and B in the accompanying sketch form the angles x and y with the horizontal plane. If a plane b-b be passed through perpendicular to their line of intersection, and the angle of flare be called F, then $\cos F = -\cos x \cos y$. The curves were calculated from this formula.



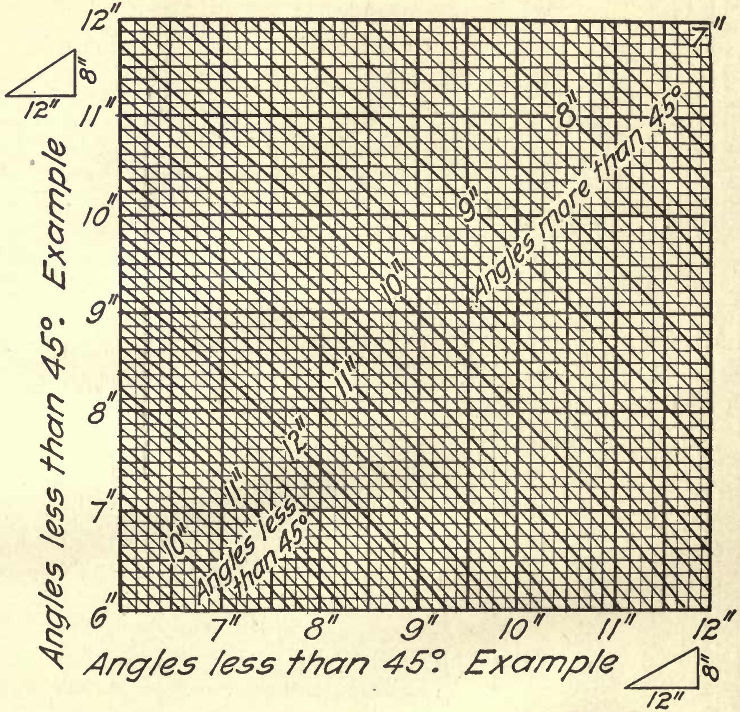
The values of the angle of flare and the angles formed by the hopper sides are expressed in the slope of inches per foot.

The angle of flare is expressed thus

if the angle is more than 45 degrees.

The angle of flare is expressed thus

if the angle is less than 45 degrees.



Three sets of curves are given for the three cases found in actual practise:

1. Two angles, x and y, both more than 45 degrees.
2. Two angles, x and y, both less than 45 degrees.
3. Two angles, x and y, one angle less, and one angle more than 45 degrees.

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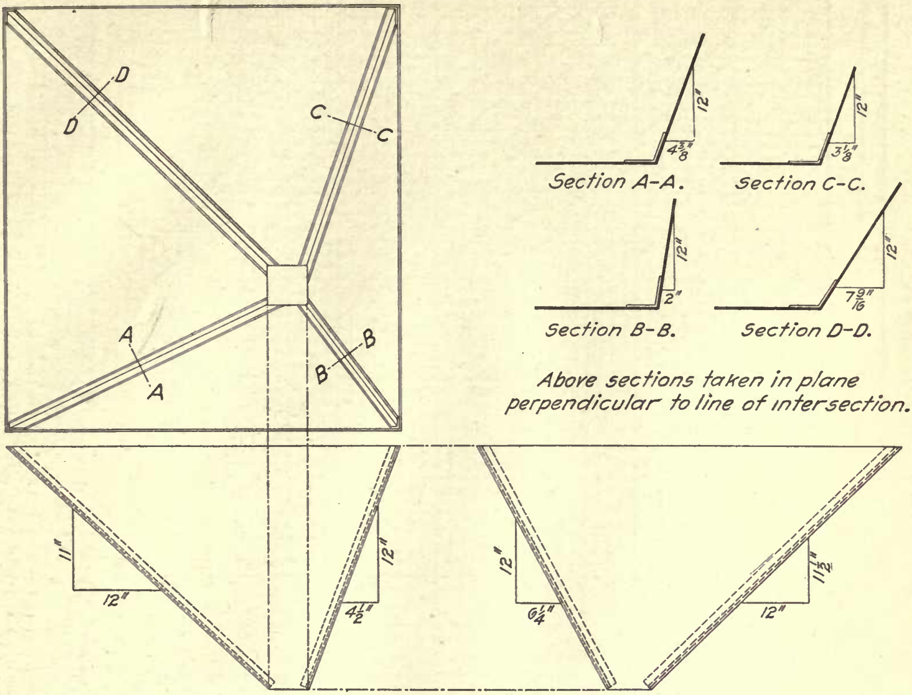
ANGLES OF HOPPER SIDE INTERSECTIONS—II



Directions for the use of the diagrams.

In the accompanying illustration of hopper, let the slopes of the four sides be known, as indicated by the slope in inches per foot. For the intersection angle of the side sloping 11 inches in 12 inches with the side sloping 12 inches in 6 1/4 inches, use diagram for one angle more than 45 degrees and one angle less than 45 degrees. (See upper diagram, sheets III and IV.) At the left of the diagram are values ranging from 6 inches to 12 inches for angles less than 45 degrees. Follow the horizontal line at 11 inches until it meets the vertical line projected up from 6 1/4 inches. The intersection of these two lines gives, on the curves across the diagrams, the nearest value for the intersection angle, which in this case is 4 3/8 inches in 12 inches. (See section A-A of hopper on this sheet.) In a similar manner, use the diagram for two angles both more than 45 degrees (lower diagram sheets III and IV) for section B-B, and for section D-D use diagram for two angles less than 45 degrees, sheet I.

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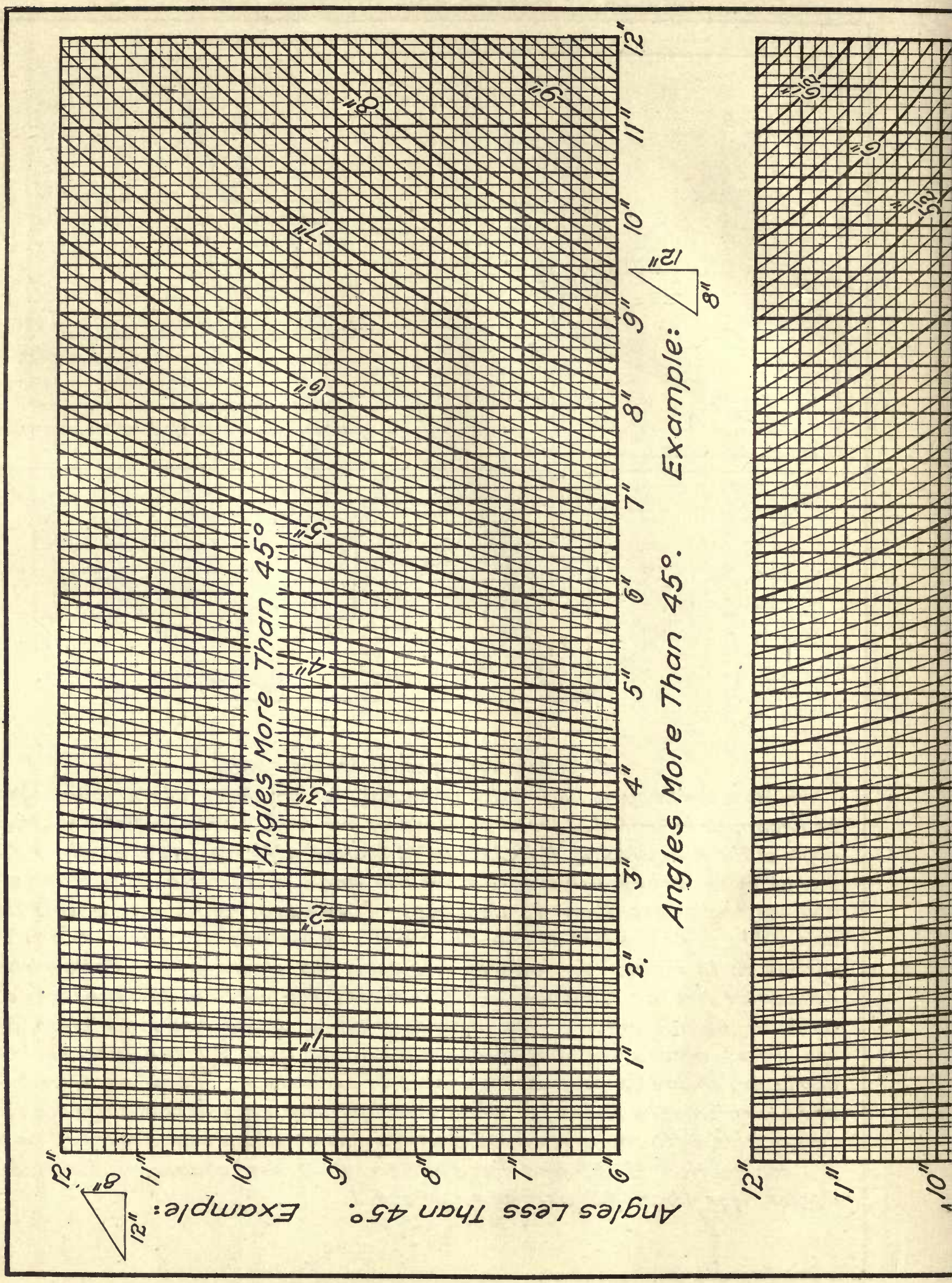
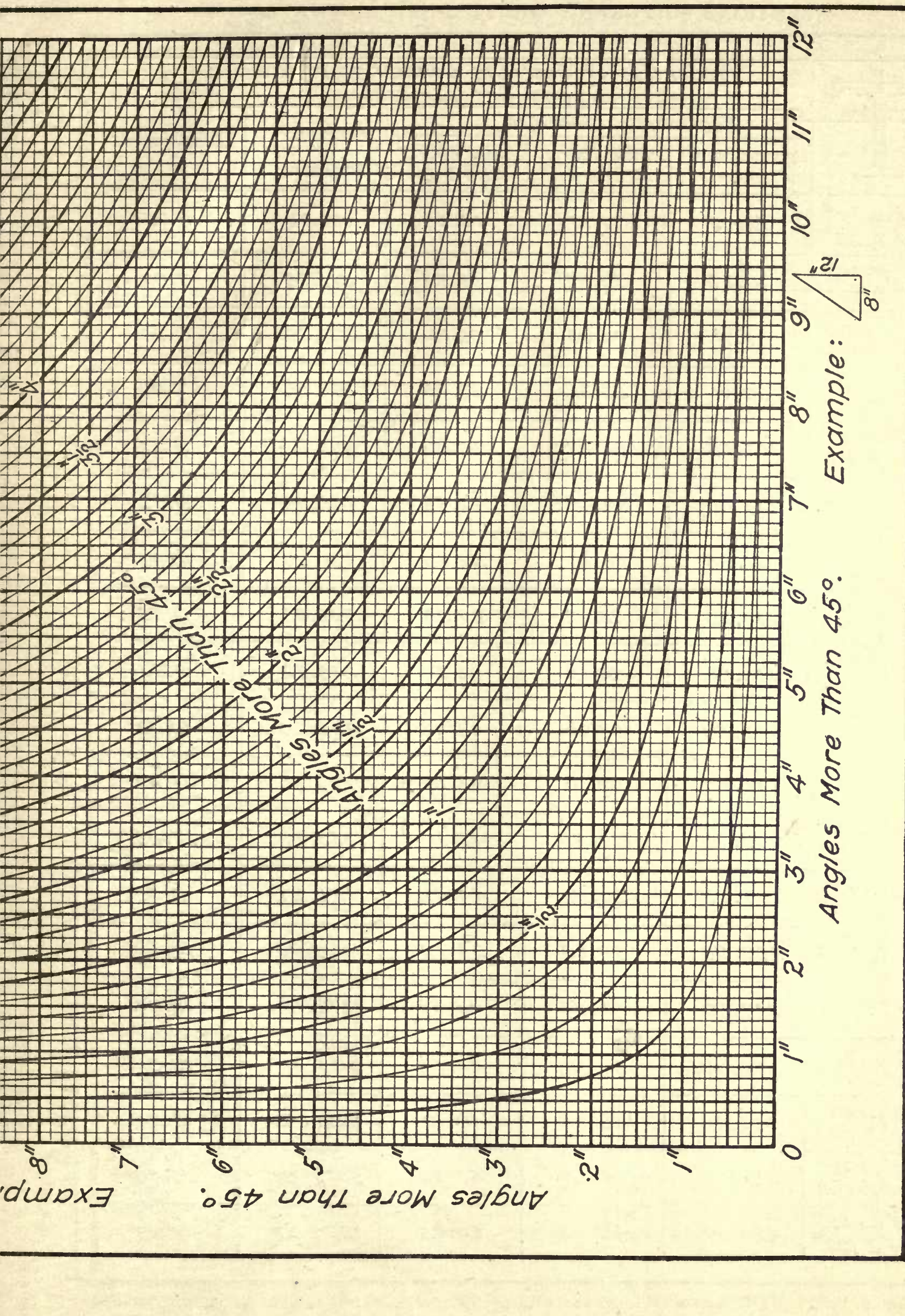
Explanatory note: Page 10.

ANGLES OF HOPPER SIDE INTERSECTIONS—III and IV





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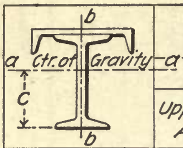
SECTIONS FOR CRANE AND TELPHER RUNWAYS—I



	Properties of Sections Consisting of One I- and One ⊔-beam.				
	Sectional Modulus			Moment of Inertia	Distance C
	Upper Chord Axis a-a	Lower Chord Axis a-a	Upper Chord Axis b-b		
10″ ⊔ 15# 10″ I 25#	52.06	27.15	14.09	182.72	6.73
10″ ⊔ 15# 12″ I 31.5#	70.22	39.97	14.35	311.78	7.80
12″ ⊔ 20.5# 12″ I 31.5#	81.71	40.66	22.19	333.39	8.20
12″ ⊔ 20.5# 12″ I 40#	90.41	50.31	22.55	396.91	7.89
10″ ⊔ 15# 15″ I 42#	103.55	64.87	14.86	607.83	9.37
12″ ⊔ 20.5# 15″ I 42#	118.80	66.06	22.62	648.68	9.82
15″ ⊔ 33# 15″ I 42#	151.94	68.18	42.65	724.77	10.63
12″ ⊔ 25# 15″ I 50#	135.28	75.02	25.33	742.67	9.90
12″ ⊔ 20.5# 15″ I 60#	140.17	90.13	23.56	838.22	9.30
15″ ⊔ 33# 15″ I 60#	173.59	93.20	43.43	933.90	10.02
12″ ⊔ 20.5# 18″ I 55#	161.57	99.11	23.16	1122.90	11.33
15″ ⊔ 33# 18″ I 55#	203.18	102.50	43.11	1253.60	12.23
15″ ⊔ 33# 15″ I 80#	197.81	120.17	44.48	1151.27	9.58
12″ ⊔ 20.5# 20″ I 65#	199.98	129.60	23.72	1594.03	12.30
15″ ⊔ 33# 20″ I 65#	247.50	133.85	43.56	1772.11	13.24
15″ ⊔ 33# 20″ I 80#	278.43	164.98	44.52	2113.31	12.81
15″ ⊔ 40# 20″ I 80#	305.44	168.05	49.12	2226.62	13.25
15″ ⊔ 33# 24″ I 80#	339.17	196.13	44.56	3032.18	15.46
15″ ⊔ 55# 24″ I 100#	455.00	239.53	60.64	3894.80	16.26

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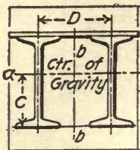
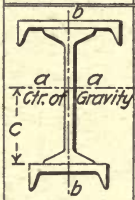
SECTIONS FOR CRANE AND TELPHER RUNWAYS—II



	Properties of Sections Consisting of Two I-beams and One Connecting Plate.					
	Sectional Modulus			Distance D	Moment of Inertia	Distance C
	Upper Chord Axis a-a	Lower Chord Axis a-a	Upper Chord Axis b-b			
1-12" x 3/8" Pl. 2-10" I's 25#	81.01	54.18	20.27	5.75	337.02	6.22
1-14" x 1/2" Pl. 2-12" I's 31.5#	131.53	81.72	36.30	7.50	630.03	7.71
1-14" x 1/2" Pl. 2-12" I's 40#	147.64	100.75	40.38	7.25	748.53	7.43
1-14" x 1/2" Pl. 2-15" I's 42#	192.53	131.50	40.03	7.00	1211.00	9.21
1-15" x 1/2" Pl. 2-15" I's 60#	239.39	179.40	55.30	7.50	1589.54	8.86
1-15" x 1/2" Pl. 2-15" I's 70#	251.22	196.35	61.22	7.50	1708.27	8.70
1-15" x 1/2" Pl. 2-15" I's 80#	285.65	230.98	65.55	7.25	1979.53	8.57
1-16" x 1/2" Pl. 2-18" I's 55#	279.02	197.60	60.51	8.50	2140.06	10.83
1-16" x 1/2" Pl. 2-20" I's 65#	347.57	257.80	65.48	8.25	3034.28	11.77
1-16" x 1/2" Pl. 2-20" I's 80#	406.10	318.45	67.99	7.50	3658.97	11.49
1-18" x 1/2" Pl. 2-24" I's 80#	504.42	379.58	90.22	9.50	5306.49	13.98
1-18" x 1/2" Pl. 2-24" I's 100#	545.59	435.11	106.12	9.50	5930.54	13.63



	The channel given first is on the top chord					
	Properties of Sections Consisting of One I and Two ⊔-beams.					
	Sectional Modulus				Moment of Inertia	Distance C
	Upper Chord Axis a-a	Lower Chord Axis a-a	Upper Chord Axis b-b	Lower Chord Axis b-b		
1-10" ⊔ 15# 1-10" I 25# 1-8" ⊔ 11.25#	62.87	43.62	14.09	8.97	321.89	5.12
1-12" ⊔ 20.5# 1-10" I 25# 1-10" ⊔ 15#	76.93	50.92	21.98	14.09	394.06	5.15
1-12" ⊔ 20.5# 1-12" I 31.5# 1-10" ⊔ 15#	99.54	68.40	22.19	14.35	603.23	6.22
1-12" ⊔ 20.5# 1-15" I 42# 1-10" ⊔ 15#	139.08	100.03	22.62	14.86	1040.34	7.80
1-15" ⊔ 33# 1-15" I 42# 1-12" ⊔ 20.5#	185.61	119.97	42.65	22.62	1336.49	8.20
1-12" ⊔ 20.5# 1-18" I 55# 1-10" ⊔ 15#	185.03	138.27	23.16	15.52	1652.32	9.35
1-15" ⊔ 33# 1-18" I 55# 1-12" ⊔ 20.5#	241.06	163.01	43.11	23.16	2075.17	9.79

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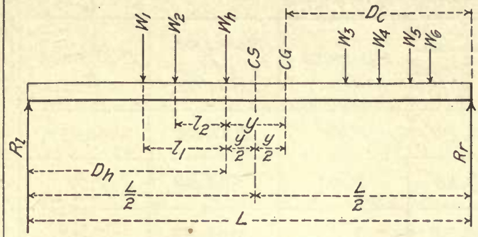
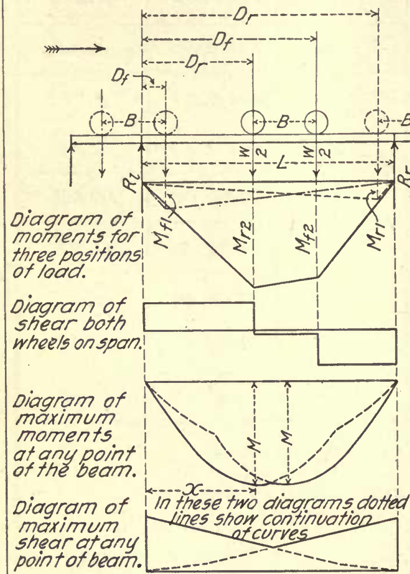
FORMULAS FOR MOVING LOADS

Location for Maximum Moment.



CS denotes center of span.
CG denotes center of gravity of loads.
W_h denotes heaviest load adjacent to CG.
Let W = total load and M = moment.
For M a maximum place CS midway between W_h and CG and find M under W_h. For reactions, $R_l = \frac{WD_c}{L}$ and $R_r = W - R_l$. For maximum moment $M = R_l D_h - (W_1 l_1 + W_2 l_2)$, or since $D_c = D_h$, $M = \frac{WD_c^2}{L} - (W_1 l_1 + W_2 l_2)$.

Two Wheels Equally Loaded.



Notation: All values in inches and pounds.
W = total load. $W/2$ = load on one wheel.
L = length of span. B = wheel base.
R_l = left reaction. R_r = right reaction.
V = vertical shear = reaction nearest to the point under consideration.
D_f = distance to front wheel } the load
D_r = distance to rear wheel } coming on from the left. M_{f1} = moment under front wheel, one wheel on the span.
M_{f2} = moment under front wheel with both wheels on the span. M_{r1} = moment under rear wheel, one wheel on the span. M_{r2} = moment under rear wheel, both wheels on the span.
x = value of D_r for M_{r2} a maximum.
M = maximum moment. Z = section modulus.
S_b = stress due to bending.

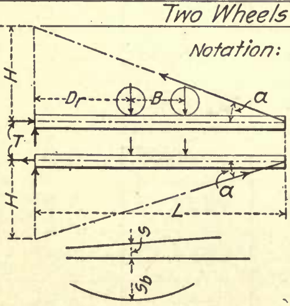
$M_{f1} = \frac{WD_f}{2L}(L - D_f)$. $M_{r1} = \frac{WD_r}{2L}(L - D_r)$. $M_{f2} = \frac{W}{L}(D_f - \frac{B}{2})(L - D_f)$.

$M_{r2} = \frac{WD_r}{L}(L - D_r - \frac{B}{2})$ For values of B less than $0.5858L$, $x = \frac{L}{2} - \frac{B}{4}$ and $M = \frac{WL}{4}(1 - \frac{B}{2L})^2$.

$Z = \frac{M}{S_b}$ or $S_b = \frac{M}{Z}$.

For B = or exceeds $0.5858L$, $M = \frac{WL}{8}$. For both wheels on the span, $R_l = \frac{W}{L}(L - D_r - \frac{B}{2})$ and $R_r = \frac{W}{L}(D_r + \frac{B}{2})$.

Two Wheels Equally Loaded, Oblique Reaction.



Notation: Same as above with addition of; α = angle of the reaction with beam. A = cross sectional area of beam. T = thrust or pull due to oblique reaction. S = direct stress due to T (tension or compression).

$T = \frac{W}{H}(D_r + \frac{B}{2})$, or $T = \frac{W}{L}(D_r + \frac{B}{2})\cot\alpha$.

$S = \frac{T}{A} = \frac{W}{HA}(D_r + \frac{B}{2})$, or $S = \frac{W}{LA}(D_r + \frac{B}{2})\cot\alpha$.

M_{f2}, M_{r2}, x, M and S_b = same as above.

$S + S_b = W\left(\frac{D_r + \frac{1}{2}B}{HA} + \frac{D_r(L - D_r - \frac{1}{2}B)}{LZ}\right)$, or

$S + S_b = \frac{W}{L}\left(\frac{(D_r + \frac{1}{2}B)\cot\alpha}{A} + \frac{D_r(L - D_r - \frac{1}{2}B)}{Z}\right)$.

$S + S_b$ = a maximum when $D_r = \frac{LZ}{2HA} + \frac{L}{2} - \frac{B}{4} = \frac{Z}{2A}\cot\alpha + \frac{L}{2} - \frac{B}{4}$.

For light weight I-beams $\frac{Z}{A}$ = about $\frac{1}{3}$ depth of beam.

Contributed by John S. Myers, MACHINERY'S Data Sheet No. 85. Explanatory note: Page 10.

TABLES FOR SHEAR OR MOMENT. TWO WHEELS EQUALLY LOADED

Notation: W = total load on wheels. $\frac{1}{2}W$ = load on one wheel. L = length of span. B = wheel base. D = distance from support to point at which moment or shear is required. R = ratio of B to $L = B/L$. x = ratio of D to $L = D/L$. M = bending moment. S = vertical shear on beam which is also the reaction of the support nearest to the point under consideration. V_m and V_s are variables to be taken from tables.

Table giving values of V_m in formula $M = WLV_m$.

$R = \frac{B}{L}$	Values of $D/L = x$.												
	0.05	0.10	0.15	0.20	0.25	0.30	0.35	0.375	0.40	0.425	0.45	0.475	0.50
0.0	0.0475	0.090	0.1275	0.16	0.1875	0.210	0.2275	0.2344	0.24	0.2442	0.2475	0.2494	0.250
0.1	0.0450	0.085	0.1200	0.15	0.1750	0.195	0.2100	0.2156	0.22	0.2231	0.2250	0.2256	0.225
0.2	0.0425	0.080	0.1125	0.14	0.1625	0.180	0.1925	0.1969	0.20	0.2019	0.2025	0.2019	0.200
0.3	0.0400	0.075	0.1050	0.13	0.1500	0.165	0.1750	0.1781	0.18	0.1806	0.1800	0.1781	0.175
0.4	0.0375	0.070	0.0975	0.12	0.1375	0.150	0.1575	0.1594	0.16	0.1594	0.1575	0.1544	0.150
0.5	0.0350	0.065	0.0900	0.11	0.1250	0.135	0.1400	0.1406	0.14	0.1381	0.1350	0.1306	0.125
0.6	0.0325	0.060	0.0825	0.10	0.1125	0.120	0.1225	0.1219	0.12	0.1222	0.1238	0.1247	0.125
0.7	0.0300	0.055	0.0750	0.09	0.1000	0.105	0.1138	0.1172	0.12	0.1222	0.1238	0.1247	0.125
0.8	0.0275	0.050	0.0675	0.08	0.0983	0.105	0.1138	0.1172	0.12	0.1222	0.1238	0.1247	0.125
0.9	0.0250	0.045	0.0638	0.08	0.0983	0.105	0.1138	0.1172	0.12	0.1222	0.1238	0.1247	0.125
1 or over	0.0238	0.045	0.0638	0.08	0.0983	0.105	0.1138	0.1172	0.12	0.1222	0.1238	0.1247	0.125
	0.95	0.90	0.85	0.80	0.75	0.70	0.65	0.625	0.60	0.575	0.550	0.525	0.50
	Values of $D/L = x$ from other support												

In the above the values enclosed by heavy lines are maximum

Table giving values of V_s in formula $S = WV_s$.

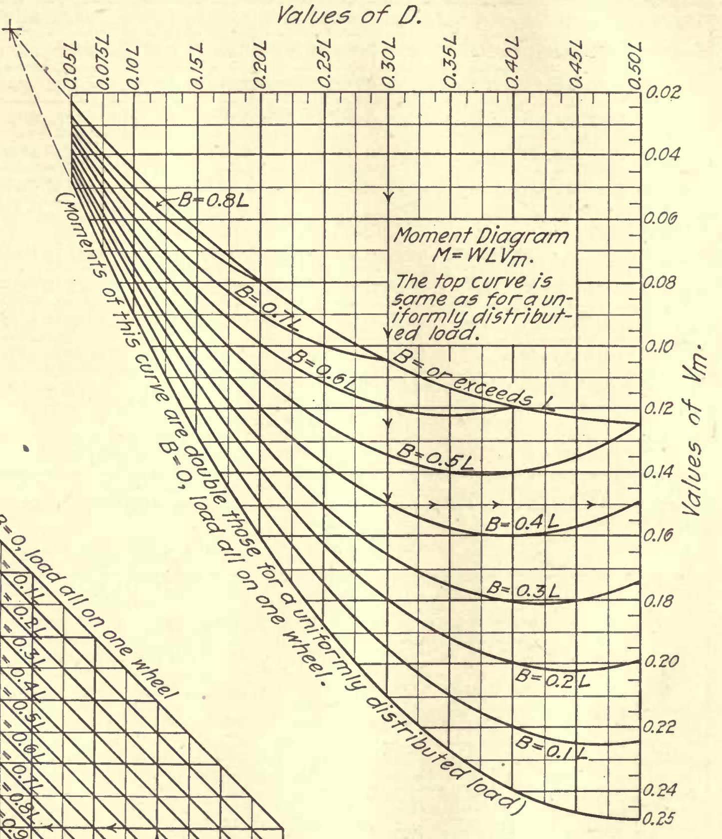
$R = \frac{B}{L}$	Values of $D/L = x$											$R = \frac{B}{L}$
	0.00	0.05	0.10	0.15	0.20	0.25	0.30	0.35	0.40	0.45	0.50	
0.0	1.00	0.95	0.90	0.85	0.80	0.75	0.70	0.65	0.60	0.55	0.50	0.0
0.1	0.95	0.90	0.85	0.80	0.75	0.70	0.65	0.60	0.55	0.50	0.45	0.1
0.2	0.90	0.85	0.80	0.75	0.70	0.65	0.60	0.55	0.50	0.45	0.40	0.2
0.3	0.85	0.80	0.75	0.70	0.65	0.60	0.55	0.50	0.45	0.40	0.35	0.3
0.4	0.80	0.75	0.70	0.65	0.60	0.55	0.50	0.45	0.40	0.35	0.30	0.4
0.5	0.75	0.70	0.65	0.60	0.55	0.50	0.45	0.40	0.35	0.30	0.25	0.5
0.6	0.70	0.65	0.60	0.55	0.50	0.45	0.40	0.35	0.30	0.275	0.25	0.6
0.7	0.65	0.60	0.55	0.50	0.45	0.40	0.35	0.325	0.30	0.275	0.25	0.7
0.8	0.60	0.55	0.50	0.45	0.40	0.375	0.35	0.325	0.30	0.275	0.25	0.8
0.9	0.55	0.50	0.45	0.425	0.40	0.375	0.35	0.325	0.30	0.275	0.25	0.9
1 or over	0.50	0.475	0.45	0.425	0.40	0.375	0.35	0.325	0.30	0.275	0.25	1 or over
	1.00	0.95	0.90	0.85	0.80	0.75	0.70	0.65	0.60	0.55	0.50	
	Values of $D/L = x$ from other support											

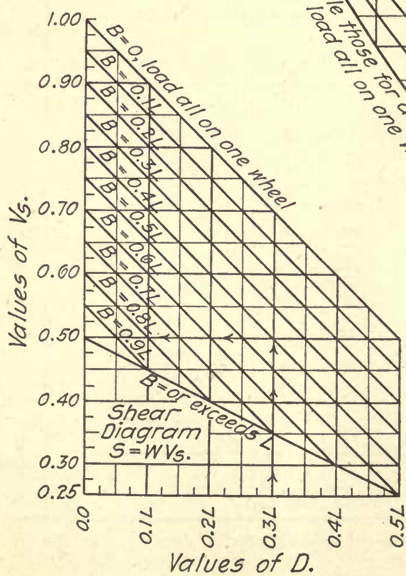
In both the above tables $R = 0$ indicates one wheel instead of two. When $B = 0.5858\,L$ the moment with one wheel in the center of span is equal to the maximum moment with both wheels on.

Contributed by John S. Myers, MACHINERY'S Data Sheet No. 85. Explanatory note: Page 10.

DIAGRAMS OF MOMENT AND SHEAR. TWO WHEELS EQUALLY LOADED

Notation: W = total load $\frac{1}{2}W$ = load on one wheel. B = wheel base. L = length of span. M = bending moment. S = vertical shear. D = distance from nearest support to point where moment or shear is required. V_m and V_s are variables to be taken from the diagrams. The shear is also the reaction at the nearest support.





Example: W = 2000 lbs. B = 8′0″ = 0.4L. L = 20′0″.
When D = 6′0″ = 0.3L, what is the bending moment and shear?
By the diagrams V_m = 0.15 and V_s = 0.5, then by formula, M = 2000 x 20 x 0.15 = 6000 ft. lbs. S = 2000 x 0.5 = 1000 lbs.

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SAFE STRESSES FOR BEAMS UNSUPPORTED LATERALLY

In order to provide the same security in both flanges of a beam the compression flange should either be supported against lateral flexure at distances not greater than 20 times the flange width, or a lower stress should be used for the compression flange than is permissible for the tension flange.

The formula given in the Cambria Steel Co's. hand-book corresponding to 16000 lbs. per sq inch safe tensile stress is:

$$S_c = \frac{18000}{1 + \frac{L^2}{3000 b^2}},$$

where the letters have the following values; S_c = safe compressive stress. L = length unsupported in inches. b = breadth of flange in inches.

The curve marked 16000 was plotted according to the above formula.

The curves for 14000, 12500 and 10000 corresponding tensile stresses were plotted from proportionally lower values.

Values of S_c read from the 10000 curve, if considered as a decimal, give the ratio of safe compressive to safe tensile stress.

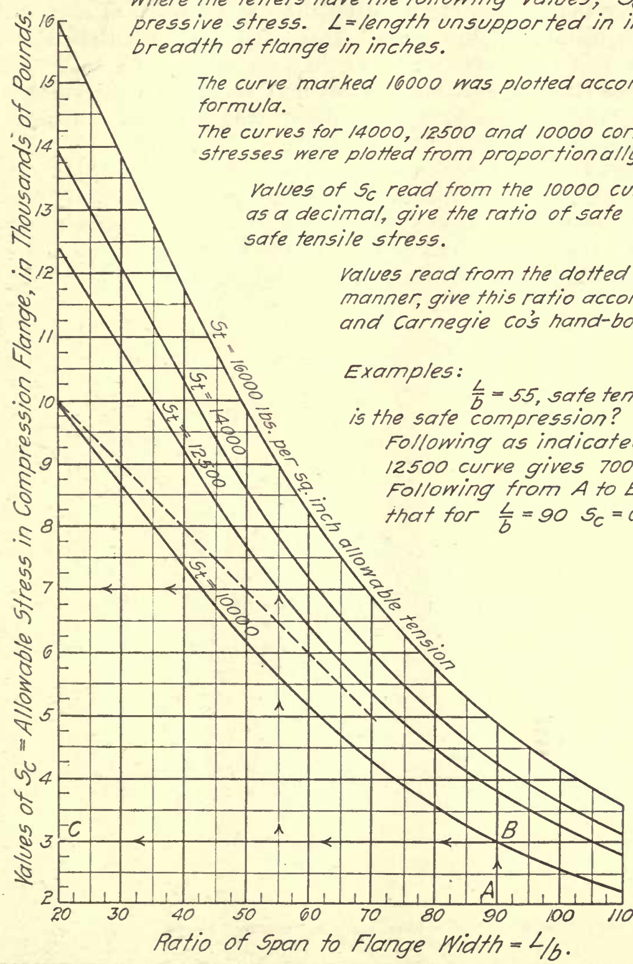
Values read from the dotted line in the same manner, give this ratio according to Pencoyd and Carnegie Co's hand-book.

Examples:

$\frac{L}{b} = 55$, safe tension = 12500. What is the safe compression?

Following as indicated by arrows, the 12500 curve gives 7000; answer.

Following from A to B then to C indicates that for $\frac{L}{b} = 90$ $S_c = 0.3 S_t$.

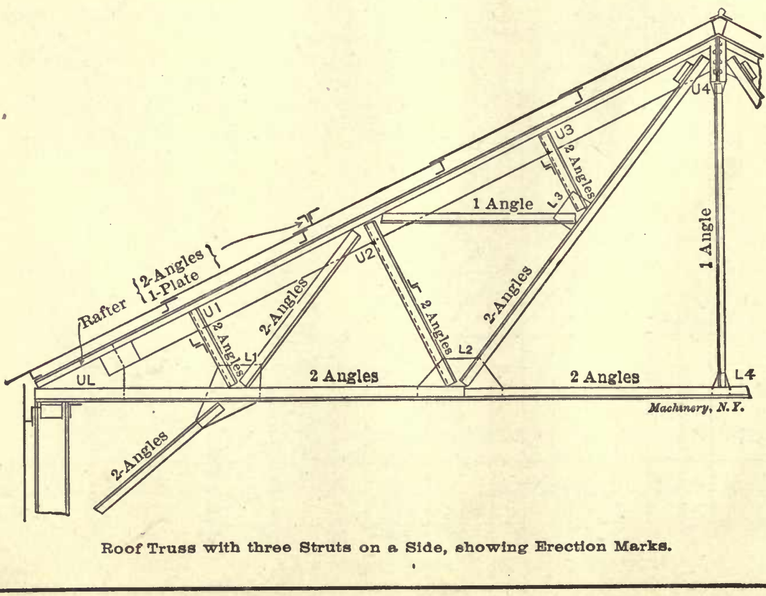


STRESSES IN THE MEMBERS OF ROOF TRUSSES.

The accompanying tables give the percentage of the total load on a roof truss which each member of that truss bears. This load is made up of the weight due to the material of the roof covering, slate, corrugated iron, or other material; the weight due to miscellaneous loads, such as shafting, suspended machinery, etc.; and the load due to wind pressure and snow. The sum of all these for a surface whose length is the total width of the roof from eaves to eaves, and whose width is the distance between the center line of adjacent spans, is the total load on each span.

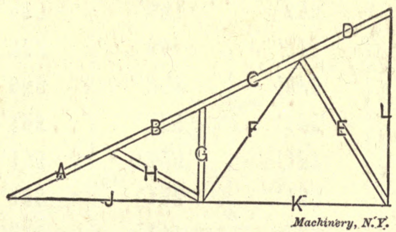
Having found the total load, select a suitable form of truss from among those represented by the skeleton diagrams in the accompanying data sheets. In these diagrams the tension members are represented by single lines, and the compression members by double lines. Under the column representing the desired pitch of roof will be found a coefficient for each member of the truss. This coefficient, multiplied by the total load, gives the tensile or compressive stress, as the case may be, for that member Knowing the values of these stresses, suitable sections may be calculated from the data given in the handbooks of the various steel companies. The pitch of a roof is the height of the span divided by its length.

The cut below illustrates the construction of a common form of roof truss. "Erection marks," U L, L 1, L 2, etc , are shown at all the connection points. Every member which goes to make up the connection at any given point is marked in the shop with the erection mark for that connection, and the drawings for each of the parts are similarly marked. This facilitates both the checking of the calculations and the erection of the structure.

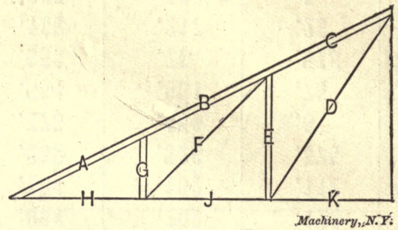


Roof Truss with three Struts on a Side, showing Erection Marks.

STRESSES IN THE MEMBERS OF ROOF TRUSSES. (Continued.)



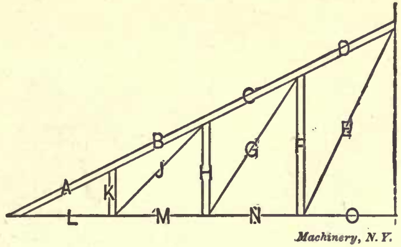
	1-3 Pitch.	30° Pitch.	1-4 Pitch.	1-5 Pitch.
A	.789	.875	.979	1.178
B	.677	.75	.839	1.005
C	.677	.75	.839	1.005
D	.451	.5	.562	.673
E	.21	.217	.225	.2445
F	.21	.217	.225	.2445
G	.125	.125	.125	.125
H	.1127	.125	.14	.168
J	.665	.758	.875	1.094
K	.469	.542	.625	.782
L	.375	.375	.375	.375



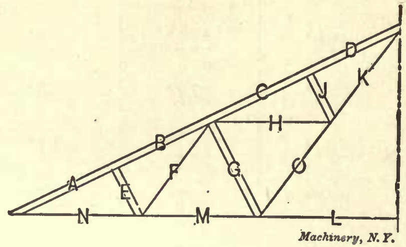
	1-3 Pitch.	30° Pitch.	1-4 Pitch.	1-5 Pitch.
A	.751	.833	.932	1.122
B	.751	.833	.932	1.122
C	.6	.667	.745	.898
D	.279	.289	.301	.325
E	.25	.25	.25	.25
F	.208	.220	.236	.267
G	.167	.167	.167	.167
H	.625	.722	.833	1.042
J	.5	.577	.667	.833
K	.375	.433	.5	.625

Contributed by R. F. Kiefer, MACHINERY'S Data Sheet No. 53. Explanatory note: Page 47.

STRESSES IN THE MEMBERS OF ROOF TRUSSES. (Continued.)



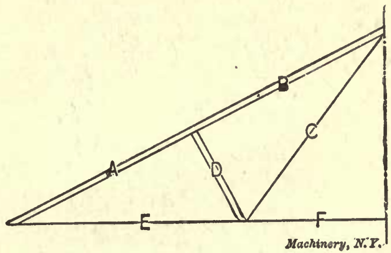
	1-3 Pitch.	30° Pitch.	1-4 Pitch.	1-5 Pitch.
A	.789	.875	.978	1.178
B	.789	.875	.978	1·178
C	.676	.75	.839	1.009
D	.563	.625	.699	.841
E	·267	.272	.28	.294
F	.25	.25	.25	.25
G	.210	.217	.225	.294
H	.188	.188	.188	.188
J	.156	.165	.177	.2
K	.125	.125	.125	.125
L	.656	.758	.875	1.094
M	.563	.65	.75	.938
N	.469	.541	.625	.731
O	.375	.433	.5	.625



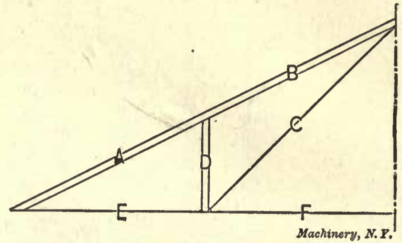
	1-3 Pitch.	30° Pitch.	1-4 Pitch.	1-5 Pitch.
A	.79	.875	.978	1.18
B	.72	.813	.922	1.133
C	.651	.75	.866	1.087
D	.532	.688	.81	1.04
E	.104	.109	.112	.116
F	.094	.109	.125	.157
G	.208	.217	.224	.232
H	.094	.109	.125	.157
J	.104	.109	.112	.116
K	.282	.326	.375	.471
L	.376	.434	.5	.625
M	.564	.651	.75	.94
N	.658	.76	.875	1.096
O	.188	.217	.25	.314
Tang	.667	.577	.5	.4
Sec.	1.202	1.155	1.118	1.077

Contributed by R. F. Kiefer, MACHINERY'S Data Sheet No. 53. Explanatory note: Page 47.

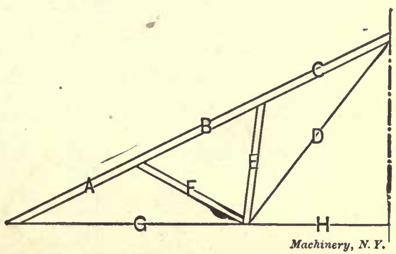
STRESSES IN THE MEMBERS OF ROOF TRUSSES. (Continued.)



	1-3 Pitch.	30° Pitch.	1-4 Pitch.	1-5 Pitch.
A	.676	.75	.839	1.01
B	.537	.625	.727	.917
C	.188	.217	.25	.312
D	.208	.217	.224	.232
E	.563	.649	.75	.938
F	.375	.43	.5	.625



	1-3 Pitch.	30° Pitch.	1-4 Pitch.	1-5 Pitch.
A	.676	.75	.84	1.01
B	.676	.75	.84	1.01
C	.313	.33	.353	.4
D	.25	.25	.25	.25
E	.563	.65	.75	.938
F	.375	.433	.5	.625

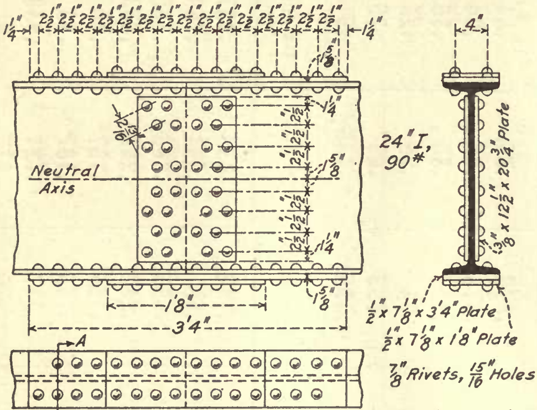


	1-3 Pitch.	30° Pitch.	1-4 Pitch.	1-5 Pitch.
A	.742	.833	.937	1.123
B	.58	.666	.759	.932
C	.555	.666	.785	1.0
D	.242	.288	.338	.418
E	.155	.167	.18	.202
F	.155	.167	.18	.202
G	.617	.721	.838	1.043
H	.375	.433	.5	.625

Contributed by R. F. Kiefer, MACHINERY'S Data Sheet No. 53. Explanatory note: Page 47.

SPLICES FOR I-BEAMS—I

Splice for 24 inch, 90 pound I-beam.



Weight of Splice Plates
177 pounds.

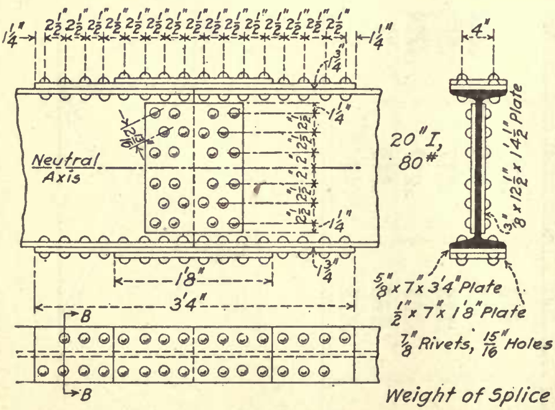
Bending efficiency of splice:

Rivets,	85.4%
Net section of beam,	85.2%

Efficiency of splice for direct tension:

Rivets,	83.7%
Net section of beam,	91.2%
Net section of splice plates,	82.4%

Splice for 20 inch, 80 pound I-beam.



Weight of Splice Plates
183 pounds.

Bending efficiency of splice:

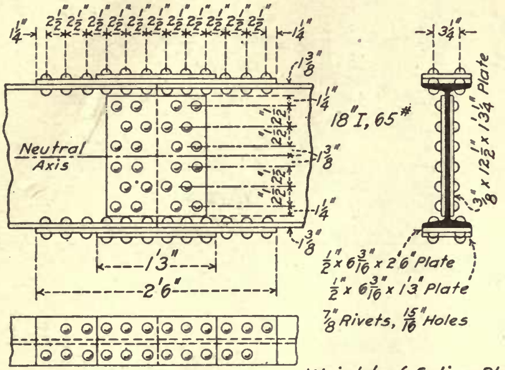
Rivets,	90%
Net section of beam	82.8%

Efficiency of splice for direct tension:

Rivets,	80.7%
Net section of beam,	88.8%
Net section of splice plates,	86.7%

SPLICES FOR I-BEAMS—II

Splice for 18 inch, 65 pound I-beam.



Bending efficiency of splice:

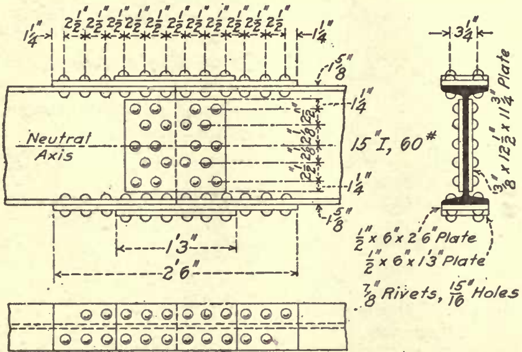
Rivets,	93.6%
Net section of beam,	84.2%

Efficiency of splice for direct tension:

Rivets,	85.8%
Net section of beam,	90.6%
Net section of splice plates,	87.8%

Weight of Splice Plates
120 pounds.

Splice for 15 inch, 60 pound I-beam.



Bending efficiency of splice:

Rivets,	87.3%
Net section of beam,	80 %

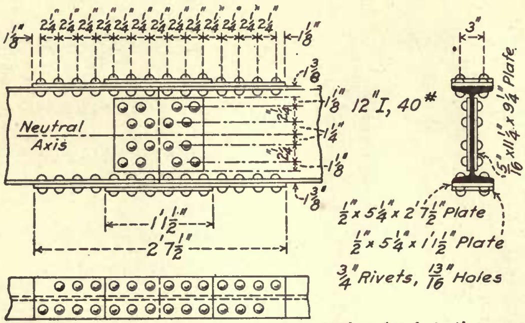
Efficiency of splice for direct tension:

Rivets,	84 %
Net section of beam,	87%
Net section of splice plates,	83.2%

Weight of Splice Plates
108 pounds.

SPLICES FOR I-BEAMS—III

Splice for 12 inch-40 pound I beam.



Weight of Splice Plates
85 pounds.

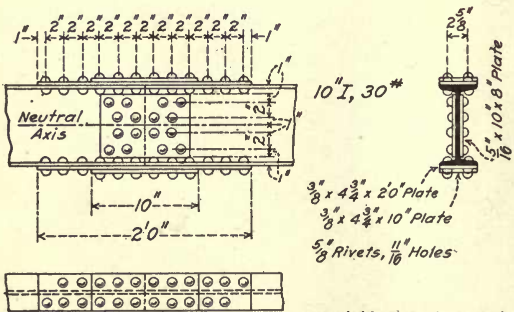
Bending efficiency of splice:

Rivets,	104%
Net section of beam,	80.7%

Efficiency of splice for direct tension:

Rivets,	89.7%
Net section of beam,	86.7%
Net section of splice plates,	95.4%

Splice for 10 inch-30 pound I-beam.



Weight of Splice Plates
50 pounds.

Bending efficiency of splice:

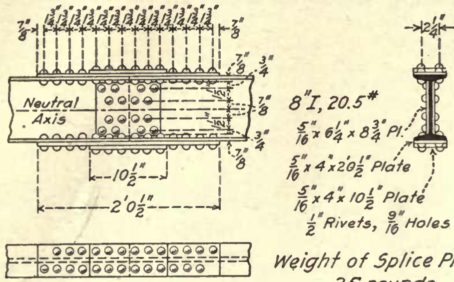
Rivets,	89.1%
Net section of beam,	84.5%

Efficiency of splice for direct tension:

Rivets,	79.2%
Net section of beam,	89.8%
Net section of splice plates	96.4%

SPLICES FOR I-BEAMS—IV

Splice for 8 inch, $20\frac{1}{2}$ pound I-beam.



Weight of Splice Plates 35 pounds.

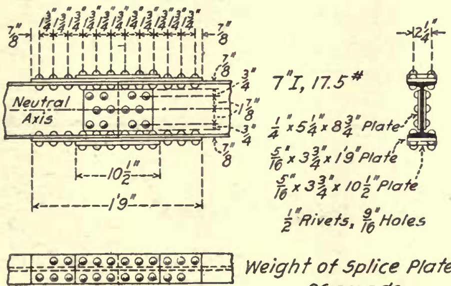
Bending efficiency of splice:

Rivets,	81%
Net section of beam,	82.6%

Efficiency of splice for direct tension:

Rivets,	82.2%
Net section of beam,	88.8%
Net section of splice plates,	100%

Splice for 7 inch, 17.5 pound I-beam.



Weight of Splice Plates 26 pounds.

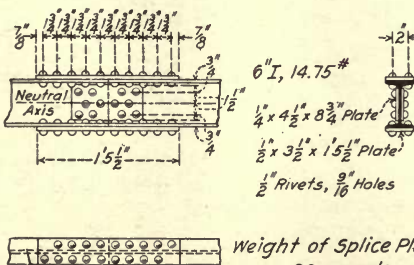
Bending efficiency of splice:

Rivets,	92.3%
Net section of beam.	82.8%

Efficiency of splice for direct tension:

Rivets,	78%
Net section of beam,	88.4%
Net section of splice plates,	89.7%

Splice for 6 inch, $14\frac{3}{4}$ pound I-beam.



Weight of Splice Plates 23 pounds.

Bending efficiency of splice:

Rivets,	83.3%
Net section of beam,	89%

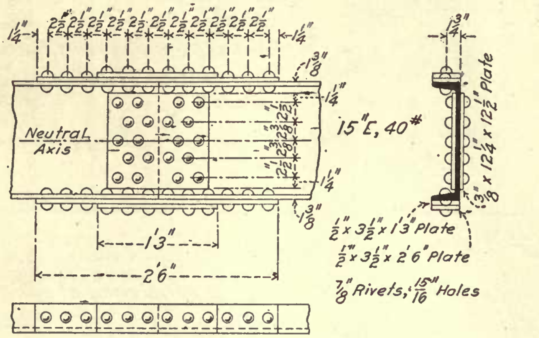
Efficiency of splice for direct tension:

Rivets,	81.3%
Net section of beam,	87.8%
Net section of splice plates,	91.5%

Contributed by A. L. Campbell, MACHINERY's Data Sheet No. 123. Explanatory note: Page 47.

SPLICES FOR CHANNELS—I

Splice for 15 inch, 40 pound Channel.



Weight of Splice Plates 77 pounds.

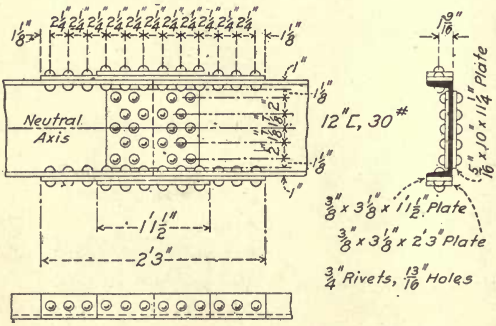
Bending efficiency of splice:

Rivets,	87.7%
Net section of channel,	81%

Efficiency of splice for direct tension:

Rivets,	87%
Net section of channel,	89.8%
Net section of splice plates	99%

Splice for 12 inch, 30 pound Channel.



Weight of Splice Plates 47 pounds.

Bending efficiency of splice:

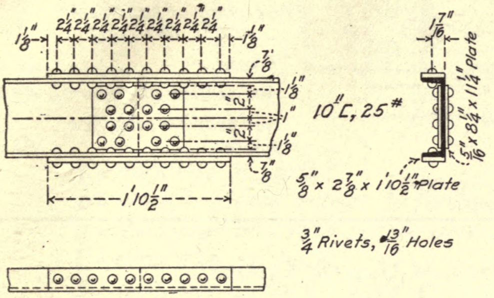
Rivets,	94.8%
Net section of channel,	83.7%

Efficiency of splice for direct tension:

Rivets	93.2%
Net section of channel,	91.6%
Net section of splice plates,	93.3%

SPLICES FOR CHANNELS—II

Splice for 10 inch, 25 pound Channel.



Bending efficiency of splice:

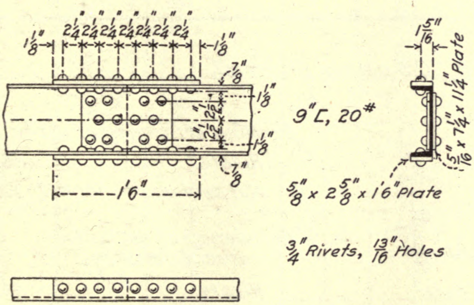
Rivets,	97.3%
Net section of channel,	92%

Efficiency of splice for direct tension:

Rivets,	91.2%
Net section of channel,	91.8%
Net section of splice plates,	83.8%

Weight of Splice Plates
37 pounds.

Splice for 9 inch, 20 pound Channel.



Bending efficiency of splice.

Rivets,	90.8%
Net section of channel,	90.4%

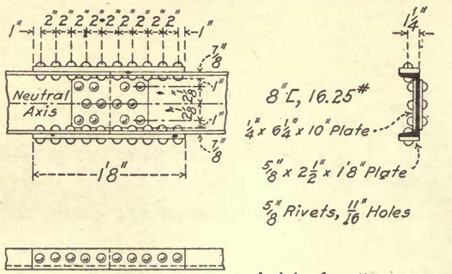
Efficiency of splice for direct tension:

Rivets,	80.7%
Net section of channel,	89.8%
Net section of splice plates,	100%

Weight of Splice Plates
31 pounds.

SPLICES FOR CHANNELS—III

Splice for 8 inch, 16.25 pound Channel.



Weight of Splice Plates
25 pounds.

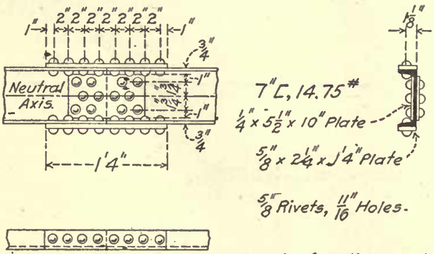
Bending efficiency of splice:

Rivets,	90%
Net section of channel,	80.2%

Efficiency of splice for direct tension:

Rivets,	79.5%
Net section of channel,	89%
Net section of splice plates,	93.3%

Splice for 7 inch, 14.75 pound Channel.



Weight of Splice Plates
21 pounds.

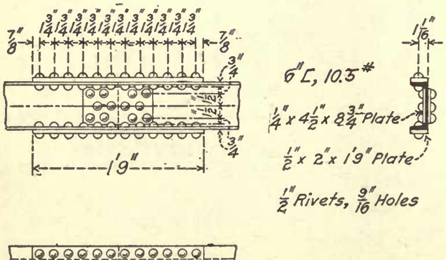
Bending efficiency of splice:

Rivets,	83.2%
Net section of channel,	79.3%

Efficiency of splice for direct tension:

Rivets,	78.7%
Net section of channel,	88.8%
Net section of splice plates,	90.3%

Splice for 6 inch, 10.5 pound Channel.



Weight of Splice Plates
18 pounds.

Bending efficiency of splice:

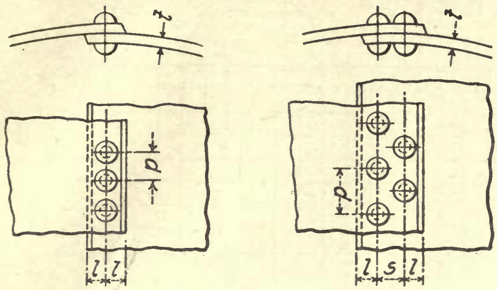
Rivets,	98%
Net section of channel,	78.2%

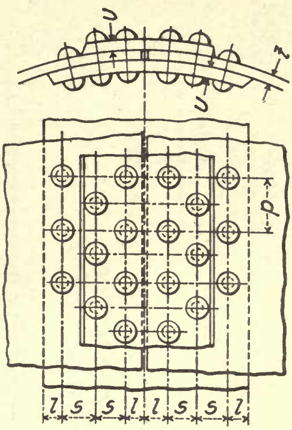
Efficiency of splice for direct tension:

Rivets,	85.7%
Net section of channel,	87.8%
Net section of splice plates,	100%

Contributed by A. L. Campbell, MACHINERY'S Data Sheet No. 125. Explanatory note: Page 47.

STANDARD PROPORTIONS OF RIVETED JOINTS FOR PRESSURE TANKS





t = thickness of plate,
p = pitch of rivets, center to center,
d = diameter of rivets before driving,
D = diameter of hole,
s = distance between lines of rivets,
l = distance from edge of plate to first line of rivets,
u = thickness of strap,
E = efficiency of joint in per cent.

Thickness of Plate t	Lap Joint Single Riveted					Lap Joint Double Riveted						Double Strap Butt Joint Triple Riveted						
	p	d	D	l	E	p	d	D	s	l	E	p	d	D	s	l	u	E
5/16	2	3/4	13/16	1 1/8	59	3 2/10	3/4	13/16	2	1 1/8	74	6	5/8	11/16	2 3/8 to 3 for all pitches	1 1/8	1/4	88
3/8	2 1/16	13/16	7/8	1 3/16	56	3 2/10	13/16	7/8	2	1 3/16	72	6	3/4	13/16		1 3/16	5/16	86
7/16	2 1/8	7/8	15/16	1 1/4	54	3 2/10	7/8	15/16	2	1 1/4	70	6 3/4	7/8	15/16		1 1/4	3/8	86
1/2	2 1/8	15/16	1	1 1/4	53	3	7/8	15/16	2	1 1/4	67	7	7/8	15/16		1 1/4	7/16	86
9/16	2 3/16	1	1 1/16	1 1/4	51	3 1/16	15/16	1	2	1 1/4	66	7	7/8	15/16		1 1/4	45/100	86
5/8						3 1/8	1	1 1/16	2	1 1/4	66	7	7/8	15/16		1 1/4	1/2	86
11/16						3	1	1 1/16	2	1 1/4	62	7	15/16	1		1 1/4	9/16	85
3/4						2 7/8	1	1 1/16	2	1 1/4	60	7	15/16	1		1 1/4	9/16	85
13/16												7 1/4	1	1 1/16		1 1/4	5/8	85
7/8												7	1	1 1/16		1 3/8	5/8	84
15/16												7 1/4	1 1/8	1 3/16		1 3/8	11/16	83
1												7	1 1/8	1 3/16		1 3/8	3/4	83

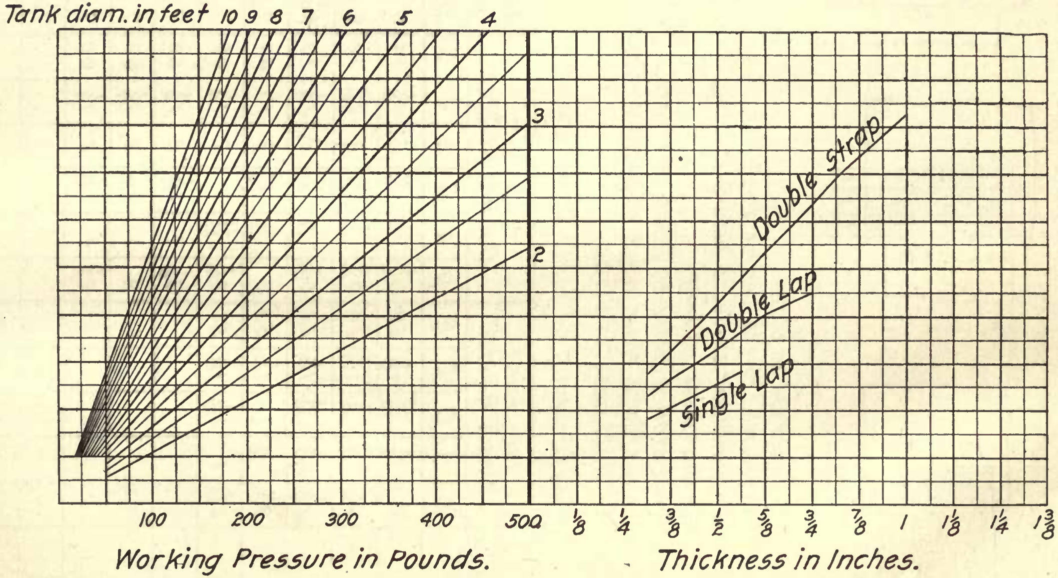
Contributed by C. R. Whittier, MACHINERY'S Data Sheet No. 132. Explanatory note: Page 48.

PLATE THICKNESS FOR PRESSURE TANKS

$$\text{Thickness in inches} = \frac{(\text{factor of safety}, 5) \times 100 \times \text{working pressure in pounds} \times \text{diam. in inches}}{2 \times (\text{breaking stress}, 55000) \times \text{efficiency in per cent}}$$

$$= \frac{0.004545 \times \text{working pressure in pounds} \times \text{diam. in inches}}{E}$$

Efficiency E = for double strap, triple riveted butt joint, 83 to 88 per cent,
for double riveted lap joint, 60 to 74 per cent,
for single riveted lap joint, 51 to 59 per cent.



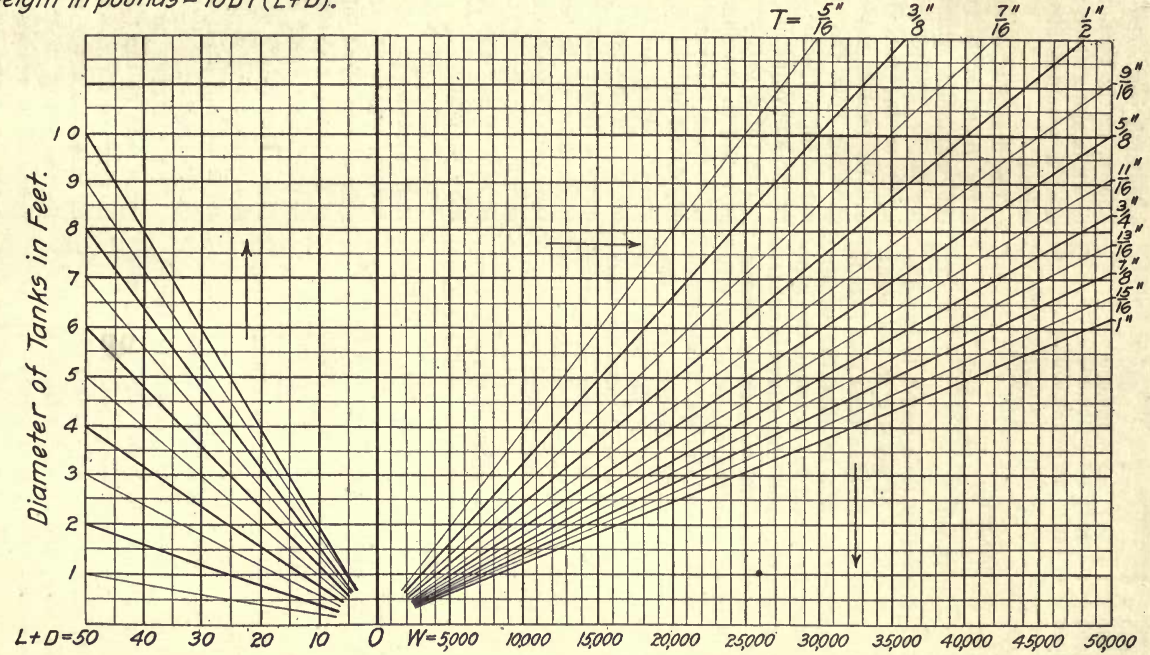
Contributed by C. R. Whittier, MACHINERY'S Data Sheet No. 132. Explanatory note: Page 48.

WEIGHTS OF CYLINDRICAL PRESSURE TANKS

Average shipping weights of cylindrical pressure and discharge tanks with dished heads $\frac{1}{16}$ inch thicker than shell, and with manholes, nozzles and inside pipes, compiled from actual tanks.

L = length in feet,
D = diameter in feet,
T = thickness in 16ths of an inch,
P = pressure per square inch,
W = weight in pounds = $10DT(L+D)$.

For double strap, triple riveted long. seams, $T = 0.01DP$ (min. $= \frac{5}{16}$) $W = P\left(\frac{G}{60} + 0.1D^3\right)$,
For lap joint double riveted long. seams, $T = 0.013DP$ (min. $= \frac{5}{16}$) $W = P\left(\frac{G}{46} + 0.13D^3\right)$,
For lap joint single riveted long. seams, $T = 0.016DP$ (min $= \frac{5}{16}$) $W = P\left(\frac{G}{37} + 0.16D^3\right)$,
G = capacity in gallons $= 6LD^2$.



Contributed by C. R. Whittier, MACHINERY'S Data Sheet No. 132. Explanatory note: Page 48.

Taking the 5000-pound load as the point of reference,

Loads	Distances		Moments
5000 ×	0	=	000
3000 ×	(+ 60)	= +	180,000
3000 ×	(+ 100)	= +	300,000
4000 ×	(— 45)	= —	180,000
15,000 lbs.			300,000

$$\frac{300,000}{15,000} = 20 \text{ inches.}$$

The dimension thus found is the distance of center of gravity to the right of the line of reference ($= x$) in Fig. 1.

Placing the load so that the center of the span is midway between the center of gravity and the heaviest wheel load, or, what is the same thing, placing the load so that the center of gravity of all the loads and the heaviest load are equidistant from the supports, gives the locations as indicated at the bottom of Fig. 1. To find R_l and R_r take moments as follows: Since the center of gravity of all loads is now known, consider them concentrated at this point; then $R_l = \frac{15,000 \times 110}{240} = 6875$ pounds and $R_r = \frac{15,000 \times 130}{240} = 8125$ pounds. Taking moments under the 5000-pound load,

$$6875 \times 110 = + 756,250$$
$$4000 \times (-45) = - 180,000$$

Maximum moment = 576,250 inch-pounds.

Two Wheels Equally Loaded

The general rule previously stated, when applied to two wheels equally loaded, may be given as follows:

When the wheel-base is less than $(2 - \sqrt{2})$ *times the span* ($= 0.5858 \times$ *span*), *the maximum moment occurs with both wheels on the span and when the distance from one support to the wheel nearest to it is equal to one-half the span minus one-fourth the wheel-base.*

When the wheel-base exceeds 0.5858 *times the span, the maximum moment occurs when one wheel is in the center of the span.*

From this the maximum stress can be calculated when the section modulus is known, or the section modulus required to withstand a given moment and not exceed a specified stress may be determined.

The first part of the chart on page 28 gives in condensed form the location for the maximum moment, with formulas for same. The second part gives a summary of the formulas for two wheels equally loaded, together with diagrams showing how the moment and shear varies for a specific location of the load, or for any point of the beam.

The third part of the chart on page 28 refers to the oblique reaction caused in a beam carrying a moving load and supported at one end by a tie-rod or a strut making an acute angle with the beam. In the case of a strut, this produces a direct tensile stress in the beam in addition to the bending stress, and in the case of a tie-rod a direct compressive stress is produced. A familiar example of this latter case is found in the ordinary jib crane.

The tables on page 29 give values of the variable V_m in the formula $M = WLV_m$, where $M =$ the moment occurring at any point throughout the length of the beam, $L =$ length of span, and $W =$ the load. The lower table on this page gives values of the variable V_s, in the formula $S = WV_s$ where $S =$ the shear at any point of the beam, and $W =$ the load.

The diagram on page 30 gives the same data as the tables on page 29, but in diagram form, which makes it easier to interpolate for intermediate values. By the aid of these tables or diagrams, the moment or shear at any point on the beam or girder can be quickly determined. This being known, it is easy to find the section modulus required, how close to the supports it may be necessary to bring the cover plates if a built-up section be used, and at what point the shear decreases sufficiently so that the web stiffeners may be omitted when such is permissible.

Example.—A girder of 20 feet span supports a load of 30,000 pounds carried on two wheels equally loaded, the wheel-base being 10 feet. What is the maximum moment?

Solution.—$L = 12 \times 20 = 240$ inches; $W = 30{,}000$ pounds; $B = 10$ feet $= 0.5L$. From the table on page 29, or the diagram on page 30, the maximum value of V_m is found to be 0.1406, say 0.14, then $M = WLV_m = 30{,}000 \times 240 \times 0.14 =$ 1,008,000 inch-pounds. This is the answer to the question.

Example.—A girder carries a moving load on two wheels equally loaded, the wheel-base being 0.2 of the span. At what point could the outside cover plate be stopped off if it constitutes one-third of the flange area?

Solution.—It could be stopped off at a point where the moment is two-thirds the value of the maximum moment. Referring to the diagram on page 30, the curve for $B = 0.2L$ shows the maximum value of V_m to be 0.2025. Two-thirds of $0.2025 = 0.135$. The same curve shows for $V_m = 0.135$ that $D =$ about $0.19L$, which is the required answer. If the girder were 40 feet long, the outside cover plate could be stopped off at $0.19 \times 40 = 7.6$ feet from each end. The plate should be carried beyond the theoretic point for a distance sufficient to insert two or three rivets.

Example.—The wheel-base being 0.4 the span, what is the maximum shear?

Solution.—By referring to either the table or diagram, the maximum shear is found to be 0.8 of the load.

Beams Unsupported Laterally

The Cambria Steel Co. gives the following formula,

$$S_c = \frac{18{,}000}{1 + \dfrac{L^2}{3000\, b^2}}$$

in which $S_c =$ safe compressive stress when the safe tensile stress is 16,000 pounds per square inch. This formula is derived from Gordon's by making an allowance for a factor of safety and taking into account the fact that the compression flange receives some support from the parts in tension.

The diagram on page 31 is based upon this formula, which gives values on the side of safety. The curve giving safe compressive stresses for various ratios of $\dfrac{L}{b}$ corresponding to 16,000 pounds per square inch tensile stress was laid out from values calculated by the above formula. The curves for the lower allowable tensile stresses were reduced proportionally; thus, for 14,000 pounds tensile stress any value of $S_c = \dfrac{14{,}000}{16{,}000} =$ ⅞ of the value for 16,000 tensile stress. [MACHINERY, March, 1908, Maximum Stresses.]

Stresses in the Members of Roof Trusses

On pages 32 to 35, inclusive, explanatory matter and tables are given for determining the stresses in the members of roof trusses. The tables give the percentage which each member of a roof truss bears of the total load, in the various designs, and the explanatory remarks on page 32 give further explanation regarding the method of using these tables.

Splices for I-Beams and Channels

It often happens in the use of rolled shapes for structural purposes, that the material could be spliced together conveniently and with economy, provided an efficient and reliable form of splice were available. Splices for I-beams and channels, efficiently arranged and carefully calculated, are shown on pages 36 to 42, inclusive. The sections are taken from Carnegie's Hand-book, and a medium section of each size has been chosen. In every case the splices for I-beams and channels consist of a top and bottom plate, or plates, riveted to the flanges, and two side plates riveted to the web.

The reason why medium-sized sections have been selected for the calculations, rather than the so-called standard sections, is that the medium-sized section more nearly fulfills the average requirements in design, and as the steel mills constantly roll other than the standard sections, they can easily be obtained.

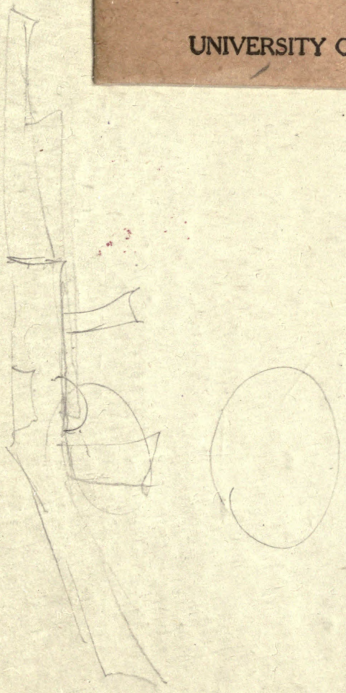
The efficiency of the riveting, net section of the beam, etc., are also given in percentages on the pages referred to. Splices are not shown for I-beams and channels smaller than the 6-inch sections, because it is not often necessary to splice such small pieces; also, the efficiency of the splice would probably be low. [MACHINERY, November, 1909, Splices for I-beams and Channels.]

Proportions of Riveted Joints for Pressure Tanks

The tables and diagrams on pages 43, 44 and 45 are made up for use when designing tanks subjected to internal pressure. On page 43 are given standard proportions for riveted joints for tanks of this kind. The standard longitudinal seams used for pressure tanks are: 1. A single riveted lap joint with an efficiency from 51 to 59 per cent. 2. A double riveted lap joint with an efficiency ranging from 60 to 74 per cent. 3. A double strap triple riveted butt joint with an efficiency varying from 83 to 88 per cent.

The dimensions required for laying out the riveted joints for any of these three types are given in the table on page 43. Page 44 gives the plate thickness required for varying working pressures in pounds, tank diameter in feet, and different types of riveted joint. For example, assume that the working pressure in a tank is 200 pounds per square inch, that the tank is 6 feet in diameter, and that a double strap triple riveted butt joint is to be used. Then locate 200 pounds on the scale at the bottom of the diagram on page 44, and follow the vertical line from 200 until it intersects the diagonal line for 6 feet tank diameter. From the point of intersection follow the horizontal line until intersecting the diagonal line for a double strap joint. From the point of intersection thus located follow a vertical line downwards to the bottom scale. It will be seen that a plate thickness of slightly more than 3/4 inch is required. In this case, a plate 13/16 inch thick would probably be used.

Page 45 gives a diagram by means of which it is possible to determine the approximate weight of a pressure tank when the length and diameter in feet and the thickness of the shell in inches are known. Assume as an example that the diameter of a tank is 10 feet and the length 20 feet. The plate thickness is 5/8 inch. Adding the length and diameter together, the sum 30 feet is located to the left on the bottom scale in the diagram on page 45 and the vertical line from 30 is followed until it intersects the diagonal line corresponding to a diameter of 10 feet. From the point of intersection follow the horizontal line until it intersects the diagonal line for 5/8-inch plate thickness, and from this point of intersection follow the vertical line downward to the bottom, where the approximate weight of the tank, 30,000 pounds, is found. [MACHINERY, July, 1910, Weights of Cylindrical Pressure Tanks.]



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