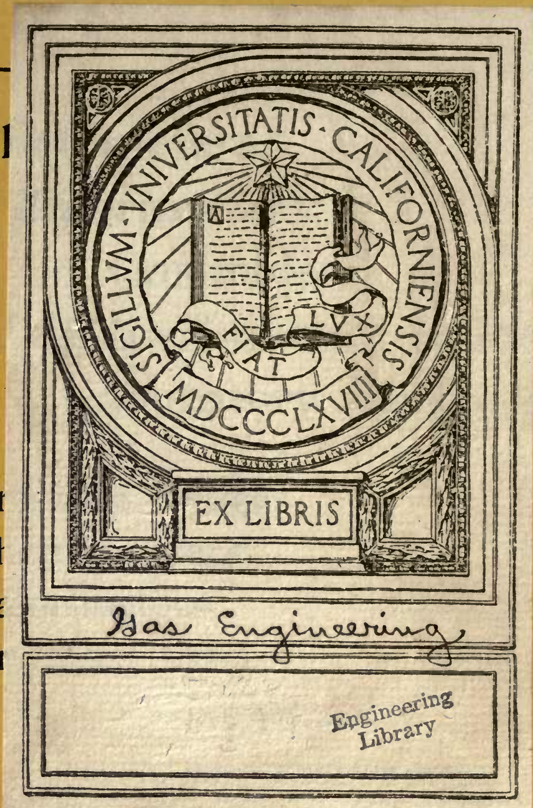
Self-Instruction For Students in Gas Manufacture:

Constructional



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Self-Instruction For Students in Gas Manufacture: Constructional.

BY

"MENTOR"

AND

JAS. T. A. TAYLOR.

[*SECOND EDITION.*]

LONDON:

"THE GAS WORLD" OFFICES, 8, BOUVERIE STREET, E C.

PREFACE.

In "Self-Instruction in Gas Manufacture: Elementary,"* "Self-Instruction in Gas Manufacture: Advanced"* and "Self-Instruction for Students in Gas Supply: Elementary,"* the author discusses, in the form of question and answer, the general principles involved in the various operations and processes connected with the manufacture and distribution of gas. In this little book notes are given which may assist the student in understanding the nature of some of the manifold operations connected with the construction of the various buildings met with in gasworks. In this edition a chapter on Steam Boilers has been added; also a chapter, by Mr. Jas. T. A. Taylor, draughtsman at the Granton gasworks, Edinburgh, on "Building Construction." The information given in the book is of an elementary character, and is intended chiefly for those who have not had the benefit of drawing-office experience.

* London: "The Gas World" Offices, 8, Bouverie Street, E.C. Price 3s. 6d. each.

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(By Jas. T. A. Taylor.)

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SELF-INSTRUCTION IN GAS MANUFACTURE.

CHAPTER I.

TAKING OUT QUANTITIES.

In these pages a brief description is given of some of the operations connected with the design and construction of the various buildings met with in a gasworks. The information is of an elementary character, as the book is not intended for experienced constructional engineers, but for those who have not had the benefit of drawing office practice. The first thing to do, in order to ascertain the cost of the erection of a building, is to "take out quantities;" that is to say, the quantities of the various materials required in the construction of the building have to be measured.

The principal item in the cost of a building is usually brickwork. We therefore commence by showing in a general way, without going into minor details, how the quantity of brickwork in a building is arrived at. In order to understand what follows, it will, first of all, be necessary to explain how brickwork in general is measured.

An ordinary stock brick is $8\frac{1}{2}$ inches long, 4 inches wide and $2\frac{1}{2}$ inches thick; but when estimating the number of bricks required for a wall of given dimensions allowance must be made for the space occupied by the mortar. This is usually done by adding ½ inch to each dimension of a brick, which is then supposed to measure 9 inches by 4½ inches by 3 inches. Brickwork is usually measured in the south of England and in the London district by the rod of the standard thickness of one brick and a half, or 13½ inches, and a standard rod is the amount of brickwork contained in so much of a wall of standard thickness as has a face of one square rod (*i.e.*, 30¼ square yards or 272¼ square feet). In practice, the face of a standard rod is taken as 272 square feet, the odd ¼ square foot being discarded; and a rod of brickwork of standard thickness contains 11⅓ cubic yards. In order to find the number of standard rods in a wall of given dimensions we find the number of square rods in the face by dividing its area, expressed in square feet, by 272. The result will be the required number of rods of brickwork, if the wall is of standard thickness; if not, the result must be multiplied by the number of half bricks in the thickness and this product divided by 3. In the north of England brickwork is valued on the basis of the square yard 9 inches thick. In Scotland brickwork is measured by the square yard, the standard thickness being 18 inches.

The following example will illustrate the method of arriving at the amount of brickwork from given dimensions:—

The length of a wall is 178 feet 6 inches and its height 8 feet. Find how many standard rods of brickwork it will contain, supposing it to be two bricks thick:—

Then	178 6	
	8	
	1428	square feet = area
	4	= number of half bricks thick
Standard divisor 3)	5712	
272)	1904	(7 rods
	1904	

The length of a wall is 57 feet 3 inches, height 24 feet 6 inches, and the thickness 2½ bricks; find the number of standard rods of brickwork in the wall.

```
              57·25
               24·5
           ---------
              28625
             22900
            11450
           ---------
           1402·625 square feet=area
                  5=number of half bricks thick
           ---------
         3)7013·125
     272)2337·708(8·6 rods
           2176
          -------
           1617
           1632
```

A gasworks is enclosed by a boundary wall, two sides of which are 150 yards long and two sides 100 yards long; tne wall is 10 feet high and 2 bricks thick. Calculate the number of rods of brickwork it contains.

```
         150×2=300
         100×2=200
              -----
               500
                 3
              -----
              1500 feet=total length
                10
             ------
             15000 square feet=area
                 4=half bricks in thickness
             ------
           3)60000
       272)20000(73 rods 144 square feet
           1904
           -----
            960
            816
           -----
            144
```

Footings are so arranged that the bottom course is twice the thickness of the wall resting upon them, each course losing in thickness half a brick, successively stepping off in offsets of $2\frac{1}{4}$-inch on each side until the desired thickness of the wall is attained. For example, a 2-brick wall would have a bottom course of 4 bricks, the next $3\frac{1}{2}$, the next 3, the next $2\frac{1}{2}$, and then the neat work. To obtain the average thickness of footings, add the thickness of the top and bottom courses of footings together and divide by 2. Thus in the case of a 2-brick wall, as assumed

Top course	$2\frac{1}{2}$	bricks
Bottom ,,	4	,,
	$6\frac{1}{2} \div 2 = 3\frac{1}{4}$	bricks, average.

And, assuming the total length of the wall to be 100 feet this would appear as :—

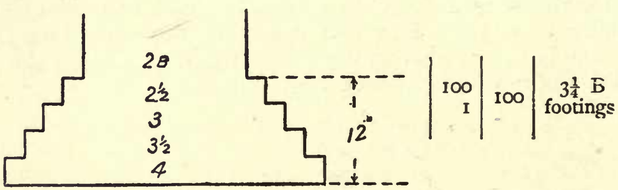


FIG. 1.

Quantities are taken out by taking measurements from the drawings. This enables one to calculate the quantity of material and amount of labour that it will take to complete the building according to the drawings and specification; and this having been arrived at, by affixing prices to the items of materials and labour the ultimate cost can be estimated. The operations involved in the production of the finished bill of quantities consists in (1) "taking off," *i.e.*, measuring the drawings and noting the dimensions, the latter being afterwards "squared" or "cubed," as the case may be; (2) "abstracting" or arranging the items according to the various trades, such as bricklaying, carpentering, etc.; (3) "billing," which consists in bringing from the abstract the totals of the various items so as to form a "bill," which can then be priced out according to local prices.

The items as they are taken off the drawings are usually entered up on a sheet of paper ruled as follows:—

1	2	3	4
	42 4 1	168	15 10 5 12 — 42 Concrete in trenches.
2	3 7	42	$1\frac{1}{2}''$ 4-panel door.

Column No. 4 gives the particulars of the item, the amount of which is placed in column No. 2, these dimensions being worked out in superficial or cubic measurement and placed in column No. 3. Should the same item occur more than once, the number of times it recurs is placed in column No. 1, as in the example shown, where we have two doors of the dimensions given.

We now proceed to show how the quantity of brickwork in a retort house would be taken off. The plan and cross section of the walls (Figs. 2 and 3, pp. 6 and 7), with the necessary dimensions marked, will easily enable the operations to be followed. The building is supposed to be built of "stocks" set in ordinary mortar.

In measuring walls you multiply the length by the height and state the thickness in the description as $1\frac{1}{2}$, 2, $2\frac{1}{2}$ brick wall as the case may be. All walls should first be taken "solid," any openings being deducted afterwards. You commence at the foundation and take the footings as one item, averaging their width as previously explained. Thus a 2-brick wall would have 4 course of footings (= 1 foot deep), and the average thickness would be $3\frac{1}{4}$ bricks.

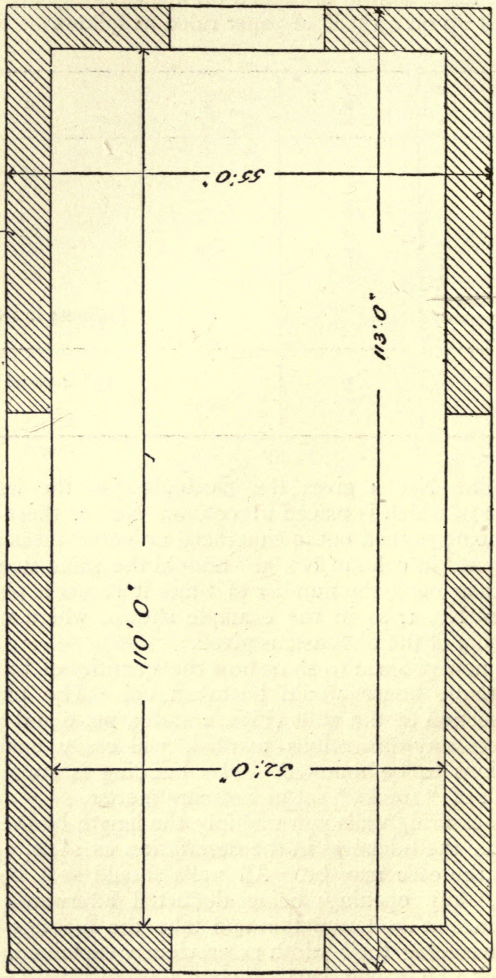


FIG. 2.

After the footings you take all the brickwork of one thickness, and then the next, according to the "set-off."

The best way of obtaining the length of walls in a

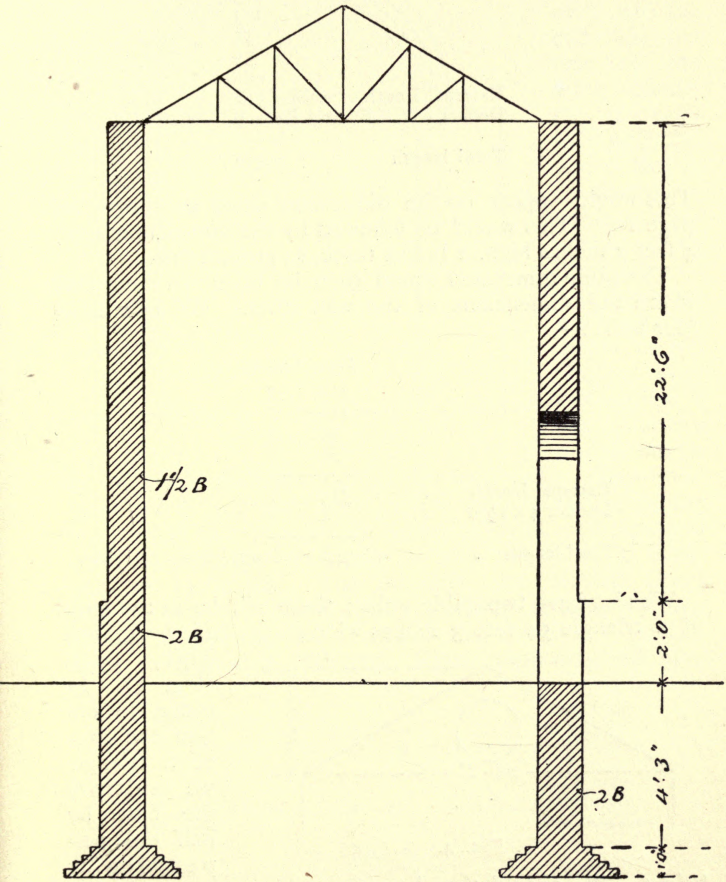


FIG. 3.

rectangular building is to add the external length of walls and deduct four times their thickness. Thus we have :—

	Feet.
	113
	113
	55
	55
External length of walls	=336
Deduct 4 × 1′ 6″ or 2 B	= 6
Total length	=330

This would appear on the dimension sheet as shown on page 10. This would be followed by the same dimension, 4 feet 3 inches high, 2 bricks thick, to ground line.

The same dimension would then be taken to the set-off where the dimensions of the wall alter. We now have four walls :—

	Feet.	Inches.	
	112	3	
	112	3	
	54	3	
	54	3	
External length . .	333	0	
Deduct 4 × 1½ B . .	4	6	
Total length . .	328	6	× 22½ feet × 1½ bricks

We also have two gable walls ; these will be in the form of a triangle 54 feet 3 inches wide at the base by 17 feet high, each (Fig. 4). In order to obtain the area of a triangle we multiply the base by half the perpendicular height. We should then have two gables, 54 feet 3 inches × 8 feet 6 inches.

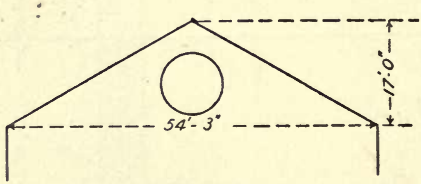


FIG. 4.

We now come to the deductions. Say there are seven circular openings 3 feet in diameter in each of the end walls; sixteen of the same diameter in each side wall and one 6 feet in diameter in each gable wall. Say there are also four doorways with semi-arches at top (Fig. 5). Four semi-arches 8 feet diameter = two circles

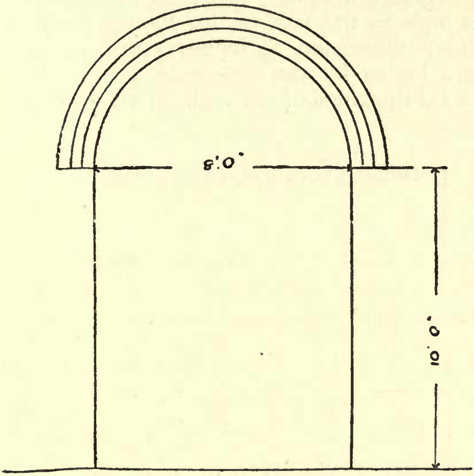


FIG. 5.

of the same diameter = 50·26 feet area each. The doorways are 8 feet wide and 10 feet high to the springing line; 2 feet of the brickwork (to set-off) is of a thickness of 2 bricks, and the remainder of the height of a thickness of $1\frac{1}{2}$ bricks. The doorways are without doors and frames, and consequently do not require reveals. Should a doorway have reveals the mode of measurement is somewhat different. Thus, supposing we have

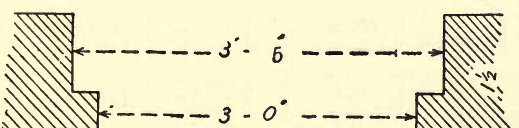


FIG. 6.

an external door with solid frame, as in Fig. 6, and the opening is 7 feet high to the springing, in this case two items will be required—first, a deduction of the external opening of 3 feet wide by 7 feet high by the outer thickness of the wall to the face of the frame, which is ½ brick, and also a dimension 2½ inches wider on each side and 3 inches higher by the difference between the ½ brick and the total thickness of the wall. This would be shown as

3 0 7 0	21	Deduct ½ brick wall, door external.	
3 5 7 3	24·7	,, 1 ,,	door internal opening.

"TAKING OFF" DIMENSION SHEET.

	330 1		330	3¼ B	Brick footings.
	330 4	3	1402·5	2 B wall	To ground line.
	330 2		660	2 B ,,	,, set-off.
	328 22	6	7380	1½ B ,,	,, top.
2	54 8	3 6	922·2	1½ B ,,	,, gable.
46			325·15	1½ B deduct	openings.
2			56·54	1½ B ,,	,, gable wall.
4			100·52	1½ B ,,	head of doorway
4	8 8		256	1½ B ,,	doorway.
4	2 8		64	2 B ,,	,,

The next operation is that of abstracting the various items from the dimension sheet, and arranging them in a convenient order for reducing to the standard thickness of

$1\frac{1}{2}$ bricks. This is accomplished, in the first place, by reducing the brickwork, where above $1\frac{1}{2}$ bricks, to either 1 brick or $1\frac{1}{2}$ bricks, whichever is the simpler, and abstracting it accordingly. Then, after it is all abstracted, the total of the 1 brick is brought into $1\frac{1}{2}$ bricks by multiplying it by $\frac{2}{3}$ rods. Thus, in the case of the footing, we have 330 feet of $3\frac{1}{4}$ brick, and this could be reduced to $1{,}072\frac{1}{2}$ of 1 brick.

The following would be the form of the abstract sheet :—

REDUCED BRICKWORK IN MORTAR SUPER.

One Brick.	One Brick Deduct.	One and a-half Brick.	One and a-half Brick Deduct.
$1072\frac{1}{2}$ 2805 1320 —— $5197\frac{1}{2}$ 128 —— $5069\frac{1}{2}$ 2 —— 3)10139 3379 6	128	7380 922·2 —— 8302·2 738·2 —— 7564 3379·6 —— 272)10943·6(40·2 rods 1088 —— 636 544	325·15 56·54 100·53 256·00 —— 738·22

The next operation is to bring the items in the abstract into the bill. The items dealt with would appear as follows :—

BRICKLAYER.

The bricks to be good sound stocks in mortar, laid to English bond, the mortar to be composed of one part of blue lias lime to three of clean sharp sand.

Rods 40 23			Super.	Reduced stock brickwork as above described in mortar, in footings and walls.		

It is necessary to note that the example given is simply intended as a guide to the general principles involved in the preparation of the quantities of a building, and must not be taken as covering the whole of the brickwork of a building of the class given. For instance, facing bricks, cutting to arches and gables, string and plinth courses, centring of arches, etc., would all figure as extras. But it would not serve any useful purpose to describe the method of measuring these. It should also be noted that builders usually express their figures duodecimally, while engineers generally employ the decimal system, which has been followed in the present instance.

In arriving at the cost per rod, local prices will necessarily vary, but it will be useful to show how to arrive at the cost from the current rates. Taking the wages of a bricklayer at 10d. and of a labourer at 6d. per hour, the cost of labour in building a rod of brickwork of standard ($1\frac{1}{2}$ brick) thickness would be, say, £3, and the total cost would be approximately as follows :—

	£	s.	d.
4,300 stocks at 35s. per 1,000	7	10	6
Water for wetting bricks, say	0	0	6
Labour	3	0	0
Fixing, taking down, and use of scaffolding, say .	0	4	0
2 cubic yards of stone lime mortar, 1 to 3, at 18s. .	1	16	0
	£12	11	0
To this must be added a profit of 10 per cent. .	1	5	2
Making the total cost per rod	£13	16	2

Mason's Work.

We now proceed to describe the method of measuring the work of the remainder of the more important trades which find a place in a gasworks buildings. Following the bricklayer comes the mason; and the principal mason's work usually met with in an ordinary retort house is coping stones and window sills. Coping stones are frequently measured by the foot run, giving sizes, the largest dimension being given each way. The nature of the workmanship should be specified—whether tooled, rubbed or otherwise, and the description should always be accompanied by a sketch, as in Fig. 7, which would have the following description :—

(sav) 140′ run.	12″ × 4″ York stone coping, as per sketch, tooled, weathered, and throated on both edges, all joints included.

Window sills are also measured by the foot run, *i.e.*, the length of the sill and the width and thickness should be stated. The nature of the workmanship should be described —whether tooled, weathered and throated, etc. The following items are numbered, viz., "fair ends" and "the ends cut and pinned to walls."

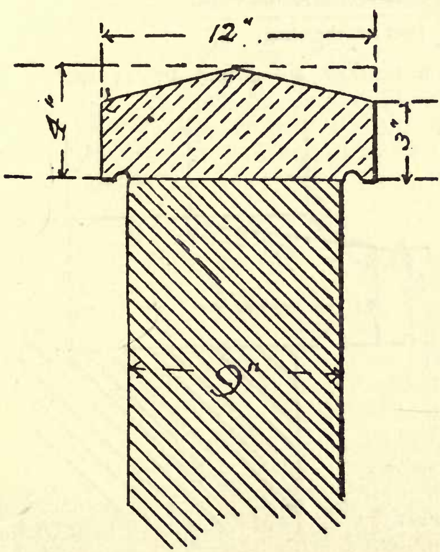


FIG. 7.

A more exact method is to take out the cubical contents of the stone and then to measure the various labours, as in the following examples :—

Fig. 7 shows the cross section of a coping stone, 12 inches wide by 4 inches thick, rubbed on top and sides and throated both edges. One stone is taken of the usual length of 3 feet, and this is multiplied by the total number of stones to get the total length.

	Ft.	Ins.	Ft.	
	3	0		
	1	0		
	0	4	1·0	Cube Portland stone.
	3	0		
	1	0	3·0	Bed.
2	3	0		
	0	3	1·5	Sides.
2	1	0		
	0	4	0·7	Ends.
			5·2	Half sawing.
2	3	0		
	0	7	3·5	Feet super., straight sunk face to weathering.
2	3	0		
	0	7	3·5	Weatherings (top).
2	3	0		
	0	3	1·5	Sides.
			5·0	Super. plain rubbed work.
2	3	0	6 0	Feet run throating.

Fig. 8 shows a window sill 4 feet by 11 inches by 4 inches, sunk, weathered, and throated, and grooved for iron tongue.

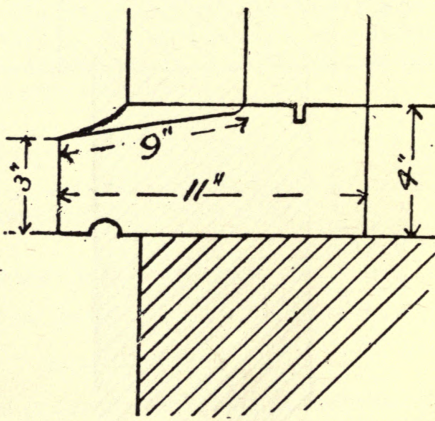


FIG. 8.

	Ft.	Ins.	Ft.	
	4	0		
		11		
		4	1·2	Portland stone sill.
	4	0		
		9	3·0	Top.
	4	0		
		11	3·7	Bed.
	4	0		
		4	1·3	Back.
2		11		
		8	1·2	Ends.
			9·2	Feet super., half sawing to top, bed, back, and ends.

	4 0 3	1·0	Feet super., plain face to front edge.
	4 0 9	3·0	Feet super., sunk face for weathering.
2			Stops for weathering.
	4 0 3	1·0	Front edge.
2	3 3	0·2	Fair ends.
		1·2	Feet super., extra only for plain rubbed work.
	4 0 9	3·0	Feet super., extra for sunk rubbed work to weathering.
2	4 0	8·0	Run groove and throat.

Slater's Work.

Slating is measured by the "square," which is 100 superficial feet. To measure a roof, take the extreme length of the eaves, A to B (Fig. 9), and multiply this length by the distance from the eaves to the ridge, C. This will give the superficial area of one side of the roof. By doubling this the measurement of the whole roof is obtained. An addition must be made for double eaves course equal to the length by the gauge of the particular description of slate used, which, in the case of Countesses slates and a 2½-inch lap, would be 8¾ inches. Slate ridging or ridge roll and cement filleting is taken

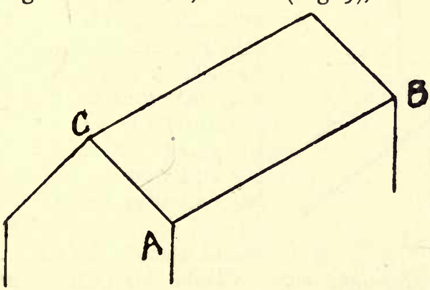


Fig. 9.

at per foot run. The space taken up by a chimney would be deducted.

Carpenter's Work.

Carpenter's work embraces the constructional woodwork of a building, including the necessary framing, and is generally taken at per cubic foot. In measuring framed work each piece is measured to the extreme length and to the end of all tenons; and where a scarf occurs its length is added. Should no scarf be shown on the drawing, one should be allowed in every 20 feet length; and it is arrived at by taking three times the depth of the particular timber joined.

The most common and important piece of carpenter's work met with on a gasworks is that of a roof truss. We now proceed to show how to take off the quantities of the truss shown in Fig. 10. In measuring a roof of the description shown, all timbers forming the truss, as the tie beam, king post, principal rafter and struts, should be kept separate from the other portion of the roof and described as "fir framed in trusses." In measuring the king post the width should be taken at the widest part, as in A (Fig. 11), no deduction being made for the portion cut away, in order to allow for the sawing and waste. We then have another item of "fir framed in roofs." This would include the purlins, rafters, pole plates, ridge, etc. Cleats for purlins are numbered, their size and shape being given. The ridge roll would be taken at per foot run. The ironwork is measured with the timber, the labour for fixing it being numbered, but it is billed under the heading of "Smith."

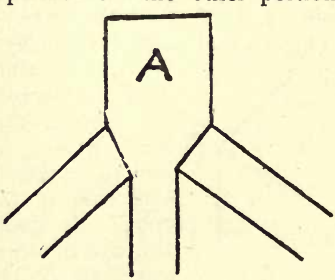


Fig. 11.

The plan of the roof would be as in Fig. 12 (page 18).

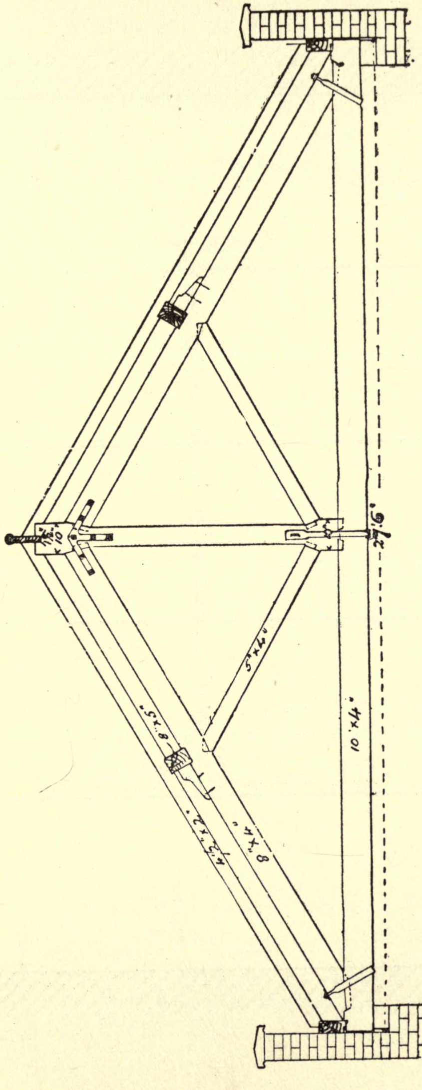


FIG. 10.

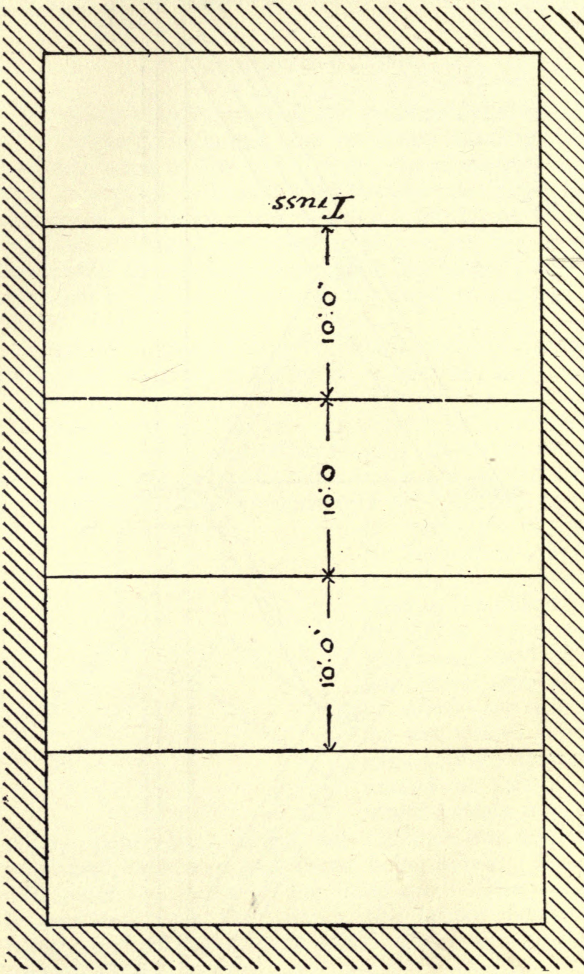


FIG. 12.

Woodwork of Roof.

	Ft.	Ins.	Feet.	
4	30	0 4 10	33·33	Fir framed in 4 roof trusses, including hoisting and fixing 25 feet from ground level . 27·6 Scarf . . . . 2 6 — Tie Beam. . . . 30·0
4/2	14	6 4 8	25·68	Ditto principal rafters.
4	8	6 4 10	9·44	Ditto king post.
4/2	6	6 4 5	7·22	Ditto strut.
4/2	3	0	24	1·4 4 1·4 — 3·0″ 2″ × $\frac{3}{8}$″ wrought iron in heel straps, ends forged and threaded with $\frac{1}{2}$″ nut and washers.
4/2		8		Fixings to heel strap.
4	4	10	19·3	2·3 ·4 2·3 — 4·10″ 2″ × $\frac{3}{8}$″ wrought iron strap junction of tie beam and king post.
4	1		4	Sets W. I. gibs and cotters for ditto.
4/2	3	6	28	1·3 1·3 1·0 — 3·6″ 1$\frac{1}{2}$″ × $\frac{3}{8}$″ W. I. strap joining principal rafter and king post.
4	2		8	Fixings to W. I. straps.
4	7		28	$\frac{1}{2}$″ W. I. bolts 6″ long and fixings to 6″ bolts.
				Labour in forming scarf to 4″ × 10″ tie beam, including bolts.

	Ft.	Ins.	Feet.		
2	55	6 4 9	27·73	Fir framed in roofs . . . . Scarfs . . . . Portion on wall, say . . . . Pole plates.	50 4·6 1 55·6″
2	55	6 5 8	30 83	Scarfs . . On wall . Ditto purlins.	50·0 4·6 1·0 55·6″
1	51	0 $1\frac{1}{2}$ 9	4·78	On walls . . Ditto Ridge.	50·0 1·0 51·0″
2,45	15	6 2 $4\frac{1}{2}$	87·18	Ditto common rafters.	
4	2		8	12″ × 4″ × 4″ fir cleats, purlins.	
	50	0	50 0	2″ roll spiked ridge.	
4	1		4	Labour in forming scarfs to 5″ × 8″ purlins, including bolts.	
4	1		4	Ditto to 4″ × 9″ pole plates.	

Abstract.

CUBE.

FIR FRAMED IN FOUR ROOF TRUSSES HOISTING AND FIXING 25 FEET FROM GROUND—	FIR FRAMED IN ROOFS.
33·33	27·73
25·68	30·83
9·44	4·78
7·22	87·18
75·67	150·52

RUN.

50 feet 2-inch rolled spike ridge.

Nos.

Labour in scarfs to 5-inch × 8-inch purlins, including bolts . = 4
" " to 4-inch × 9-inch pole plates . . . . = 4
12-inch × 4-inch × 4-inch shaped cleats . . . . . . = 8
Fixings only to bolts 28 6-inch . . . . . . =28
Fixings to straps 8
" " 8 =16

From the abstract we obtain the following bill, so far as the carpenter's work proper is concerned :—

Feet.			£	s.	d.
76	Cube	Fir framed in four roof trusses, hoisting and fixing 25 feet from ground level.			
150	,,	Ditto in roofs.			
50	Run	2-inch ridge roll.			
No.	4	Labour in scarfs to 5-inch × 8-inch purlins.			
,,	4	Labour in scarfs to 4-inch × 9-inch pole plates.			
,,	8	12-inch × 4-inch × 4-inch shaped cleats.			
,,	28	Fixing only to 6-inch bolts.			
,,	16	,, ,, ,, straps.			

A fair price to allow for the above work is 3s. 6d. per cubic foot, plus 30s. for hoisting.

Joiner's Work.

The measurement of the work of the joiner differs from that of the carpenter in respect that the net superficial measurements are taken, and they do not include tenons except in the case of door frames. The principal items which occur under the head of joiner's work is that of doors and windows. In measuring doors you measure the width by the height, stating the thickness of the material, the number of panels and method of finishing, after which the size and description of hinges, bolts, locks and fastenings should be taken. In measuring the door frames you take the height of the door, multiply by 2 for the two sides and include on each side the tenons into the head, allowing an additional two inches on each side for "stubbing" into the sill. To this is added the width of the door, plus twice the thickness of its frame and an extra 6 inches for the horns. Thus, supposing you have a door $7' \times 3'$, the frame being made of timber $4'' \times 4''$, we should have:—

	Ft.	Ins.
Height of door for one side	7	0
,, ,, other side	7	0
Add for two tenons	0	8
,, ,, stubs	0	4
Width of door	3	0
Two thicknesses of frame	0	8
Extra for horns	0	6
	19	2

and this would appear as :—

19′ 2″		
4		
4	2·1	Fir wrought in door frame.

In measuring window sashes and cased window frames, which are taken at per foot superficial, the usual method is to take the width between the pulley stiles, adding 4 inches on each side for the frame. The height is taken from the top of the stone sill to the under side of the head, adding 4 inches for the head and 3 inches for the sill. An alternative method for obtaining the size of the frame is to add 9 inches to the net width of the external opening in the wall and 4½ inches to the height between the top of the stone sill and the soffit of the arch. The two dimensions multiplied together will give the superficial measurement. The thickness of the pulley stiles, head and lining, the size of the sash bead, thickness of the sash bars and sashes should be given, also the method of hanging and the description of the lines, pulleys, weights, sash fasteners, etc. It should be specified if the sill is of oak, and if single or double sunk, weathered or throated, and the number of feet run of metal tongue and groove in sill should be given.

Ironwork and Plumber's work.

Ironwork is usually charged by weight; and this can be obtained from the drawings, by taking out either in superficial or cubic measurement, according to choice. An example of each method is given, showing how to arrive at the weight of a wrought-iron joist and of a plate girder. Useful data to recollect in working out these weights are that a bar of wrought-iron 1 inch square and 1 yard long weighs 10 lbs. and a square foot of wrought-iron $\frac{1}{4}$-inch thick weighs the same. Iron eaves gutters are measured per foot run, the stopped ends and brackets being numbered extra.

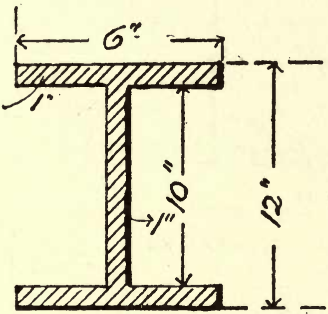


FIG. 13.

Rain water piping is also taken at per foot run, shoes, heads and gratings being numbered extra.

Plumber's work, including the labour of laying to gutters and flashings, is taken out at per foot superficial, but billed at per cwt.

Fig. 13 shows the cross section of a wrought-iron joist, flanges 6″ × 1″, depth 12 inches, length 20 feet. Find its weight.

	20		240 × (6 × 1 × 2) = 12			
	12		12			
12 − 2(1″) = 10	240		2880			
	10		2400			
	2400		5280			
	1		0·28 weight in lbs. of a cubic inch of iron.			
	2400		42240			
			10560	cwts.	qrs.	lbs.
		112)	1478·4(	13	0	22
			112			
			358			
			336			
			22			

The dimensions of a rolled iron joist, Fig. 14, are length 20 feet, flanges 8 inches by $1\frac{1}{2}$ inch, depth 24 inches; find its weight.

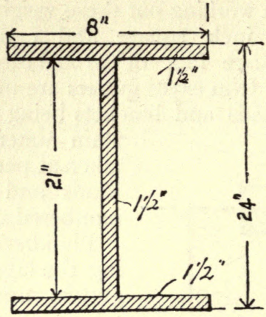


FIG. 14.

20
12
———
240 = inches.
$24 - 2(1\frac{1}{2}'') = 3 =$ 21
———
240
480
———
5040
$1\frac{1}{2}$
———
5040
2520
———
7560

$240 \times 8 \times 1\frac{1}{2} \times 2$
8
———
1920
$1\frac{1}{2}$
———
1920
960
———
2880
2
———
5760
7560
———
13320
0·28 = weight in lbs. of a cubic inch of wrought iron.
———
106560
26640
2240)3729·60(1
2240
112)1489(13
112
———
369
336
28) 33(1
28
—
5

Tons.	cwts.	qrs.	lbs.
1	13	1	5

The following is a method of taking off the quantities in a wrought-iron plate girder, 25 feet long, as per Fig. 15 :—

	Ft. In.	Feet.		
	25 0 1 6	37·5	¼″ plate in web	
	25 0 0 9	18·75	½″ plate bottom flange	
	25 0 0 9	18·75	½″ plate top flange	
4	25 0 0 8	66·00	⅜″ angle irons	4″ 4″
				8

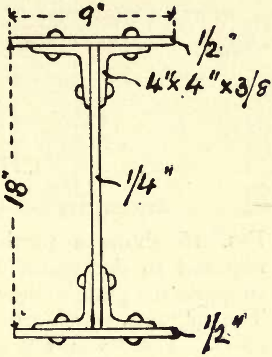


FIG. 15.

Feet.	*Calculation of Weight.*	Lbs.
37·5	¼-inch plate at 10·10 lbs. per foot . .	378·75
18·75	½ ,, ,, 20·21 ,, ,, . .	378·93
18·75	½ ,, ,, 20·21 ,, ,, . .	378·93
66·00	⅜ ,, ,, 15·16 ,, ,, . .	1010·56
		2147·17
	Add 5 per cent. for rivets . .	107·35
	Total weight of girder . T. 1 c. 0 q. 0 lbs. 14	2254·52

The above brief description of the method of arriving at the "quantities" of the various trades appertaining to the construction of gasworks buildings should enable the student to form an idea of how the cost of such buildings is arrived at, and thus serve the purpose intended.

CHAPTER II.

STRENGTH OF COLUMNS AND GIRDERS.

FIG. 16 shows a portion of a retort house, and it is required to determine the size of the column A, which supports the girders shown, together with the stage plates. The columns, which are 10 feet high, are spaced 10 feet apart. The stage will contain a certain amount of coal, and it is necessary to make the column strong enough to withstand a moving load due to the employment of stoking machinery. We will therefore assume that the column has to support a weight of 50 tons.

The following are the chief points to be kept in view in the designing of columns:—The principal calculation is that for determining the sectional area of the shaft of the column, and this depends partly upon the ratio of the diameter to the length and partly upon the ratio of the thickness to the diameter. The strength of cast-iron columns is dependent greatly upon the ratio of the diameter to the length. In the experiments of Mr. Kirkaldy it was found that cast-iron pillars under five diameters in length failed entirely by crushing, from five to twenty diameters partly by crushing and partly by bending, while over twenty diameters the failure was entirely due to bending. The thickness of metal in cast-iron columns should not be less than one-twelfth of the external diameter, the range varying between one-twelfth and one-sixth. It is usual in the designing of cast-iron columns to allow a factor of safety of 10 in arriving at the safe load from the breaking weight.

The columns in common use are usually tapered, the diameter at the top being from one-eighth to one-fourth less than at the bottom; and the strength of the column is calculated upon the smallest diameter. Before commencing to design a column it is necessary to know the weight it has to sustain; and this frequently depends upon the distance of the column from another column, a wall, or other support. The proportion of the weight sustained by each support may be found by the following rule:—"If a load be placed at any point on a beam (or girder) supported at both ends, the proportion of the load sustained by either support is equal to the load multiplied by the distance from its centre of gravity to the other support and divided by the length of the beam between the supports."

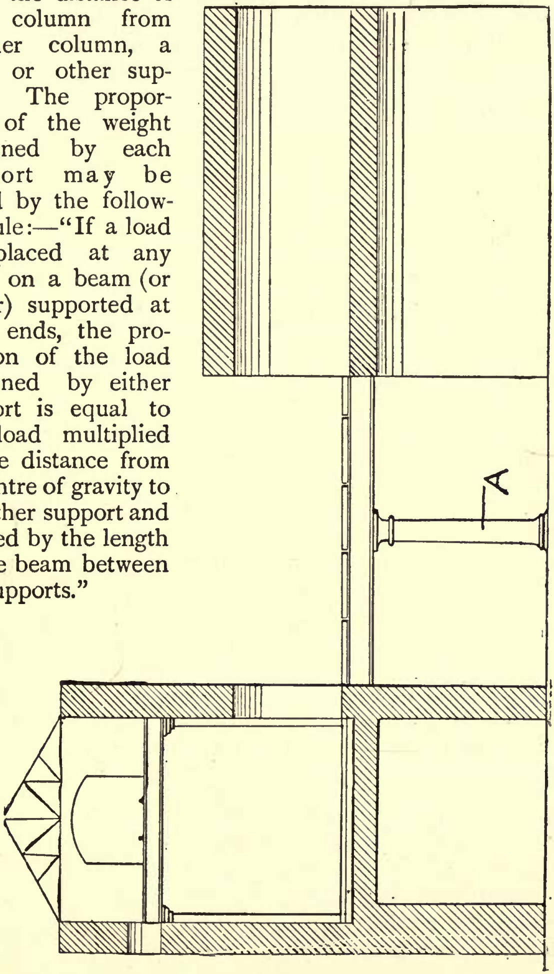


FIG. 16.

Fig. 17 shows a girder 25 feet long, supported at one end by a wall and at the other end by a column. The girder carries one end of another girder, at A, which carries a distributed load of 35 tons; hence the weight on the girder will be $35 \div 2 = 17 \cdot 5$ tons at a distance of 5 feet from the column. The weight of the main girder is 2·2 tons, and in order to arrive at the proportion of the weight on the column and wall respectively we say,

$$\frac{20}{25} \times 17 \cdot 5 = 14$$

$$\frac{5}{25} \times 17 \cdot 5 = 3 \cdot 5.$$

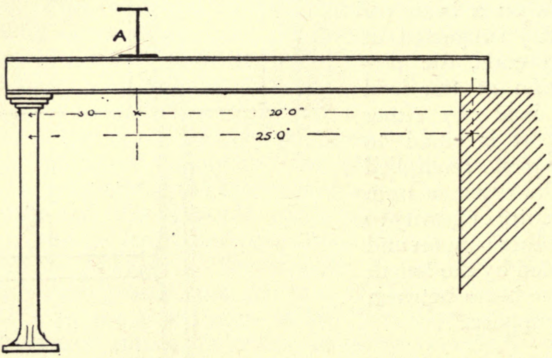


FIG. 17.

The weight of the girder itself, which will act as a distributed load, will be equally divided between the column and the wall, making 1·1 tons on each. The total weight on each will then be

On column.	On wall.
14	3·5
1·1	1·1
15·1	4·6

making the total weight 19·7, which agrees with the total weight of both loads—$17 \cdot 5 + 2 \cdot 2 = 19 \cdot 7$.

The proportion of the load sustained by each support is termed the reaction at that support. Thus, the reaction at the column end is $\frac{20}{25} \times 17.5$ and the reaction at the wall end $\frac{5}{25} \times 17.5$.

The formula most relied upon for determining the size of cast-iron columns is that known as Gordon's, which reads as follows :—

$$BW = \frac{36}{1 + \frac{r^2}{400}}$$

where BW = breaking weight in tons per square inch
36 = the ultimate crushing resistance of cast-iron in tons
r = ratio of length to least diameter.

It is usual in the designing of columns to, first of all, assume a certain diameter, and then to see if this will comply with the required conditions. In the example, if we assume that the external diameter is 9 inches, then the ratio of the length to the diameter is $\frac{10 \times 12}{9} = 13.3$, and $r^2 = 13.3^2 = 176.89$, say 177; therefore,

$$BW = \frac{36}{1 + \frac{177}{400}} = 25 \text{ tons.}$$

In order to provide against contingencies, the safe load is usually taken at one-tenth of the breaking load, so $25 \div 10 = 2.5$ the safe load, and the number of square inches of metal required will be $50 \div 2.5 = 20$. Now, we know the area of the ring of metal, also the external diameter, and we obtain from a table of areas of circles the nearest internal diameter corresponding to the area of 20. The difference will, of course, give the thickness of metal.

$$\begin{aligned} \text{Thus } 9'' \text{ area} &= 63.617 \\ 7\tfrac{3}{8}'' \quad ,, \quad &= 42.718 \\ \hline &\ 20.899 \end{aligned}$$

Difference between 9″ and $7\frac{3}{8}''=1\frac{5}{8}''$ = internal diameter $\div 2=\frac{13}{16}$ as the thickness of metal required. This would be taken as $\frac{7}{8}''$.

In calculating the strength of cast-iron columns, much assistance may be obtained from the following table, which is of American origin:—

ULTIMATE STRENGTH OF HOLLOW, CAST-IRON COLUMNS IN POUNDS PER SQUARE INCH OF SECTIONAL AREA (BERKMIRE).

$\frac{L}{D}$	Round.	Square.	$\frac{L}{D}$	Round.	Square.
5	75,300	76,200	17	46,444	50,700
6	73,400	74,630	18	44,200	48,540
7	71,270	72,860	19	42,100	46,460
8	68,970	70,920	20	40,000	44,450
9	66,530	68,850	21	38,100	42,510
10	64,000	66,670	22	36,200	40,650
11	61,420	64,410	23	34,460	38,870
12	58,820	62,110	24	32,790	37,175
13	56,240	59,890	25	31,220	35,560
14	53,860	57,470	26	29,740	34,010
15	51,200	55,170	27	28,340	32,550
16	48,780	52,910	28	27,030	31,150

In order to show the use of the table we will apply it to the example previously given, *i.e.*, to find the safe load on a cast-iron column with fixed ends, 10 feet long, 9 inches diameter, thickness of metal, $\frac{13}{16}''$, factor of safety, 10.

Here $\frac{L}{D}=\frac{120}{9}=13{\cdot}3$, the nearest equivalent strength for which in the table is 56,240 lbs. per square inch. The area of the material in the column is $0{\cdot}7854(9^2-7\frac{3}{8}^2)=20{\cdot}9$. Therefore the total safe load is

$$\frac{56240\times 20{\cdot}9}{10}=117541 \text{ lbs., or } 52{\cdot}4 \text{ tons,}$$

which practically agrees with the previous calculation. If we could hit exactly upon a thickness equivalent to the 20 inches area, we should get the 50 tons exactly, thus—

$$\frac{56240 \times 20}{10} = 112480 \text{ lbs.}$$

In the table of safe loads on cast-iron columns given in Hurst's Pocket-Book, a 9-inch column $\frac{7}{8}$-inch thick is stated to be capable of sustaining a load of 55 tons; so our calculations are shown to agree with practice.

Fig. 18 shows a column in detail. In this type of column

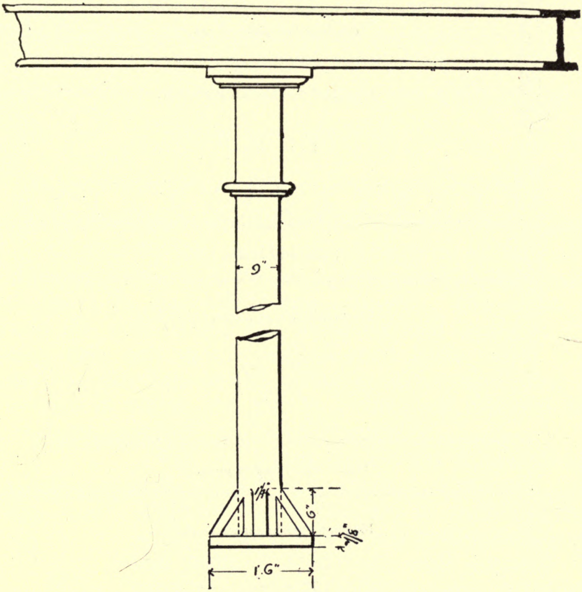


FIG. 18.

the cap and base plates are made twice the diameter of the column.

At the present time a considerable portion of the constructional steel work met with in gasworks is made up of various combinations of joists, which take the place of plate or built up girders. One of the advantages attending the use of such joists is that, in many instances, a suitable size can be at once selected from a maker's list, without the necessity of working out elaborate mathematical calculations; all that it is requisite to know being the general effect of different systems of loading on the weight capable of being supported by a girder or joist, as shown in Figs. 19, 20, 21 and 22; from which

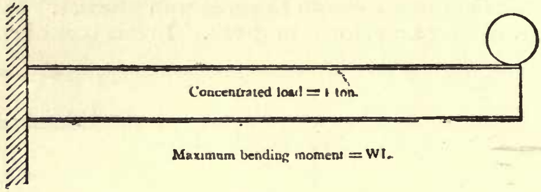


FIG. 19.

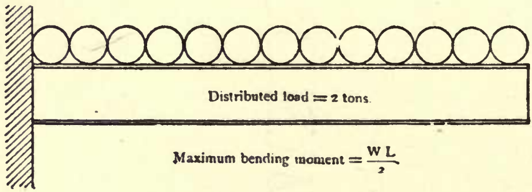


FIG. 20.

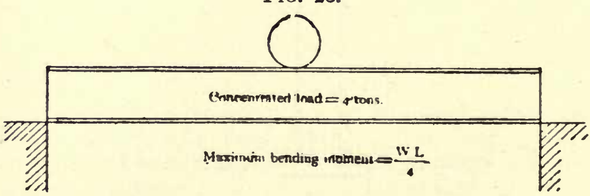


FIG. 21.

it will be seen that the same sized joist is capable of carrying eight times the load when its ends are supported and the weight distributed that it would be capable of carrying if one end was fixed and the load concentrated. Of course, there are examples of loading other than those shown which sometimes occur. These will be explained later on. The following are some of the more important points which it is necessary to understand before commencing the study of loads on girders and joists.

A dead load is a load steadily applied, such as the weight of a wall; a live or moving load is a load applied suddenly and accompanied by vibration, such as the floor of a room or the stage of a retort house. A live load is twice as destructive as a dead load of the same nominal amount. Hence a live load is reduced to an equivalent dead load by doubling it. A concentrated load is applied at

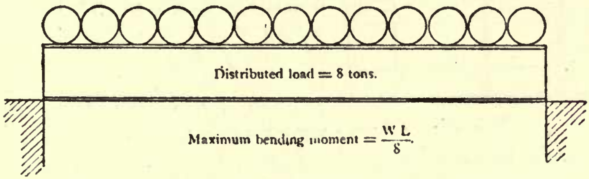


FIG. 22.

a single spot, while a uniformly distributed load is spread equally all over the joist or girder. The same sized girder similarly supported will carry twice the load if uniformly distributed that it would if concentrated. The factor of safety is the ratio which the breaking load bears to the working load, and in the case of steel joists varies from one-third to one-fifth of the breaking strain, according to the manner in which the joist is loaded, *i.e.*, whether the load is dead, or "live" and rapidly applied.

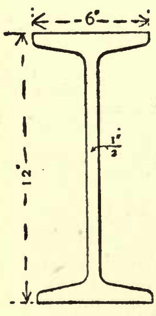


FIG. 23.

Fig. 23 shows the section of an ordinary joist, while Fig. 24 shows a compound joist made by connecting two or three ordinary joists by means of cast-iron distance-pieces and bolts. These are well adapted for carrying wide doorways and windows. Fig. 25 shows various methods of connecting rolled joists to one another. We now proceed to show the method of using a manufacturer's list of joists in selecting a joist capable of supporting one side of the structure shown in the rough sketch, Fig. 26. The span is 18 feet, and the structure consists of a brick shed, roofed in. The thickness of the brickwork is 9 inches, and the weight is assumed to be 14 tons, which will act as a distributed load. The maker's list selected is that of Messrs. Dorman Long and Co., of Middlesbrough; and the drawings of the joists in Figs. 23, 24, and 25 are from the same source. The steel employed in these joists is capable of standing a tensile strain of 32 tons per square inch; and taking a factor of safety of one-fifth of the breaking strain, we find that a 12-inch by 6-inch steel joist, weighing 54 lbs. per foot, is capable of carrying a distributed load of 14 tons over a span of 18 feet. We will next proceed to see if the size selected agrees with the size demanded by theory, and also

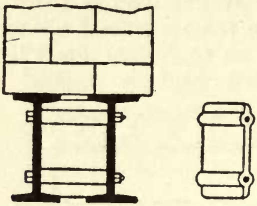


FIG. 24.

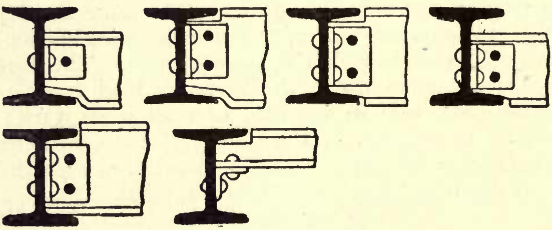


FIG. 25.

if it conforms to certain standard conditions. The following is an approximate formula for arriving at the size of joist capable of sustaining a given load :—

$$W = 1{\cdot}2(w - 0{\cdot}3bd)\,\frac{d}{L}.$$

W = safe uniformly distributed load in tons.
w = weight of joist in pounds per foot.
b = breadth in inches.
d = depth in inches.
L = span in feet.

The factor of safety in this case is 3.

Another approximate formula is :—

$$SL = 7\frac{ad}{S}.$$

SL = safe uniformly distributed load in tons.
a = area of one flange in inches.
d = depth in inches.
S = span in feet.

The power of a joist to resist cross fracture depends upon the relationship of the moment or leverage of the load, known as the bending moment, to the moment or

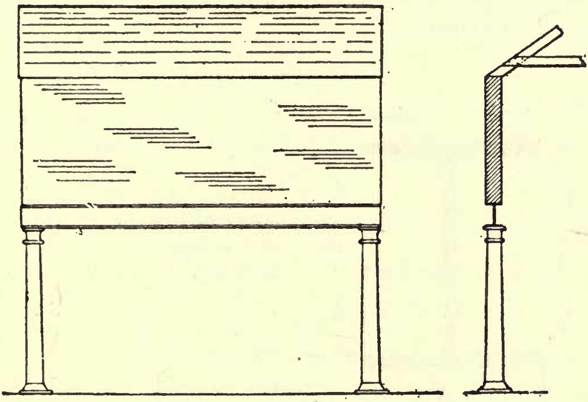


FIG. 26.

leverage of the forces due to the resistance of the material, known as the moment of resistance. The principal cases of bending moment are shown in Figs. 19, 20, 21 and 22.

In the case of a girder or joist fixed at one end, known as a cantilever, and having a concentrated load, M = WL, W being the load and L the length of the joist; if the load were distributed over the whole length, the maximum bending moment at the point of support would be $M = \frac{WL}{2}$; in the case of a girder supported at both ends and the load in the middle $M=\frac{WL}{4}$; and with a distributed load, $M=\frac{WL}{8}$.

In the accurate mathematical formula for ascertaining the strength of a joist the bending moment is equated with the moment of resistance. The moment of resistance is obtained from the formula, $M=\frac{rI}{y}$.

M = moment of resistance in inch-tons.
r = limiting stress per inch of material.
y = half the depth of joist.
I = moment of inertia.

The moment of inertia for a rolled joist, Fig. 27, is obtained from the formula

$$I=\frac{BD^3-2bd^3}{12}$$

In Messrs. Dorman and Long's list the moments of inertia and moments of resistance are given, so we have reliable data to work upon. We will now proceed to show how to work out the strength of the joist selected.

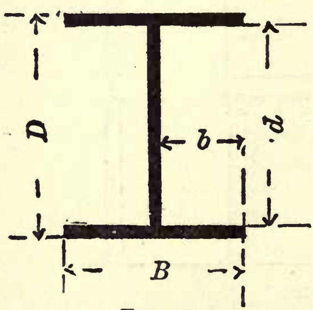


FIG. 27.

The formula for the bending moment of a joist with a distributed load and ends supported is $\frac{WL}{8}$ and the moment of resistance is $\frac{rI}{y}$, r being 32 tons and I 370.

Then $370\times32\div6=1{,}973$ inch-tons.

$M=Wl\div8=W\times12\div8=1\cdot5W$ inch-tons, and as the bending moment = moment of resistance, $1\cdot5W$ inch-tons $=1{,}973$ inch-tons.

Hence $W=1{,}973\div1\cdot5=1{,}314$ tons. Using a factor of safety of 5, the safe load that one foot would carry would be 262 tons, or for our span of 18 feet $262\div18=14\cdot6$ tons, showing that the section of joist selected is strong enough.

The depth of a joist varies from $\frac{1}{15}$th to $\frac{1}{20}$th of the span. In this case $18 \times 12 = 216 \div 12 = \frac{1}{18}$th.

The width of a joist is, as an average, one-half the depth of the girder, and should, as a rule, be not less than $\frac{1}{40}$th of the span, in order to guard against the risk of lateral flexure of the compression flange, unless the sides are supported.

In the present case $\frac{18 \times 12}{6} = \frac{1}{36}$.

One important point to ascertain when calculating the size of joists is the amount of deflection to which the joist is liable. This can be obtained from the formula, when the load is distributed,

$$D = \frac{5wl^3}{384EI}$$

w = the weight in tons.
l = length of span in inches.
E = modulus of elasticity = 12,000 tons.
I = moment of inertia.

Then, $\frac{5 \times 14 \times 216^3}{384 \times 12{,}000 \times 370} = 0{\cdot}41$, or $0{\cdot}023$ inches per foot of span. As a general rule the deflection of a joist or girder should not exceed $\frac{1}{30}$th of an inch per foot of span.

One of the principal uses of steel joists lies in the construction of floors; and we next proceed to show how to calculate the size of joists to carry the floor of the building shown in Fig. 28. In planning a floor the first thing requisite is to calculate the weight of the load to be placed upon it. This load consists of the weight of the material composing the floor (or the dead load, as it is termed) and the weight of the persons or other moving bodies, which constitutes the live load; the two items making up the total load. The dead load of a fire-proof floor constructed of steel joists and 6-inch coke breeze concrete may be taken at 70 lbs. per square foot, and the live load, for offices, etc., may be taken as an additional 84 lbs., making a total load of 154 lbs. In the case of buildings where heavy goods are stored the safe total loads may be taken at from 200 to 400 lbs. per square foot. In the present example we have a building 30 feet by 15 feet, with steel joists spaced 2 feet apart, centre to centre. The building being 30 feet long there will be 15 bays and 14 joists, the latter carrying a total load of 350 lbs. per square foot of floor area

$$15 \times 2 \times 350 = 10{,}500 \text{ lbs.},$$

or 4·7 tons on each joist.

Now, in selecting a suitable joist one of the principal considerations is to guard against deflection, by arranging that the depth of the joist shall not be less than one-

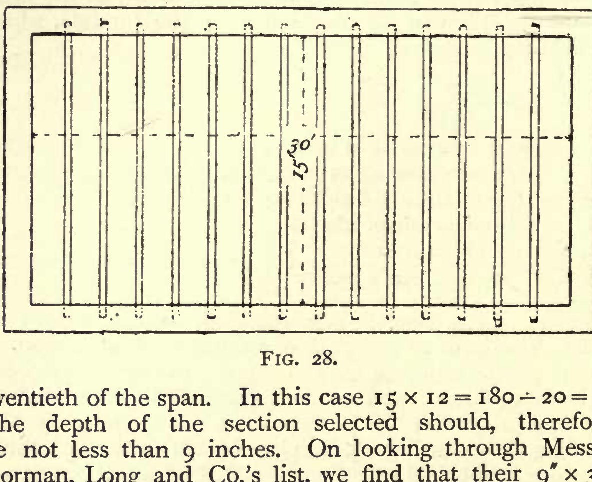


FIG. 28.

twentieth of the span. In this case $15 \times 12 = 180 \div 20 = 9''$. The depth of the section selected should, therefore, be not less than 9 inches. On looking through Messrs. Dorman, Long and Co.'s list, we find that their $9'' \times 3\frac{3}{4}''$ rolled steel joist weighing 20 lbs. per foot will sustain a distributed load of 4·74 tons over a clear span of 15 feet. This will, therefore, meet the requirements of the case.

We will next proceed to check the strength by equating the bending moment with the moment of resistance, as previously described. The joist being supported at each end and the load uniformly distributed,

$$M = Wl \div 8 = W \times 12 \div 8 = 1 \cdot 5W \text{ inch-tons.}$$

The moment of inertia for the section selected is 75·0 Consequently, R, or resistance $= 32 \times 75 \div 4{\cdot}5 = 533{\cdot}3$ inch-tons, 32 being the tensile strength of steel and 4·5 half the depth of joist. Now, since the bending moment = moment of resistance,

$$1{\cdot}5W \text{ inch-tons} = 533{\cdot}3 \text{ inch-tons.}$$

Hence $W = 533{\cdot}3 \div 1{\cdot}5 = 355{\cdot}5$. Using a factor of safety of 5, the safe load for 1 foot is 71·1 tons, or, for our span of 15 feet, 4·74 tons; showing that the strength given in the list is correct.

It frequently happens that we can effect an economy of material in the planning of floors by reducing the span. This can be effected by means of main girders, which divide the building into smaller areas. Thus, supposing we have a building 30 feet square and we wish to support the floor by means of rolled steel joists, as in the examples previously given, then we could either use a joist 30 feet clear span, or we could place a main girder half-way along the building, which would have the effect of reducing the span to 15 feet; and as the strength (and size) of joist required to sustain a certain load increases with the span it would be found advantageous to reduce the span in the manner indicated. It will be noticed in the example that we speak of the clear span. This is the item which enters into the calculations; but as it is necessary to allow a certain bearing for all joists, it is essential, when calculating the number required, to allow for this portion of the joist. The length of bearing for the span in the example may be taken as 9 inches at each end. It should be noted that it is sometimes necessary to take the dead weight of the joist itself into account. But when, as is generally the case, the weight of the joist is small as compared with the load to be carried, the surplus strength ensured by choosing a suitable stock section is usually sufficient to provide for the dead load due to the joist. Thus, in the example of the floor joist previously given we have 20 lbs. by 15 lbs. = 0·13 tons, which is insignificant, the section selected giving a sufficient margin of safety without taking this weight into consideration.

Owing to local circumstances it is sometimes found necessary to support tanks, etc., on joists the ends of which are fixed into a wall. An example of this is shown in Figs. 29 and 30, where we have a tank 6 feet square by 6 feet deep, which receives the return water from an Arrol-Foulis stoking

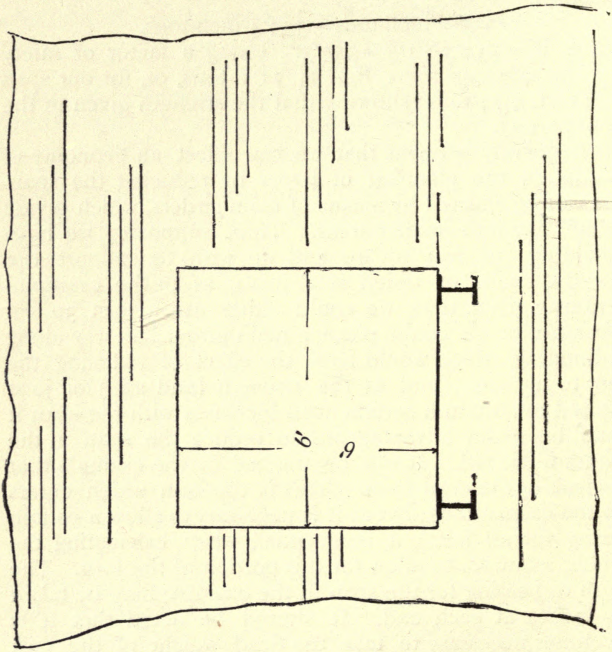


Fig. 30.

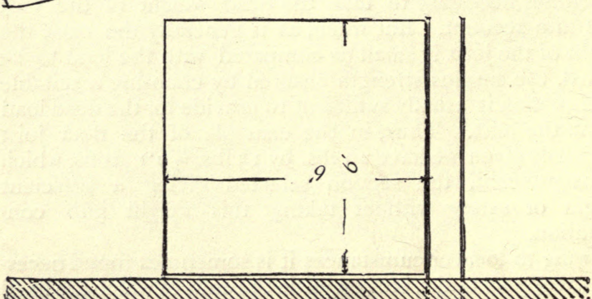


Fig. 29.

machine. In order to fix upon the size of joist requisite to support the weight of the tank, we first of all obtain the weight of the tank and water. $6 \times 6 \times 6 = 216$ cubic feet; and as the weight of a cubic foot of water is 62·5 lbs., $216 \times 62{\cdot}5 = 13{,}500$ lbs., or, say, 6 tons. In the tank itself we have five plates 6 feet square. $6 \times 6 \times 5 = 180$ superficial feet. Assuming the thickness of the metal to be $\frac{1}{4}$-inch, this would weigh about 10 lbs. per foot; therefore $180 \times 10 = 1{,}800$ lbs., or 0·8 of a ton; making the total weight 6·8 tons, which is supported on the two joists as shown. Consequently, as the weight is equally distributed on each joist, they will each have to support a weight of $6{\cdot}8 \div 2 = 3{\cdot}4$ tons. Now, Messrs. Dorman, Long and Co.'s list shows the weight which their joists will carry when the ends are supported. As in the present instance the ends of the joists are "fixed," it will be necessary to divide the load given in this list by 4, in order to obtain the load which the joist will carry when loaded in the manner shown. In order to obtain the size of joist required, it is further necessary to divide the distributed load which 1 foot will carry, as given in the tables, by the length of the joist in feet. In the present instance we will assume that the joist is 7 feet long; consequently, $7 \times 4 = 28$, is the number which must be used as the divisor into the weights given in the table in order to give the safe load which the joist will carry. Taking the latter at one-fourth of the breaking weight, we find that the nearest sized joist complying with the conditions enumerated above is 8 inches by 4 inches, weighing 25 lbs. per foot. The tabular number for this being 97·65 per foot, then, $97{\cdot}65 \div 28 = 3{\cdot}48$ tons.

We now proceed to show how to check the size of the joist selected. We will first take the conditions upon which the choice of the joist depends. The data given are a distributed load of 3·4 tons resting on a cantilever 7 feet long. In this case $M = Wl \div 2 = 3{\cdot}4 \times 7 \div 2 = 11{\cdot}9$ foot-tons, or 142·8 inch-tons. R should be $142{\cdot}8 \times 4 = 571{\cdot}2$ inch-tons, or $R = 571{\cdot}2 \div 32 = 17{\cdot}85$ square inches. The nearest sized joist having the moment of resistance given is the one selected, 8 inches by 4 inches, whose moment of resistance is 18·31, thus giving a small margin of strength.

Another way of checking the size is on the assumption that we have selected the joist (8 inches by 4 inches) and require to know the load it is capable of carrying.

$$M = Wl \div 2 = W \times 12 \div 2 = 6 \text{ inch-tons.}$$

The moment of inertia of an 8-inch by 4-inch joist is 73·24. Consequently, for the moment of resistance of the section we have $R = 32 \times 73{\cdot}24 \div 4$ (half depth of joist) = 585·92 inch-tons. And as $M = R$ 6W inch-tons = 585·92 inch-tons, and $BW = 585{\cdot}92 \div 6 = 97{\cdot}65$ tons, using a factor of safety of 4, the safe load would be $97{\cdot}65 \div 4 = 24{\cdot}41$ tons for a span of 1 foot, and dividing this by the length of the joist, $24{\cdot}41 \div 7 = 3{\cdot}48$, the weight which the joist selected would carry; and this agrees with the weight given in the tables and also answers the requirements of the case.

From the above examples, it will be seen that the selection of a joist capable of bearing a distributed load or a concentrated load when fixed as a cantilever, or a concentrated load in the centre of a supported joist, is a comparatively easy matter. But the case of a concentrated load in any other position on a supported joist requires a little calculation, and this condition frequently occurs in practice. Thus, let A B (Fig. 31) represent a girder with a concentrated

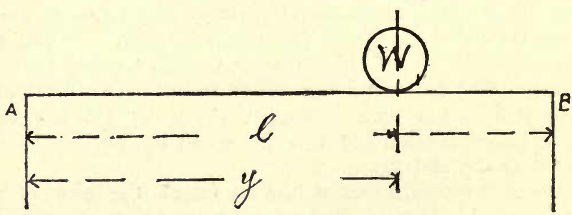


FIG. 31.

load, W, at the distance, y, from the support, A. The maximum bending moment will be directly under the load, W, and will equal the reaction $W\left(\frac{l-y}{l}\right)$ at the point, A, multiplied by the leverage $y = W\left(\frac{l-y}{l}\right) + y$; and equating this with $\frac{wl}{8}$, the maximum bending moment from a uniformly distributed load, we obtain

$$\frac{wl}{8} = W\left(\frac{l-y}{l}\right)y,$$

$$\text{and } w = 8W \times \left\{\frac{y}{l} - \left(\frac{y}{l}\right)^2\right\}.$$

As a practical example, supposing we have a joist (Fig. 32)

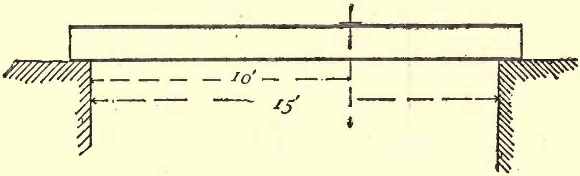


FIG. 32.

15 feet long, $=l$, supporting another joist which with its load weighs 12 tons, $=W$, at a point 10 feet from the end, $=y$, then

$$w = 8 \times 12 \times \left\{\frac{10}{15} - \left(\frac{10}{15}\right)^2\right\} = 22 \text{ tons},$$

as the equally distributed load, which would give the same maximum moment of stress; or 11 tons concentrated in the centre would have the same effect.

The following example is a typical instance of the application of joists in gasworks construction. Fig. 33 shows a portion of a retort house consisting of the stage resting upon a rolled steel joist. The stage is 20 feet wide, which will be the length of the joist, and the joists are spaced 10 feet apart. The stage plates are 3 feet wide, with the exception of the end one, which is 2 feet, and they weigh 5 cwts. per lineal foot of stage. The total weight due to the stage plates will, therefore, be $5 \times 20 = 5$ tons, the weight of which will rest equally upon two joists, the weight on one joist being, therefore, 2·5 tons, which will act as a distributed load. In addition, the stage is intended to contain a certain amount of coal, say 20 tons, which is stored on the space between two joists. Half of this weight, therefore, will be distributed on each joist, and it is assumed that this weight of 10 tons will act as a concentrated load at a distance of 5 feet from the wall. We now require to find the size of joist which will carry the distributed load of 2·5 tons, plus the concentrated load of 10 tons 5 feet from the wall. The weight due to the distributed load will be $2·5 \div 20 = 0·125$ tons per foot of span, and the moment of stress under the concentrated

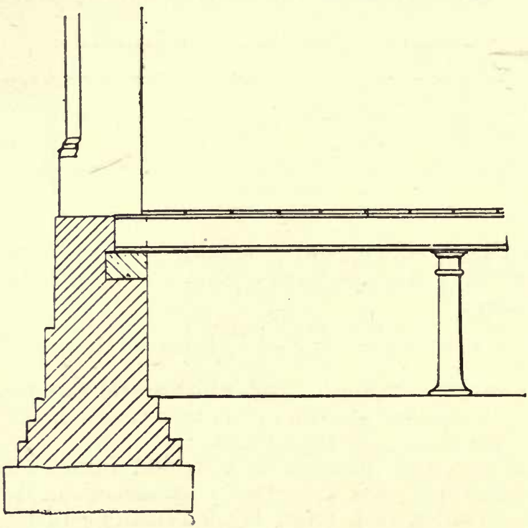


FIG. 33.

load, but due to the equally distributed load, calling w weight per foot of span, x distance from wall, and l total length, will be

$$M = \frac{wx}{2} \left\{ x - l \right\} = \frac{0·125 \times 5}{2} \left\{ 5 - 20 \right\} = -4·68 \text{ foot-tons.}$$

The moment from the concentrated load will be, calling W^1 = weight of 10 tons, y 5 feet distance from wall, and l total length

$$M = -W^1 \times \frac{l-y}{l} \times y = -10 \times \frac{20-5}{20} \times 5 = -37{\cdot}5 \text{ foot-tons.}$$

The total weight due to the two loads will therefore be $-37{\cdot}5 - 4{\cdot}68 = -42{\cdot}18$ foot-tons, and the uniformly distributed load which will produce the same stress is thus found:

$$\frac{Wl}{8} = 42{\cdot}18.$$

$$\text{Therefore } \frac{W \times 20}{8} = 42{\cdot}18 = 16{\cdot}87 \text{ tons.}$$

And we find on referring to Messrs. Dorman, Long and Co.'s list that their 14-inch by 6-inch joist, weighing 57 lbs. per foot, will answer the requirements.

In cases where a single joist is not sufficient to carry the load, two joists, or more, connected together may be employed. Their strength may be calculated in the same manner as in the case of the single joists previously explained. Thus, supposing we have a distributed load of 52 tons over a span of 20 feet, the joist being supported at both ends, this could be carried by the joist shown in Fig. 34, which shows one of Messrs. Dorman, Long and Co.'s 16-inch by 10-inch compound girders, weighing 127 lbs. per foot. The strength of this could be checked as follows: The moment of inertia for the joist shown is 1585, and R or resistance $= 32 \times 1585 \div \frac{16}{2} = 6340$, and $M = Wl \div 8 = W \times 12 \div 8 = 1{\cdot}5W$ inch-tons, and as $M = R$, $1{\cdot}5$ inch-tons $= 6340$ inch-tons; consequently, $6340 \div 1{\cdot}5 = 4227$; and using a factor of safety of 4 the safe load would be 1056 tons for a span of 1 foot. Dividing

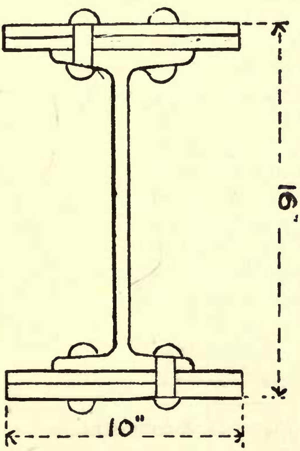


FIG. 34.

this by 20, we obtain 52 tons as the safe load for the 20 feet span, showing that the joist would be strong enough.

In certain cases, in place of rolled joists, plate or built up girders are employed in gasworks construction. Fig. 35 shows the general form of the cross section of a plate girder. The flanges are made up of one or more plates riveted to angle irons, which are also connected to a thin plate known as the web, the latter stiffened against crumpling by meams of vertical **T** or **L** iron stiffeners. In a plate girder it can be assumed that practically the whole of the direct stresses come upon the flanges, the web taking the shearing strain only. We shall now proceed to show how the principal items which enter into the construction of a wrought-iron plate girder of 20 feet span and carrying a distributed load of 32 tons are calculated.

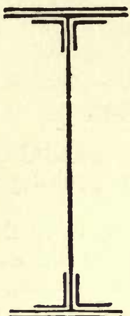


FIG. 35.

The depth of plate girders varies from one-eighth to one-fifteenth the span, the average being one-twelfth, which will, in our supposed case, make the depth in inches to equal the span in feet: $20 \div 12 = 1' \ 8''$, or $1{\cdot}66''$ as the depth of the girder. Having determined this point we are enabled to find the strain on either flange from the rule, "To find the strain on either flange of a girder supported at both ends and with a distributed load, multiply the load in tons by the span in feet and divide the product by eight times the depth of the girder in feet; the quotient will be the strain at the centre on either flange in feet."

Thus:—

Depth of girder 1·66	32 tons load
8	20 feet span
13·28	)640·00(48 tons strain
	5312
	10,880

In practice the sectional area of plate girders is so proportioned as to allow a safe strain of 4 tons per square inch, both in tension and compression, making no allowance for loss by rivet holes. This amounts to the same thing as allowing 5 tons for tension per square inch of net effective area and 4 tons per square inch in compression; for it will, as a rule, be found that the effective sectional area of the bottom flange is about four-fifths of the gross sectional area; consequently if the top and bottom flanges be made of the same gross sectional area, the correct proportions will be obtained. Then, on dividing 48 by 4 we obtain 12 square inches as the sectional area of either flange, which will be made up of two plates 12-inch by $\frac{1}{2}$-inch for each flange. The flanges of wrought-iron plate girders are usually made of a width of from one-twentieth to one-fortieth of the span. The compression flange, in particular, should not be less than one-thirtieth to one-fortieth of the span, or it will be liable to buckle sideways.

A sufficient area having been provided in the top and bottom flanges to resist the compression and tensile strain, it will be necessary to provide sufficient metal in the web to resist the shearing strain. This strain is theoretically *nil* at the centre of a girder uniformly loaded, but from that point it increases by equal increments to the supports, where it is equal to one-half of the whole load, or $32 \div 2 = 16$ tons. The web should be calculated for a direct shearing stress of $2\frac{1}{2}$ tons per square inch; then $16 \div 2{\cdot}5 = 6{\cdot}4$ square inches, and

$$\frac{6{\cdot}4 \text{ inches area}}{20 \text{ inches depth}} = 0{\cdot}32$$

—say a uniform thickness of $\frac{3}{8}$ inch. In plate girders a saving of material may often be effected by reducing the thickness of the flanges towards the ends of the girder, where the strain is less. The inner flange plate will, of course, run through from end to end, but the outer one may be cut off a little beyond where a parabolic curve would cut through, when drawn with a base equal to the centre distance of the girder bearings and a height equal to the combined thickness of the plates; roughly speaking, the outer plate will be about two-thirds the length of girder. The angle irons may be, say, a quarter the width of the flange—say 3 inch, or 3 inch × 3 inch × $\frac{3}{8}$ inch. The rivets generally used in girder work are $\frac{3}{4}$-inch diameter, and the pitch should not exceed 6 inches nor be less than 3 inches, and should be least at the ends and at all points where heavy loads are applied; it should be noted that when rivets connect the angle arms to the web, as in a plate girder, they are in double shear. Stiffeners should be placed from 3 to 6 feet apart, and in the present example may be formed of single bent angle irons, 3-inch by 3-inch by $\frac{3}{8}$-inch, on each side of web plate. One stiffener should be placed at each end of the girder on each side of the web, the end of the girder being closed up with $\frac{3}{8}$-inch plate.

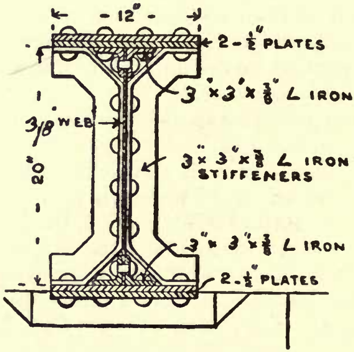


FIG. 36.

Another pair of stiffeners should be placed over the edge of each abutment, where the shearing stress is the greatest, and the remaining distance should be divided into as many equal parts as will give an equal number of stiffeners placed 4 feet apart. It is usual to allow a certain amount of camber to girders, say $\frac{1}{2}$-inch per 10 feet of span.

The approximate weight of a plate girder may be obtained from Professor Unwin's formula, which reads as follows:—

$$\frac{W \times L^2}{Cr_cD - L^2}$$

W being the distributed load in tons.
L „ span in feet.
C „ a factor, usually 1,500 for small girders.
r_c „ the stress in compression flange, say 4 tons per square inch.
D „ effective depth of girder in feet.

Then, applying the above formula to the girder in the example, we have :—

$$32 \times 20^2 = 12{,}800.$$
$$1{,}500 \times 4 \times 1·66 = 9{,}960 - 20^2 = 400 = 9{,}560.$$
$$12{,}800 \div 9{,}560 = 1·3 \text{ tons as the weight of the girder;}$$

and it may be noted that in practical designing the weight of the girder itself is usually included in the weight to be carried.

Fig. 36 shows a cross section of the plate girder as just described.

EXAMPLES.

1. Square, abstract, reduce and bill the following dimensions of brickwork :—

3	240′ 6″	
	9″	$2\frac{1}{2}$ bricks in lime mortar.
3	240′ 6″	
	12′	$1\frac{1}{2}$ „ „
3	240′ 6″	
	18′ 9″	1 „ „
2	47′ 6″	
	6′ 6″	Deduct 1 brick in lime mortar.
4	3′ 9″	
	3′ 9″	
	8′ 3″	Brickwork in cement mortar.
2	53′ 9″	
	11′ 6″	Half brick partition in cement.

(1) Example of squaring brickwork :—

	240′ 6″		
3	20′ 9″	14,971·12	2½ B in lime mortar.
	240′ 6″		
3	12′ 0″	8,658	1½ B ,, ,,
	240′ 6″		
3	18′ 9″	13,528·12	1 B ,, ,,
	47′ 6″		
2	6′ 6″	617·5	Deduct 1 B in lime mortar.
	3′ 9″		
	3′ 9″		
4	8′ 3″	464·0	Brickwork in cement mortar.
	53′ 9″		
2	11′ 6″	1,236·25	Half brick partition in cement.

Example of abstracting :—

Super. reduced brickwork in mortar—

1½ B.	1 B.	Deduct 1 B.
8,658	13,528	617·5
14,971	14,971	
23,629	28,499	
18,587·7	617·5	
42,216·7	27,881·5	
	9,293·8	Deduct ⅓
	18,587·7	

```
272)42216·7(155·2 rods
    272
    ----
    1501
    1360
    ----
     1416
     1360
     ----
     56·7
```

Extra only in cement—

1½ B.
272)464(1·7 rods.
272

1920
1904

Half brick partition in cement—

9)1,236·25

137·36 super. yards

Example of billing:—

Rods. 155			Super.	Reduced brickwork in mortar			
1·7			,,	Extra only in cement . .			
Yards. 137·3			,,	Half-brick partition in cement			

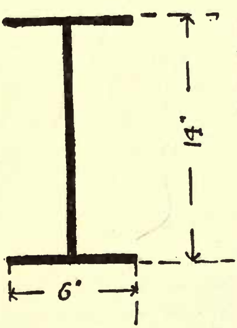


FIG. 37.

2. Find the moment of inertia of the rolled-iron joist shown in Fig. 37, the thickness of the web being $\frac{7}{16}$ of an inch, and the average thickness of flanges $\frac{5}{8}$ inch.

(2) The moment of inertia of the $14'' \times 6''$ joist would be found thus:—

$$\tfrac{1}{12}(6 \times 14^3 - 5{\cdot}56 \times 12{\cdot}75^3) = 412.$$

The thickness of the web being $\frac{7}{16}$-inch and the average flange thickness being $\frac{5}{8}$-inch, the above calculation shows that you take one-twelfth of the extreme width multiplied by the cube of the extreme length, minus the width, less thickness of web, multiplied by the depth, less the thickness of the flanges.

3. What would be the safe distributed load for a rolled-iron joist over a 20 feet span, its depth being 14 inches

and its flanges 6 inches by $\frac{3}{4}$ inch? The weight of the joist to be neglected and the stress on the metal not to exceed 5 tons to the inch.

(3) There are several ways of answering this question, the simplest, perhaps, being as follows:—Taking the formula for a flanged beam, the bending moment = moment of resistance and $\frac{Wl}{8} = 5 \times ad$, a being the area of flanges and d the depth.

$$\text{Then } W = \frac{40ad}{l} = \frac{40 \times 6 \times \frac{3}{4} \times 14}{20 \times 12} = 10{\cdot}5 \text{ tons.}$$

4. What is the bending moment in the middle of a beam 30 feet long, supported at both ends, and loaded in the middle with 10 tons?

(4) Fig. 38 will help to explain this answer. In the first place it will be seen that half the load will be supported at each end, consequently the force acting at the ends will be

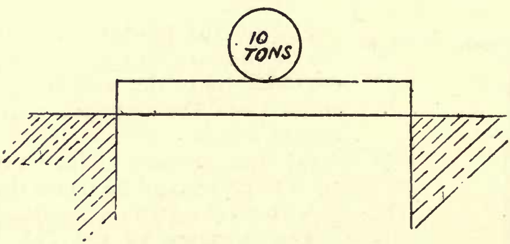


FIG. 38.

$10 \div 2 = 5$ tons; and this force will act as a lever whose length is the distance from the supports to the centre, or $30 \div 2 = 15$ feet. The bending moment in the centre will consequently be $15 \times 5 = 75$ tons.

5. A wrought-iron girder, 12 inches by 6 inches, has an average thickness of $\frac{7}{8}$ inch in the flanges and has to carry a uniform load of 15 tons over a 20 feet opening. Determine the amount of flexure at 5 feet from one of the sup-

ports and the intensity of stress per square inch on the flange metal at that point, neglecting the web.

(5) The bending moment = reaction at abutment multiplied by the leverage distance from reaction to the given point, minus the load between the given point and end of girder multiplied by the leverage distance from the centre of gravity of this part of the load to the given point, or

$$(7\cdot5 \times 5) - \left(\frac{5}{20} \text{ of } 15 \times \frac{5}{2}\right) = 37\cdot5 - 9\cdot375 = 28\cdot125 \text{ foot-tons.}$$

In order to find the intensity of stress on flange at the same point, bending moment ÷ depth in feet multiplied by sectional area of flange in square inches = intensity of stress in flange. Sectional area of flange $\frac{7}{8} = 0\cdot875 \times 6 = 5\cdot250$.

Then, $\frac{28\cdot125}{1 \times 5\cdot25} = 5\cdot357$ tons per square inch intensity of stress on the flange metal.

6. A girder, 30 feet long, over a span of 26 feet, is loaded with 10 tons 4 feet away from the centre, what will be the pressure on the nearest support, omitting the weight of the girder?

(6) The distance 4 feet from the centre would be $13 - 4 = 9$ feet; consequently, 10 tons $\times 17 \div 26 = 6\cdot54$ tons will represent the pressure on the nearest support.

7. Supposing a cantilever to be capable of carrying with safety a load of 10 tons at its extremity, how much would it carry evenly distributed?

(7) The load which the cantilever would bear if the load were equally distributed, in place of being concentrated at the end, would be just double, or 20 tons.

8. If a girder, supported at both ends, just breaks when loaded with a distributed load of 30 tons, what load, placed in the middle, would cause its fracture?

(8) In this case the load which would cause fracture of the girder when placed in the centre would be just half that

which would cause it to break if the load were distributed or 15 tons.

9. Give sketches showing the construction of a riveted plate girder to carry 30 tons over a span of 26 feet. The girder in each case being supported at both ends and the load distributed; figure the sizes of metal in each part, and give the calculations by which you determine them.

(9) The formula for obtaining the stress in a plate girder uniformly loaded and supported at the ends is $\frac{WL}{8D}$, or in this case $\frac{30 \times 26}{8 \times 2} = 48{\cdot}75$ tons stress in flange at centre. Taking the tensile strength of wrought-iron at 4 tons per square inch, we have $48{\cdot}75 \div 4 = 12{\cdot}19$ square inches as the gross area of flanges, which can be obtained from two plates, 12 inches by $\frac{1}{2}$ inch for each flange. The web plate for a girder of this size would be not less than $\frac{3}{8}$ inch, and the depth of girder, say, 2 feet, the cross-section being as in Fig. 39.

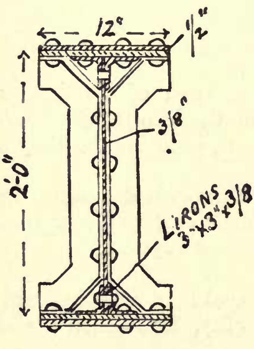


FIG. 39.

10. What is the sectional area of either flange of a girder 20 feet span carrying a load of 14 tons at a distance of 7 feet from one support?

(10) The rule for finding the sectional area of either flange of a girder under a concentrated load not in the centre of the girder is as follows :—Multiply the distance of one point of support in feet from the point of application of the load by the distance of the other support in feet from the load; multiply the product by the amount of the load in tons and by 3, and divide by the square of the span in feet. The quotient will be the sectional area required in square inches. In the example, 20 feet − 7 feet = 13 feet, and $13 \times 7 = 91 \times 14$

tons = 1,274, and 1,274 × 3 and ÷ 20^2 = 400 = 9·55 square inches, the sectional area required.

Although rarely used at the present day, it is sometimes found expedient to employ cast-iron girders in gasworks construction. A few notes concerning them will therefore be now given. In the case of wrought-iron girders the resistance to tension differs but slightly from the resistance to compression, but in the case of cast-iron the resistance to compression is much greater than the resistance to tension, the working resistance to tension being $1\frac{1}{2}$ tons per square inch against 8 tons to compression. Consequently, the calculations relating to cast-iron girders are different from those of wrought-iron. The information relating to cast-iron girders is principally based upon the experiments of the late Mr. Eaton Hodgkinson, who designed the girder shown in cross section in Fig. 40 from the data that cast-iron required about six and a-half times as much force to crush it as it did to tear it apart. In this form of girder the upper or compression rib or flange has but one-sixth of the area of the lower or tension flange. The area of the top flange being therefore somewhat greater than the proportion of 1 to $6\frac{1}{2}$, fracture would take place from the yielding of the bottom flange by extension. As the result of numerous experiments Mr. Hodgkinson deduced the following rule for cast-iron girders :—

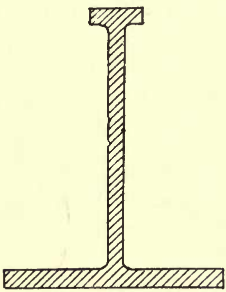


FIG. 40.

Breaking load in centre in tons

$$= \frac{\text{area of bottom flange}}{\text{in square inches}} \times \frac{\text{total depth}}{\text{of girder}} \times \frac{\text{constant}}{2·166}$$

÷ clear length in feet.

The advantages of cast-iron over wrought-iron or steel is its comparative immunity from corrosion, which makes it well adapted for supporting the stages of retort houses, but against this it is liable to fracture by sudden blows, etc., owing to its brittleness. We now proceed to show the practical

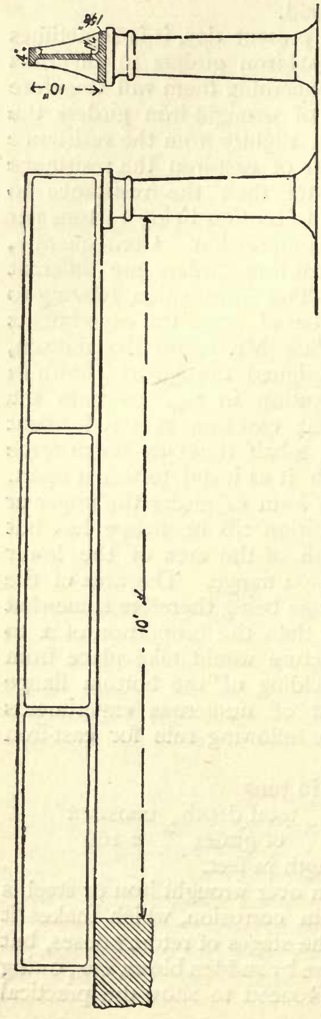


FIG. 41.

calculations necessary in the designing of the cast-iron girder shown in Fig. 41, which carries a distributed load of 20 tons over a span of 10 feet. As in the case of wrought-iron girders, the depth should be about $\frac{1}{12}$ of the span, or, say, 10 inches deep. With a uniformly distributed load the maximum stress will be in the centre of the span and is obtained from the formula

$$\frac{WL}{8d} = \frac{20 \times 10}{8 \times \cdot 83}$$

= 30 tons stress in flange at centre; and taking the working tensional stress of cast-iron at $1\frac{1}{2}$ tons per square inch we have 20 square inches as the area of the bottom flange, or, say, $12'' \times 1\frac{5}{8}''$. Although, theoretically, cast-iron is six times stronger in compression than in tension, the proportion usually adopted in practice is 4 to 1, or, say, $20 \div 4 = 5$, which would be met by a flange $4'' \times 1\frac{1}{4}'' = 5''$, the thickness usually being $\frac{1}{3}$ to $\frac{1}{4}$ of the width. The thickness of the web, which is tapered toward the top, should be from 0·66 to 0·75 of the bottom flange. In order to prevent buckling the girder should be provided with stiffeners of the same thickness as the web, placed about 4 feet 6 inches apart and equally distributed over the whole length of the girder. It is usual in the case of cast-iron girders to allow a camber of, say, 1 inch in every 20 feet.

Areas of Hollow Columns.

Outside Diameter. Inches.	Thickness. Inches.	Area.	Outside Diameter. Inches.	Thickness. Inches.	Area.	Outside Diameter. Inches.	Thickness. Inches.	Area.
6	¾	12·4	10	1¾	45·4	13	2	69·1
6	⅞	14·1	11	1	31·4	14	1	40·8
6	1	15·7	11	1⅛	34·9	14	1¼	50·1
7	¾	14·7	11	1¼	38·3	14	1½	58·9
7	⅞	16·8	11	1½	44·8	14	1⅝	63·2
7	1	18·9	11	1⅝	47·9	14	1¾	67·4
7	1⅛	20·8	11	1¾	50·9	14	2	75·4
8	¾	17·1	12	⅞	30·6	14	2⅛	79·2
8	⅞	19·6	12	1	34·6	15	1	44·0
8	1	22·0	12	1⅛	38·4	15	1¼	54·0
8	1⅛	24·3	12	1¼	42·2	15	1½	63·6
9	¾	19·4	12	1⅜	45·9	15	1⅝	68·3
9	⅞	22·3	12	1½	49·5	15	1¾	72·9
9	1	25·1	12	1⅝	53·0	15	2	81·7
9	1⅛	27·8	12	1¾	56·4	15	2⅛	85·9
9	1¼	30·4	12	1⅞	59·6	15	2¼	90·1
9	1½	35·3	12	2	62·8	16	1¼	57·8
10	⅞	25·1	13	1	37·7	16	1½	68·3
10	1	28·3	13	1⅛	41·9	16	1⅝	73·3
10	1⅛	31·4	13	1¼	46·1	16	1¾	78·3
10	1¼	34·4	13	1½	54·2	16	1⅞	83·2
10	1½	40·1	13	1⅝	58·0	16	2	87·9
10	1⅝	42·7	13	1¾	61·9	16	2⅛	92·6

The following tables of joists, manufactured by Messrs. Dorman, Long and Co., of Middlesbrough, will be of service. The loads given in the tables include the weight of the joists themselves and are based on an extreme fibre stress of 7·5 tons per square inch, being one-fourth of the average breaking stress. They are also calculated on the assumption that the girders receive the usual side support, as in builders' work. Being calculated for a distributed load, any other system of loading will necessitate the calculations shown on page 32.

It is necessary, in selecting joists, that the deflection is not too great for the purpose for which they are intended.

The zigzag line in the table indicates the generally accepted limit of span to depth, which is as 20 to 1. In the case of joists of uniform section throughout their lengths, the deflection in inches for tabular loads is found by multiplying the square of the span in feet by the coefficient given for each section. If the actual load is less than the tabular load, the deflection will be less in exactly the same proportion.

DORMAN, LONG AND CO.'S I BEAMS OR JOISTS.

Safe load in Tons uniformly Distributed

Size. Inches.	Weight per Foot. Lbs.	Span in Feet.																		Deflection Coefficient.
		2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	36	40	
24×7½	100					102	92	79	69	61	55	50	46	42	39	36	34	30	27	·00078
20×7½	89				94	83	69	59	52	46	41	38	34	32	29	27	26	23	20	·000937
18×7	75				78	64	53	45	40	35	32	29	26	24	22	21	20	17		·00104
16×6	62			73	56	45	38	32	28	25	22	20	19	17	16	15	41	12		·00117
15×6	59			62	52	42	35	30	26	23	21	19	17	16	15	14	13	11		·00125
15×5	42			47	35	28	24	20	18	16	14	13	12	11	10	9·5	9			·00125
14×6	57			59	47	38	31	27	24	21	19	17	16	14	13	12				·00133
14×6	46			43	39	31	26	22	19	17	15	14	13	12	11	10				·00133
12×6	54		53	52	39	31	26	22	19	17	15	14	13	12	11					·00156
12×6	44			40	33	26	22	19	16	14	13	12	11	10	9					·00156
12×5	39		45	36	27	22	18	15	13	12	11	9·9	9	8·3	7·7	7·2				·001562
12×5	32		32	30	23	18	15	13	11	10	9	8·3	7·6	7	6·5					·00156
10×8	70			53	43	34	28	24	21	19	17	15	14	13						·001875
10×6	42			35	26	21	17	15	13	11	10	9·6	8·8	8						·001875
10×5	35		37	28	21	17	14	12	10	9·3	8·4	7·6	7	6·4						·001875
10×5	30		30	24	18	14	12	10	9	8	7·2	6·6	6	5·6						·001875
9×7	58		44	42	32	25	21	18	16	14	12	11	10	9·8						·00208
9×4	21		22	15	11	9	7·5	6·4	5·6	5	4·5	4	3·7							·00208
8×6	35		31	23	17	14	11	9·8	8·6	7·7	7	6·3								·00234
8×5	28		25	18	14	11	9	8	7	6·2	5·5	5·0								·00234
8×4	25	27	23	16	12	9·4	7·8	6·7	5·9	5·2	4·7	4·2								·02344
8×4	18	19	17	11	8·7	7	5·8	5	4·3	3·8	3·5	3·2								·00234
7×4	16	15	14	9·4	7	5·6	4·7	4	3·5	3·1	2·8	2·5								·00268
6×5	25	22	18	12	9	7·3	6	5·2	4·5	4										·003125
6×4½	20	20	14	9·6	7·2	5·8	4·8	4·1	3·6	3·2										·003125
6×3	16	18	11	7·3	5·4	4·4	3·6	3·1	2·7	2·4										·003125
6×3	12	14	8·4	5·6	4·2	3·4	2·8	2·4	2·1	1·9										·003125
5×5	24		15	9·8	7·3	5·9	4·9	4·2	3·7											·00375
5×4½	18	13	11·3	7·6	5·6	4·5	3·8	3·2	2·8											·00375
5×3	11	9·8	6·8	4·5	3·4	2·7	2·3	1·9	1·7											·00375
4×3	9·5	7·8	4·7	3·1	2·3	1·9	1·6	1·3												·00469
3×3	8·5	5·3	3·2	2	1·6	1·2	1	·9												·00625
3½×1½	6	4·4	2·2	1·5	1·1	·88	·73	6·3												·005357

Since steel joists are now extensively used as stanchions. The following table, showing the weight capable of being sustained by joists made by Messrs. Dorman, Long and Co., will often be found useful. The stanchions are supposed to have their ends fixed.

Size of Joists. Inches.	Safe Load in Tons for Lengths in Feet.								Weight Per Foot. Lbs.
	6	8	10	12	14	16	18	20	
24 × 7½	164	154	143	130	115	100	87	76	100
20 × 7½	146	138	129	118	105	92	80	70	89
10 × 8	118	113	108	101	94	86	78	70	70
18 × 7	122	115	106	96	84	73	63		75
9 × 7	96	92	86	79	72	64	56	50	58
16 × 6	98	89	79	67	57	48			62
15 × 6	94	86	77	67	57	48			59
14 × 6	91	84	76	66	56	48			57
12 × 6	87	80	73	64	55	47			54
14 × 6	73	67	60	52	44	37			46
12 × 6	70	65	59	51	44	38			44
10 × 6	68	63	57	51	44	38	32		42
8 × 6	56	52	47	41	35	30			35
15 × 5	62	54	44	36					42
12 × 5	59	52	43	35					39
10 × 5	53	47	40	33	27				35
12 × 5	48	42	35	28					32
10 × 5	45	40	34	28	23				30
8 × 5	43	39	33	28	23				28
6 × 5	38	34	30	25	20				25
6 × 4½	29	25	21	17					20
5 × 4½	27	24	20	16					18
9 × 4	29	23	18						21
8 × 4	25	20	15						18
7 × 4	22	18	14						16

CHAPTER III.

TIMBER BEAMS.

THE use of timber as a constructional material in gasworks is not very extensive. There are times, however, when a knowledge as to the load which a wood beam or strut will safely bear will be found useful. The next subject of study will therefore be that of timber beams and struts. It has long been known that a rectangular beam placed edgeways will carry a heavier load than the same beam if placed on its side; and this property of beams is taken advantage of in cases where the ends can be rigidly fixed (as in floor joists) to make the depth much greater than the breadth. All beams carrying a weight, when supported at both ends, have their upper fibres in compression and their lower fibres in tension; therefore, should any particular balk be found to have a knot, or shake, etc., on one side, the beam should be placed with the defective side uppermost.

It may be stated generally that the strength of solid rectangular timber beams varies inversely as the length, directly as the breadth, and directly as the square of the depth up to a certain point, *i.e.*, so long as the beam can be kept from twisting. The strength of square wooden beams varies inversely as the length and directly as the cube of the side of the square. The following table gives the constants required for ascertaining the strength of rectangular beams of the more common description of timber met with in gasworks. The constants are based upon experiments in which the beams were supported at each end and loaded in the centre. Should the method of supporting and loading differ from that referred to, then the load capable of being sustained in any other manner can be obtained from the knowledge that a beam supported at the ends and the load equally distributed will carry twice the weight of the beam similarly loaded but having the weight in the centre; also, that when the beam is supported at one end and the load distributed, it will carry half the load of that mentioned in the first example, and when supported at one end and having the load at the other it will only carry one-fourth of the load which the beam supported at both ends and loaded in the centre would carry.

In using the table one multiplies the breadth of the beam in inches by the depth (also in inches) squared, then by the constant of strength given in the table, the product of the three being finally divided by the length of the beam in feet.

Table of Strength of Timber.

Description.	Constant.
Oak	5 cwts.
Pitch pine	5 ,,
Good Memel deal	5 ,,
Red pine	4 ,,
Red deal	4 ,,
Yellow pine	3 ,,
Yellow deal	3 ,,

In order to show the application of the figures given in the table we will suppose that we wish to find out the breaking weight in the centre of a pitch pine beam 12 inches deep, 9 inches wide and 18 feet between the supports. Then,

$$\frac{9 \times 12 \times 12 \times 5}{18} = 360 \text{ cwts.}$$

360 cwts. would therefore represent the breaking weight of the pitch pine beam in question. But what is usually required is not the actual breaking load but the load which the beam would carry with safety. The safe dead load on timber beams should never exceed one-fifth of the breaking weight. Supposing one wished to know the weight which the same beam would carry if the load were equally distributed, the above result should be multiplied by 2.

In order to find the breadth of beam which will break under a stated load, the depth and length between supports being given, the rule is, "Multiply the length in feet by the breaking weight in cwts. and divide the product by the depth in inches squared multiplied by the constant; the quotient will be the breadth required in inches." Thus, reversing the previous example, supposing we wish to find the breadth of a pitch pine beam 18 feet long which will support a weight of 360 cwts. in the centre,

$$\frac{18 \times 360}{12^2 \times 5} = 9'' = \text{breadth required.}$$

Again, to find the depth of beam capable of supporting a given load, the width and distance between the supports being given, the rule is "Multiply the length in feet by the breaking weight in cwts. and divide the product by the breadth in inches multiplied by the constant; the square root of the quotient will give the depth in inches." Working on the same example as above, supposing we wish to find the depth of a pitch pine beam 18 feet long 12 inches wide which will support a weight of 360 cwts. in the centre, we have

$$\frac{18 \times 360}{9 \times 5} = 144, \text{ the square root of which is } 12.$$

It may be noted that the strongest rectangular shaped beam which can be cut out of a round log of timber possesses a cross section the square of whose breadth is equal to a third of the square of its diagonal; or, put in another form, the proportion of breadth to depth is practically as 5 to 7. Where it can be arranged the above proportion should be employed. Thus, supposing we wish to obtain the breadth and depth of a rectangular pitch pine beam, the length, breaking weight, and constant being given, the breadth and depth being as 5 to 7, the length is 28 feet, the constant 5, and the breaking weight 62 cwts. The breaking weight is obtained from the formula $\frac{b \times d^2 \times c}{L}$, which embodies the rule previously given. We then substitute $\frac{5}{7} d$ in place of b, and the formula then becomes

$$\frac{\frac{5}{7} d \times d^2 \times c}{L} = \frac{\frac{5}{7} d^3 \times c}{L} \text{ and } d^3 = \frac{\frac{7}{5} \times W \times L}{c}$$

$$\text{and } d = \sqrt[3]{\frac{\frac{7}{5} \times W \times L}{c}} = \sqrt[3]{\frac{\frac{7}{5} \times 62 \times 20}{5}}$$

$=\sqrt[3]{347}=7$ inches. Consequently $d=7$ inches, and 7 inches $\times\frac{5}{7}=5$ inches, the breadth.

The above-mentioned rules can be easily remembered by means of the following formulæ. Let W be the breaking weight, b the breadth, d the depth, c the constant, and L the length, then

$$\text{(I.)}\quad W=\frac{b\times d^2\times c}{L}$$

$$\text{(II.)}\quad b=\frac{L\times W}{c\times d^2}$$

$$\text{(III.)}\quad d=\frac{\sqrt{L\times W}}{c\times b}$$

We next proceed to give some rules for the strength of special forms of timber. One common example is that of floor joists. Assuming these to be of the ordinary common form and spaced 12 inches centre to centre, the timber being fir, the formula for their strength is

$$D=\sqrt[3]{\frac{L^2}{B}\times 2\cdot 2}$$

The following rules by Tredgold give the principal data for calculating the sizes of roof timbers :—

B = breadth of timber in inches;
D = depth in inches;
A = area of section of timber in inches = B × D;
L = length of piece of timber in feet;
S = span of roof in feet.

To calculate the size of a fir tie beam supporting a ceiling only, u representing the length of the longest unsupported part in feet,

$$D=\frac{u}{\sqrt[3]{B}}\times 1\cdot 47.$$

To calculate the size of a king post in fir, area, or B × D = L × S × 0·12.

To calculate the size of struts and braces, r representing the length of part of principal rafter supported by the strut in feet,

$$D = \sqrt{L \times \sqrt{r} \times 0{\cdot}8}\,;$$
$$B = \frac{6}{10} D.$$

Principal rafters, supported by struts over which the purlins rest,

In king post roof of fir, $D = \frac{L^2 \ S}{B^3} \times 0{\cdot}096.$

In queen post roof of fir, $D = \frac{L^2 \ S}{B^3} \times 0{\cdot}155$, the thickness being generally the same as that of the tie beam and king or queen posts.

Purlins of fir, C being the distance in feet that the purlins are apart,

$$D = \sqrt[4]{L^3 \times C \times 1}\,;$$
$$B = \frac{6}{10} D\,;$$
$$\text{Common rafters} = \frac{L}{\sqrt[3]{B}} \times 0{\cdot}72.$$

Straining beam.—In the best form for strength the depth is to breadth as 10 to 7.

$$D = \sqrt{L \times \sqrt{S \times 0{\cdot}9}}\,;$$
$$B = \frac{7}{10} D.$$

The strength of a circular pole is about one-tenth that of a square beam the side of which is equal to the diameter of the pole.

The calculation of the strength of wooden struts is not altogether satisfactory, since different authorities vary very much in their data. Perhaps the most useful rule is that of Mr. Shaler Smith, deduced from experiments made by himself on moderately seasoned white and common yellow pine, with flat ends, firmly fixed and equally loaded.

If the timber is square in cross section, one side would be treated as the breadth, and if rectangular, the least side would appear as the breadth.

The rule is—the breaking load in pounds per square

$$\text{inch of area} = \frac{5{,}000}{1 + \left(\frac{\text{square of length in inches}}{\text{square of breadth in inches}}\right) \times 0{\cdot}004.}$$

Or square the length in inches and divide this by the square of the breadth in inches, multiply the quotient by 0·004, add 1 to the product, and divide the sum into 5,000. Thus, supposing you wish to know what would be the breaking load of a strut of white pine 10 inches square and 20 feet long, the square of the length is $20 \times 12 = 240^2 = 57{,}600$; the square of the breadth is $10^2 = 100$, and $\frac{57{,}600}{100} = 576$, and $56 \times 0{\cdot}004 = 2{\cdot}3$, and $2{\cdot}3 + 1 = 3{\cdot}3$, and $\frac{5{,}000}{3{\cdot}3} = 1{,}515$ lbs., the breaking load per square inch. As the area of the strut is 100 square inches, the total breaking load is 151,500 lbs., or 67·6 tons The safe load should not be less than one-seventh of the breaking weight as given above.

EXAMPLES.

1. A beam has safely carried a centre load of 6 tons over an 8 feet span; what uniformly distributed load would you consider it safe to put over a 16 feet span?

(1) The centre load for a 16 feet span = half the centre load for an 8 feet span $= \frac{6}{2}$ tons = 3 tons. The distributed load for a 16 feet span = twice centre load, therefore the required load $= 3 \times 2 = 6$ tons.

2. Supposing the sectional area of a timber girder to be 90 square inches, give the dimensions of depth and width which, in your opinion, will produce the strongest section.

(2) Since the strength of a beam increases as the square of the depth and directly as the breadth, the strongest section, theoretically, should be one with a great depth and narrow breadth. In practice the breadth and depth of rectangular beams should be as 5 : 7. Now, let $5x$ and $7x$ be the required dimensions, then $5x \times 7x = 90$. Multiplying $5x$ by $7x$ we have $35x^2 = 90$ and $x^2 = \frac{90}{35} = \frac{18}{7} = 2{\cdot}5714$;

$x\sqrt{2{\cdot}5714} = 1{\cdot}6036 : 5x = 1{\cdot}6036 \times 5 = 8{\cdot}018$ and $7x = 1{\cdot}6036 \times 7 = 11{\cdot}225$. This can be proved by multiplying 8·018 by 11·225 = 90·002 square inches.

3. What would be the breadth of a fir girder according to the following dimensions $\frac{74L^2}{d^3} = b$. L, or length in feet, being 15 feet, d, or depth in inches, being 12 inches, and b being breadth in inches.

(3) From the data given in the question

$$b = \frac{74L^2}{d^3} = \frac{74 \times 15^2}{12^3} = \frac{74 \times 15 \times 15}{12 \times 12 \times 12} = \frac{74 \times 225}{1728} = \frac{16650}{1728} =$$

9·64 inches.

4. What must be the scantling of a fir beam to carry safely a distributed load of 5 tons over a span of 10 feet?

(4) In this question we have a load of 5 tons = 100 cwts. A distributed load of 100 cwts. will be equivalent to a central load of 50 cwts., since if a beam breaks with a given central load it would take twice the amount of load to break a similar beam if the load is distributed. Assuming that we have a factor of safety of 5, the load on the beam must be one-fifth of that which would cause it to break. We must therefore calculate the breaking weight as $50 \times 5 = 250$ cwts. Now, employing the formula given previously, viz., $W = \frac{b \times d^2 \times c}{l}$, in conjunction with the fact that the strongest beam is that in which the breadth is to the depth as 5 is to 7, we have two unknown quantities whose relationship is known; consequently, if we substitute $\frac{5}{7}d$ in the place of b, we have the general formulæ

$$W = \frac{\frac{5}{7}\, d \times d^2 \times c}{l} = W = \frac{\frac{5}{7}\, d^3 \times c}{l}; \text{ and}$$

$$d^3 = \frac{\frac{7}{5} w\, l,}{c}; \text{ therefore } d = \sqrt[3]{\frac{\frac{7}{5}\, wl}{c}}.$$

If we now fill in the corresponding values we have

$$d = \sqrt[3]{\frac{\frac{7}{5} \times 250 \times 10}{31}} = \sqrt[3]{1166 \cdot 6}, \text{ or } d = 10 \cdot 5\,;$$

and since $b = \frac{5}{7}$ of d, $\frac{10 \cdot 5 \times 5}{7} = 7 \cdot 5 = b$.

The scantling of beam required is therefore $10\frac{1}{2} \times 7\frac{1}{2}$.

CHAPTER IV.

HYDRAULICS, ETC.

SINCE the Arrol-Foulis stoking machinery is now frequently met with in gasworks a knowledge of the means by which the machines obtain their power, together with the details of the various calculations incidental thereto, will probably be of service to some. The pressure of water necessary to work the machines is obtained by means of an apparatus known as the accumulator, a sketch of which is shown in Fig. 42. A steam engine drives a pump of the combined piston and plunger type. From the pumps the water is forced into the accumulator cylinder at such a pressure that it acts on the accumulator ram and forces up the latter with its cross-head and the weight attached to it until the ram has reached nearly to the end of its stroke. At a predetermined height a projecting bracket on the side of the casing containing the weighting material engages with and lifts a small weight attached to a chain which passes over a pulley and is directly connected to the throttle-valve of the steam engine which works the pumps. The chain being provided with a counterbalance weight the engine and pump are stopped automatically by the raising of the weight and chain. If, owing to the demands of the retort house, the water which has been forced into the accumulator cylinder is now taken away from the accumulator, the load on the ram causes it to follow up and maintain a constant pressure on the water, since, as the accumulator descends, it pulls the starting chain and thus opens the throttle valve of the steam engine and again starts the pump. There is also an arrangement by which a relief valve opens on the accumulator attaining a certain height, allowing the water to flow back to the circulating tank and thus preventing damage to the accumulator. The weighting material is usually contained in a wrought-iron cylindrical casing, and in the London district clean, washed, heavy Thames ballast weighing 27 cwts. per cubic yard is usually employed on account of its cheapness.

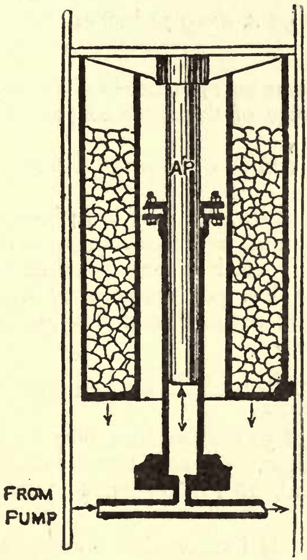


FIG. 42.

We will now give some useful calculations bearing on this subject :—

1. In a hydraulic accumulator the ram is 16 inches in diameter and the load upon it 50 tons. Find the pressure of the water in pounds per square inch.

(1) In answering this question, let P = the pressure in pounds per square inch on the ram, d the diameter of ram, and L the load in pounds. Then

$$P \times d^2 \times 0{\cdot}7854 = L\,;$$

$$P = \frac{L}{d^2 \times 0{\cdot}7854} = \frac{L}{\text{area}} \text{ and area} = \frac{L}{P}\,;$$

$$P \times 16 \times 16 \times 0{\cdot}7854 = 50 \times 2240\,;$$

$$\therefore P = \frac{50 \times 2240}{16 \times 16 \times 0{\cdot}7854} = \frac{112000}{201{\cdot}06} = 557 \text{ lbs.}$$

2. The ram of a hydraulic accumulator is 9 inches in diameter. Find the load requisite to produce a pressure of 700 lbs. per square inch.

(2) $$\text{Load} = \frac{9 \times 9 \times 0{\cdot}7854 \times 700}{2240} = \frac{44531{\cdot}9}{2240} = 19{\cdot}8 \text{ tons.}$$

3. Find the diameter of the ram of an accumulator

when the pressure is 1,500 lbs. per square inch and the load 50 tons.

(3) $d^2 \times 0{\cdot}7854 \times 1500 = 50 \times 2240$;

$$\therefore d^2 = \frac{50 \times 2240}{0{\cdot}7854 \times 1500} = 95 \therefore d = 9{\cdot}74 \text{ inches.}$$

4. If the ram of an accumulator be 17 inches in diameter, what load will bring the pressure of the water to 700 lbs. per squre inch?

(4) $17 \times 17 \times 0{\cdot}7854 \times 700 = 226{\cdot}98 \times 700 = 158{,}886$ lbs.

5. If, in a hydraulic accumulator, the ram is 14 inches in diameter and a load of 50 tons produces a pressure of water of 727·5 lbs. per square inch, if it were required to increase the pressure to 1,000 lbs. per square inch, what would be the additional weight required, and how much ballast would this represent?

(5) $$\text{Total load} = \frac{14 \times 14 \times 0{\cdot}7854 \times 1000}{2240} = 68{\cdot}7 \text{ tons.}$$

Deducting the original weight of 50 tons we have 68·7 – 50, 18·7 due to the increased weight, and as Thames ballast weighs 27 cwts. per cubic yard, $18{\cdot}7 \times 20 = 374 \div 27 = 14$ yards of ballast required.

It sometimes happens that it is inconvenient to employ a cast-iron circular column, and in its place a stanchion is used, the general cross-section being +, but this is not nearly so economical as a hollow cylindrical column, as regards the amount of metal required, since a cylindrical column of the same external diameter as a +-shaped stanchion and having the same sectional area will be nearly twice as strong. As an example, we will work out the strength of the stanchion shown in Fig. 43. This is 10 feet long, and is intended to sustain a dead distributed load of 30 tons. In the first place we will assume that the width is one-fifteenth of the length; then $10 \times 12 \div 15 = 8''$ as the width. We will next assume that the stanchion is capable of sustaining a safe load of 2 tons per square inch of sectional area; consequently, $\frac{30}{2} = 15$

square inches, which in a +-shaped stanchion could be obtained by making it $8'' \times 8''$ with a thickness of metal of $1''$ or $(8''+8''-1'')=15''$ square inches area. We next proceed to see if the $15''$ area will give the necessary amount of metal to make the stanchion strong enough.

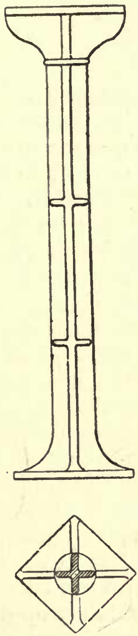


FIG. 43.

The formula most generally employed for obtaining the strength of a stanchion is that of Gordon, where

W = crushing weight in tons,
s = sectional area in square inches,
d = diameter over all in inches,
l = length in inches.

The formula then reads :—

$$W = \frac{36s}{1 + \frac{3l^2}{400d^2}}$$

Applying this to the present example we have

$$W = \frac{36 \times 15}{1 + \frac{3 \times 120^2}{400 \times 8^2}} = 166{\cdot}7 \text{ tons crushing weight;}$$

and using a factor of safety of one-sixth the safe load $= 166 \div 6 = 27{\cdot}6$ tons, showing that the section is strong enough. It is usual to cast stiffeners in the angles, spaced about 3 feet apart, of the same thickness of metal as the general body of the stanchion. The size of the base of the stanchion will be determined by the resisting properties of the foundation beneath, but assuming that it will be bedded directly on a York stone template sufficiently thick to spread the load over the pier or footings, the area of the stanchion base may be determined on the basis of 7 tons per superficial foot. The area required will, consequently, be $30 \div 7'' = 4{\cdot}3$ square feet, $\sqrt{4{\cdot}3} = 2{\cdot}06$, say 2 feet each way.

CHAPTER V.

THE LEVEL.

WE next proceed to give a few notes on the construction and use of the level. Levelling occupies an important place in the engineering work of a gasworks, since in the setting out of new buildings and the laying of pipes in the district it is essential that the relationship between the various levels should be known. Although the levels of different makers vary somewhat in their details, the essential features can be understood from Figs. 44 and 45. It will be seen from Fig. 44 that the level consists of a telescope having attached to it a spirit level parallel to its length and another one at right angles to it. The instrument works on a movable axis, and is arranged so that it can be screwed on to a tripod. In order to set up the instrument you arrange it so that the top plate, C D, is as nearly parallel as can be roughly judged by the eye with the bottom plate, E F. This is effected by means of the four screws shown in the figures. The three legs of the tripod are then fixed in the ground, while keeping, if possible, the bubbles in the level tubes in the centre of their runs. This is, as a rule, a rather difficult operation. Having brought them as nearly as possible in the centre you

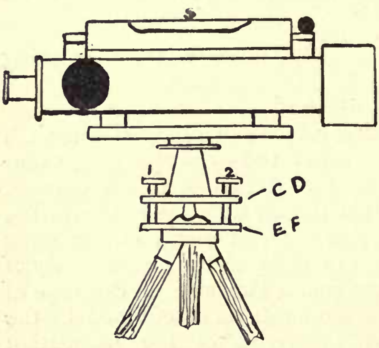


FIG. 44

level the telescope by means of the four screws, 1, 2, 3, 4, by bringing the telescope first over one pair of screws, 1, 2, and levelling it up and then over the other pair, 3, 4, whose position is shown by dotted lines in Fig. 45. This is then brought up level. It is necessary to note that the operations mentioned may have to be repeated many times before the telescope can be (as it ought to be capable of being) turned completely round, with the bubble remaining in the centre of the tube. In order to show when the bubble is in the middle of the tube, the latter is marked with a number of lines to allow for the variations in the length of the bubble with changes of temperature, which have a considerable effect upon it, causing it to shorten on a cold day, with a corresponding increase of length on a warm day. If we look through the telescope there will be seen a couple of vertical hairs and a horizontal hair, as shown in Fig. 46, but these will appear very dim until the small eye-piece is drawn out, which will render them distinctly visible. The eye-piece should not require touching again unless it is accidentally deranged, or there is a change of observers with differing eyesights. The next operation is the focussing of the telescope by the screw, which will require to be

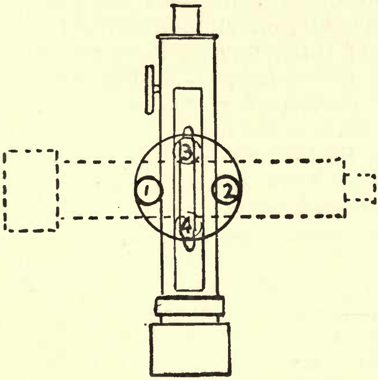


FIG. 45.

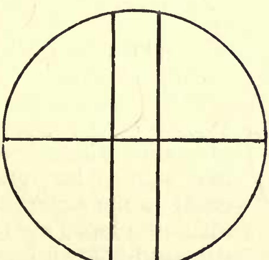


FIG. 46.

altered every time the position of the levelling staff is changed. The levelling staff (Fig. 47), which is telescopic and about 14 feet long when fully drawn out, is divided into feet, and usually the feet are sub-divided into hundredths. The numbers indicating the feet are generally painted red, and the height to be read off is the line on the levelling staff cut by the crossed hair, as in Fig. 48, which shows the portion of a staff cut off by the level and reads 2·24 feet. In holding the staff it must be held so that it is parallel with the two vertical hairs shown in Fig. 48. Since the levelling staff appears to the eye to be upside down, some difficulty in reading it may be experienced at first, but this will soon be overcome with a little practice. In taking levels for important building works they are always referred to what is known as ordnance datum (O.D.), which is assumed to be the mean level of the sea as recorded on the sill of the dock wall at Liverpool. In the London district the level of Trinity high water, or T.H.W., as it is frequently termed, is taken as the datum line.

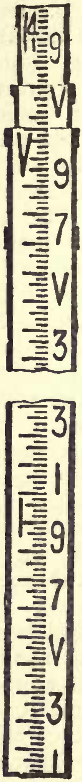


FIG. 47.

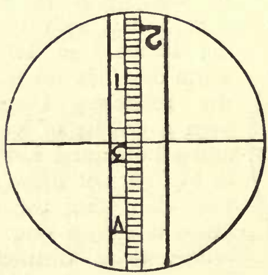


FIG. 48.

The method of performing the operation of levelling is briefly as follows :—The instrument having been "set up" and adjusted as previously described, the staff-holder proceeds to the points at which the levels are to start, and holds up the staff perfectly vertical with the marked face turned toward the leveller. The division on the staff which coincides with the horizonal hair in the telescope is then noted and entered in the level book. The staff-holder proceeds to the next point, and the reading on the staff is again noted, and this is repeated until the distance from the telescope or the difference of level which makes the staff invisible makes it necessary for the leveller to take up a fresh position. While the level is being shifted it is very necessary to see that the staff-holder does not move from his last position until the level has been readjusted, when he carefully turns the face of the levelling staff so as to be visible from the level in its new position. A second reading of the staff is then noted, after which the holder is at liberty to proceed forward, as before, for a fresh series of observations. In every set of observations the first is called a back sight and the last a fore sight, the remaining observations being known as intermediates. The leveller should, at the commencement, set the staff on some conspicuous mark which can readily be referred to at any future time, such as a door-step, plinth, course, etc. These points, which serve as bench marks, are essential in checking the work as it proceeds, or in carrying it on at any subsequent period.

As a simple illustration of the method of using the level, we will suppose that we wish to ascertain the difference in level between the points A and B (Fig. 49), B being a bench mark on the step of a building

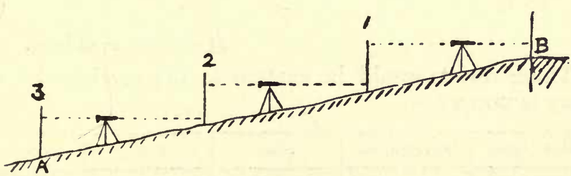


FIG. 49.

300 feet above ordnance datum, as ascertained from an ordnance map. The instrument would first be fixed up so that the staff could be read at B. Supposing the reading on B to be 2 feet, adding this to 300, we have 302 feet. The telescope is then turned towards the staff in the position 1, and suppose the reading now to be 12 (it will

be noticed that as the level of the ground falls the readings are higher), then 302 − 12 = 290. The position of the telescope is now shifted to a point between 1 and 2, but the staff is only turned round. Suppose the reading in the new position to be 3, then 290 + 3 = 293. The staff is now shifted to the point 2, where we will suppose the reading to be 10. Then 293 − 10 = 283. The instrument is again shifted between the position 2 and the point A, and the staff turned round for a new reading. Suppose the reading now to be 1. Then 283 + 1 = 284. The staff is then moved to the point, A. Suppose the reading now to be 8, then 284 − 8 = 276 feet as the level at the point, A; and the difference of level between A and B = 300 − 276 = 24 feet.

In all cases the first reading on setting up the level is a "back" sight, and the last reading before shifting the level a "fore" sight. The difference of the sums of the back and fore sights will more readily give the difference of the levels. Thus:—

Back Sight, Feet.	Fore Sight, Feet.
2	12
3	10
1	8
6	30
	6
	24 = difference of level.

These results would be entered in the level-book somewhat as under:—

Back Sight.	Fore Sight.	Rise.	Fall.	Remarks.
				Point B
2	12		10	,, 1
1	10		7	,, 2
3	8		7	,, 3
6	30		24	

It is usual, when taking a series of levels, to measure the distance between the different points at which the staff is fixed, and in plotting the sections of the ground levelled it is usually the practice to make the vertical scale much greater than the horizontal, thus enabling small variations of level to be easily measured on the drawing without causing the latter to extend to an inconvenient length.

CHAPTER VI.

ESTIMATING COST OF A BUILDING.

IT is proposed in the present chapter to give an outline of the method by which estimates of the cost of a building are obtained from the pricing out of the quantities. Of course, in many instances the local rates for excavating, concrete work, bricklaying, carpenter's and joiner's work, etc., are known, but in cases where no local rates are obtainable the essential data for obtaining such prices may sometimes be of service. The working out of the various costs is greatly facilitated by the use of tables of constants which have been compiled by various authorities, so that by multiplying the constant by the wages paid to the workmen the cost of performing the various labours appertaining to the erection of a building can be closely arrived at; although, of course, these must not be taken as entirely reliable, since it is a difficult matter to obtain the absolute amount of work capable of being performed by any artizan. We will commence by taking the item of excavation in a trench not exceeding 6 feet deep, including the levelling of the bottom and fixing and taking down planking where required. The ground is assumed to be of the ordinary description, and the amount of soil capable of being thrown out per man 8 cubic yards per day of 10 hours. This is equal, at 7d. per hour, to 5s. 10d. per day. Dividing one day by the cubic yards capable of being excavated we obtain the figure 0·125, which is the constant. Then, on multiplying 0·125 by the wages per day, or 70d., we get 8·75d. as the cost per cubic yard; to which must be added 1·25d. for fixing planking, levelling, etc., making the total cost 10d. per yard.

We will next take concrete, and work out the cost of a cubic yard of concrete composed of 1 part of hydraulic lime to 6 parts of Thames ballast, which will contain about one-third of its bulk of sand, the rest being gravel. In practice it is usual to allow 1⅕ cubic yards of ballast for each cubic yard of concrete, to allow for the diminution of the sand in the ballast. We should then have—

	s.	d.
1·2 cubic yards of Thames ballast at, say, 5s.	6	0
4 bushels of hydraulic lime at, say, 9d.	3	0
30 gallons of water, costing, say, 1d.	0	1
Labour, 0·230 of a day by 70d.	1	4
	10	5
To this it is usual to add a profit of, say, 10 per cent., amounting to	1	0½
Making the total cost per yard	11	5½

It should be noted that the constants of labour are always applicable, the items that vary being the cost of materials and of labour. But by multiplying the rate of the latter by the constant one can always obtain the cost of such labour.

As another simple illustration we will take the cost of preparing by hand 1 yard of lime mortar composed of 1 of grey stone lime to 3 of sand. It has been proved by practical experiments that it requires 9 bushels of lime, 1 cubic yard of sand and 50 gallons of water to make a cubic yard of mortar of the above description. We consequently have the following as the cost:—

	s.	d.
9 bushels of stone lime at, say, 9d.	6	9
1 cubic yard of sand ,, ,, 5s.	5	0
50 gallons of water, say	0	2
Labour mixing by hand 0·720 of a day × 70d.	4	2
Making the total cost per yard, exclusive of profit	16	1

Constants will be found of great service in the pricing out of brickwork. The constants for brickwork in mortar, worked fair both sides, exclusive of pointing, are as under:—

	Days of a Bricklayer and Labourer.
In walls 1 brick thick per rod	5·132
,, 1½ ,, ,,	4·500
,, 2 ,, ,,	4·316
Add to any of the foregoing if built in Portland cement	0·300

The following would be the method of obtaining the cost of labour in one rod of brickwork, $1\frac{1}{2}$ bricks thick, taking the wages for a bricklayer at 8s. 4d. and labourer at 5s. per day of ten hours. Constant, 4·500 multiplied by 13s. 4d. = £3. We now have the data for calculating the cost of a rod of brickwork of standard thickness:—

	£	s.	d.
4,300 stocks at, say, 30s. per 1,000 . . .	6	9	0
Water for wetting bricks, say, 500 gallons .	0	0	4
Labour as above	3	0	0
Use of scaffolding	0	4	0
Two cubic yards of mortar at 16s. 1d, as per estimate	1	12	2
	11	5	6
Add 10 per cent. profit	1	2	7
	£12	8	1

The above does not include the cost of pointing, which, in the case of new work, flat joint in mortar, including the raking out of joints, is 0·090 day per super. yard for a bricklayer and labourer; and since 170 yards of walling requires a cubic yard of mortar, we have for the cost of pointing—

	s.	d.
0·006 cubic yards of mortar at 16s. 1d.	0	1·15
0·090 day at 13s. 4d.	1	2
	1	3·15
Adding 10 per cent. profit . .	0	1·5
We have . . .	1	4·6 or, say, 1s. 5d.

In estimating the cost of slating, we may assume that in the case of Countesses slates the time of a labourer and boy preparing and laying one square of slating will be 0·190 of a day. In order to ascertain the number of slates required to cover a given area of roofing, you take from the length of the slate the lap—*i.e.*, as much as the third slate covers the first, divide the remainder by 2, multiply the quotient by the width of the slate, and the product will be the number of square inches covered by a single slate. By dividing the total area of the surface required to be covered in square inches by this, the quotient will give the number required. Thus in the case of Countesses slates with a 3-inch lap we have $\frac{20'' - 3}{2} = 8\frac{1}{2}''$, and $8\frac{1}{2}'' \times 10''$ (breadth of slate) = 85″; and dividing this into the number of superficial inches in a square = $100 \times 144 = 14{,}400$, we obtain the quotient 170 as the number of Countesses slates required per square; but it is usual to allow 10 per cent. for waste, making the actual number required 180. Since each slate requires two nails, doubling the number of slates will give the number of nails required. The wages of a slater is assumed to be 11d. and that of his boy $3\frac{1}{2}$d. per hour. The cost of a square of slating would, therefore, be approximately :—

	£	s.	d.
180 slates at £9, 10s. per 1,200	1	8	6
2 lbs. of $1\frac{1}{2}''$ copper nails at, say, 10d. .	0	1	8
Slater and boy 0·190 day	0	2	3
	1	12	5
Add 10 per cent. profit . .	0	3	3
	£1	15	8

Carpenter's work, which is usually of a heavy description, is executed partly from balk timber and partly from deal, the basis of the calculation of the cost of such timber being the load of 50 cubic feet. Joiner's work, being of a lighter description, is generally converted out of deal, the basis of price being the St. Petersburg standard of 120, 12 feet by 11 inches by $1\frac{1}{2}$ inches = 1,320 feet super. of $1\frac{1}{2}$ inch thick, or 165 feet cube, the cost including carriage, sawing and "waste." The total cost divided by 660 gives the price per superficial foot of 3-inch deal.

It is necessary to note that in arriving at the actual quantity of timber required account must be taken of the amount due to the waste caused by planing. If "finished sizes" are specified, then it will be necessary to add $\frac{1}{8}$ inch for the loss in planing. This works out to about 1d. per super. foot to add to the nominal prices.

The following are constants for labour for this description of work :—

	Hours of a Carpenter.
Labour fixing fir in roofs	0·90
,, in roof trusses, exclusive of hoisting	1·23
Making $1\frac{1}{2}$-inch teal ledged doors, ploughed and tongued	0·51
Square framed four panelled doors	0·42
Hanging doors 1s. 6d. each	...
Deal-cased window frames for 2-inch sashes, oak sunk sill, deal pulley siles, single hung	0·76
Making purifier grids, 1d. per super. foot	...

The following are constants for mason's work on Portland or similar stones per super. foot:—

Sawing	0·60 hours.
Plain work in beds and joints	1·25 ,,
Sunk work	1·20 ,,
Plain face, rubbed	1·25 ,,
Sunk work, rubbed	1·23 ,,
Moulded work	2·00 ,,

The proportional cost of labour to cost of material varies with the different trades. The following are general averages:—

	Labour per cent.	Plant and Materials per cent.
Excavator	90	10
Bricklayer	75	25
Mason	60	40
Slater	20	80
Carpenter	25	75
Joiner	60	40
Smith	20	80
Plumber	25	75

It should be noted that the rates of wages quoted are on the basis of London prices.

The approximate cost of a building may frequently be arrived at by what is known as "cubing," which consists in multiplying the outside length of the building by the breadth and the product by the height from the bottom of the footings to half way up the roof. An experienced contractor, from a perusal of the drawings, and from the cubic contents of the building as described above, together with a general description of the materials to be used, will frequently be able to estimate the cost very closely; and if those having the design of gasworks buildings would in every case take out the cubic contents and, from the actual cost, work out the price per cubic foot, some valuable material for the comparison of relative costs would be obtained. The author has no available data as to gas-works buildings, but the following costs per cubic foot of brick buildings will give an approximate idea of what buildings should cost per cubic foot:—Barracks, 8d.; baths, 1s.; breweries, 5d. to 7d; cottages, 4½d.; factories, exclusive of machinery, 6d.; schools (London Board), 6d. to 8d.; corrugated iron sheds with roof, 2½d.; town halls, 10d. to 1s. 6d.; warehouses, plain, 5d. to 6d.; workshops for mechanics, 6½d.

The following are prices for main laying, including contractor's profit, the rates for labour being as under:—

	s.	d.
Ganger per day of ten hours	8	6
Jointmakers ,, ,, ...	7	0
Timbermen ,, ,, ...	6	6
Excavators ,, ,, ...	5	0
Watchman ,, ,, ...	4	6
Boys ,, ,, ...	3	3
Cartage, single horse and cart	11	0
Use and repair of tools per man per day . . .	0	6

Size in Inches.	Laying Without Rubbish Carting. Per Yard.	Laying Including Rubbish Carting. Per Yard.	Reduction for Turned and Bored Pipes. Per Yard.	Taking up in Same Trench. Per Yard.	Taking up in Separate Trenches. Per Yard.
	s. d.	s. d	s. d.	s. d.	s. .
3	0 8	0 8	0 1	0 2	0 4
4	0 9	0 9	0 1	0 2½	0 4½
6	0 11	1 1	0 1	0 3½	0 6
8	1 3	1 7	0 2	0 5	0 8
9	1 6	1 10	0 2	0 6	0 9
12	1 9	2 3	0 3	0 8	1 0
16	...	3 3	0 6	...	...
18	...	4 0	0 6	1 3	...
20	...	5 0	0 9	...	2 0
24	...	6 0	1 0	...	...
30	...	8 0	1 6	...	...

The following are prices for some of the tools required in gasworks, the work being done "piecework" and exclusive of cost of materials :—

	s.	d.
Making augers	1	3
Repairing "	0	11
Making patching slices	0	11
Making "horses"	0	8
Repairing "	0	6
Making bar hooks	0	6
" scurfing bars	1	6

CHAPTER VII.

PRACTICAL MENSURATION

IN this concluding chapter it is proposed to give a few rules and examples in practical mensuration which are not usually found in text-books. It is, of course, assumed that the student is familiar with the ordinary rules. In setting out a square or rectangular building, a washer, or set of purifiers, in fact any object in which it is requisite that one side is at right angles to the other, we make use of the 47th proposition of Euclid, that in a right angled triangle the square of the side subtending the right angle is equal to the sum of the squares of the two other sides; and it will be found that these are in the ratio of 3, 4 and 5. Thus, supposing we wish to set out a building (Fig. 50), and we measure 6 feet one way and 8 feet

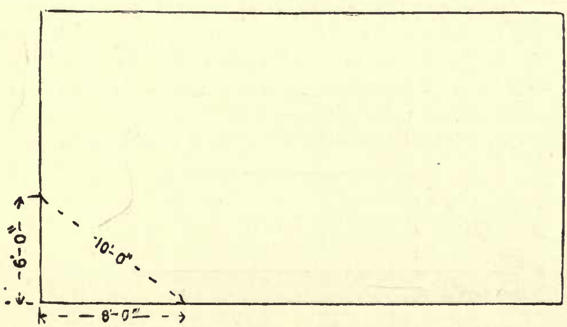


FIG. 50.

the other, if the walls are rectangular, on joining these points the distance should be exactly 10 feet, since $6^2 = 36 + 8^2 = 64 = 100$, and $10^2 = 100$.

A considerable amount of time can be saved by the use of the table of natural sines given on page 85. As an example, suppose we have a king post roof of 20 feet span, shown in diagram form in Fig. 51, the pitch being 30°

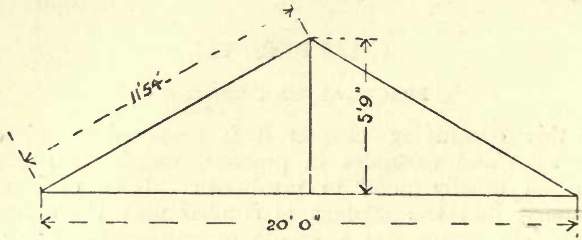


FIG. 51.

The span being 20 feet, the half-span will be 10 feet. Then to get the length of the rafter we look up the number 30 in the table of natural sines, and we find that the cosine is 0·86603. Then on dividing the base (10 feet) by this, or multiplying by the secant 1·15470, we get 11·54 feet as the length of the rafter. Similarly, if we wish to obtain the depth of the king post, we multiply the base (10 feet) by the tangent 0·57735, or, say, 0·5774, and we thus get 5 feet 9 inches as the length of the king post.

The same table is very useful in determining the contents of large heaps of coke, earth, etc. As an instance, suppose we have a heap of coke of the cross section shown in Fig. 52, we can measure the width on the top. Say we

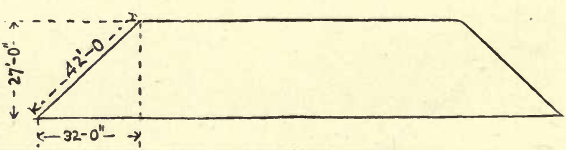


FIG. 52.

find it to be, on an average, 90 feet. We can also level off the depth and find it to be 27 feet. We cannot tape over the extreme width of the heap. What we do, therefore, is to take the average inclination and also the length of the slope.

Supposing the average angle to be 40° and the length of slope 42 feet. Then on multiplying this by the cosine of the angle of the slope, or 0·76604, we get 32 as the horizontal distance, half this representing the average width

TABLE OF NATURAL SINES.

Deg	Sine.	Coversine	Cosec.	Tan.	Cotan.	Secant.	Versine.	Cosine.	
0	0·00	1·00000	Infinite	0·0	Infinite	1·00000	0·0	1·00000	90
1	0·01745	0·98255	57·2987	0·01746	57·2900	1·00015	0·00015	0·99985	89
2	0·03490	0·96510	28·6537	0·03492	28·6363	1·00061	0·00061	0·99939	88
3	0·05234	0·94766	19·1073	0·05241	19·0811	1·00137	0·00137	0·99863	87
4	0·06976	0·93024	14·3356	0·06993	14·3007	1·00244	0·00244	0·99756	86
5	0·08716	0·91284	11·4737	0·08749	11·4301	1·00382	0·00381	0·99619	85
6	0·10453	0·89547	9·5668	0·10510	9·5144	1·00551	0·00548	0·99452	84
7	0·12187	0·87813	8·2055	0·12278	8·1443	1·00751	0.00745	0·99255	83
8	0·13917	0·86083	7·1853	0·14054	7·1154	1·00983	0·00973	0·99027	82
9	0·15643	0·84357	6·3925	0·15838	6·3138	1·01247	0·01231	0·98769	81
10	0·17365	6·82635	5·7588	0·17633	5·6718	1·01543	0·015 9	0·98481	80
11	0·19081	0·80919	5·2408	0·19438	5·1446	1·01872	0·01837	0·98163	79
12	0·20791	0·79209	4·8097	0·21256	4·7046	1·02234	0·02185	0·97815	78
13	0·22495	0·77505	4·4454	0·23087	4·3315	1·02630	0·02563	0·97437	77
14	0·24192	0·75808	4·1336	0·24933	4·0108	1·03061	0·02970	0·97030	76
15	0·25882	0·74118	3·8637	0·26795	3·7321	1·03528	0·03407	0·96593	75
16	0·27564	0·72436	3·6280	0·28675	3·4874	1·04030	0·03874	0·96126	74
17	0·29237	0·70763	3·4203	0·30573	3·2709	1·04569	0·04370	0·95630	73
18	0·30902	0·69098	3·2361	0·32492	3·0777	1·05146	0·04894	0·95106	72
19	0·32557	0·67443	3·0716	0·34433	2·9402	1·05762	0·05448	0·94552	71
20	0·34202	0·65798	2·9238	0·36397	2·7475	1·06418	0·06031	0·93969	70
21	0·35837	0·64163	2·7904	0·38386	2·6051	1·07115	0·06642	0·93358	69
22	0·37461	0·62589	2·6695	0·40403	2·4751	1·07853	8·07282	0·92718	68
23	0·39073	0·60927	2·5593	0·42447	2·3559	1·08636	0·07950	0·92050	67
24	0·40674	0·59326	2·4586	0·44523	2·2460	1·09464	0·08645	0·91355	66
25	0·42262	0·57738	2·3662	0·46631	2·1445	1·10338	0·09369	0·90631	65
26	0·43837	0·56163	2·2812	0·48773	2·0503	1·11260	0·10121	0·89878	64
27	0·45399	0·54601	2·2027	0·50953	1·9626	1·12233	0·10899	0·89101	63
28	0·46947	0·53053	2·1301	0·53171	1·8807	1·13257	0·11705	0·88295	62
29	0·48481	0·51519	2·0627	0·55431	1·8040	1·14335	0·12538	0·87462	61
30	0·5000	0·5000	2·000	0·57735	1·7321	1·15470	0·13397	0·86603	60
31	0·51504	0·48496	1·9416	0·60086	1·6643	1·16663	0·14283	0·85717	59
32	0·52992	0·47008	1·8871	0·62487	1·6003	1·17918	0·15195	0·84805	58
33	0·54464	0·45536	1·8361	0·64941	1·5399	1·19236	0·16133	0·83867	57
34	0·55919	0·44081	1·7883	0·67451	1·4826	1·20622	0·17096	0·82904	56
35	0·57358	0·42642	1·7434	0·70021	1·4281	1·22077	0·18085	0·81915	55
36	0·58779	0·41221	1·7013	0·72654	1·3764	1·23607	0·19098	0·80902	54
37	0·60182	0·39819	1·6616	0·75355	1·3270	1·25214	0·20136	0·79864	53
38	0·61566	0·38434	1·6243	0·78129	1·2799	1·26902	0·21199	0·78801	52
39	0·62932	0·37068	1·5890	0·80978	1·2349	1·28676	0·22285	0·77715	51
40	0·64279	0·35721	1·5557	0·83910	1·1918	1·30541	0·23396	0·76604	50
41	0·65606	0·34394	1·5243	0·86929	1·1504	1·32501	0·24529	0·75471	49
42	0·66913	0·33087	1·4945	0·90040	1·1106	1·34563	0·25686	0·74314	48
43	0·68200	0·31800	1·4663	0·93252	1·0724	1·36733	0·26865	0·73135	47
44	0·69466	0·30534	1·4396	0·96569	1·0355	1·39016	0·28066	0·71934	46
45	0·70711	0·29289	1·4142	1·0000	1·0000	1·41421	0·29289	0·70711	45
	Cosine.	Versine.	Secant.	Cotan.	Tan.	Cosec.	Coversine	Sine.	Deg.

of one side. The same result could be obtained by dividing the height (27 feet) by the tangent 0·83910.

Shortly expressed, any horizontal distance = sloping distance multiplied by the cosine of angle of slope; sloping distance = horizontal distance divided by the cosine of angle of slope; and vertical height is equal to the horizontal distance multiplied by the tangent, or is equal to the sloping distance multiplied by the sine.

It may be mentioned that angles can be measured approximately by means of an ordinary 2-foot rule. If the inner edges of a common 2-foot rule are opened to the extent shown in the column of inches in the following table they will be inclined to each other at the angles given :—

The opening is measured along the line A (Fig. 53).

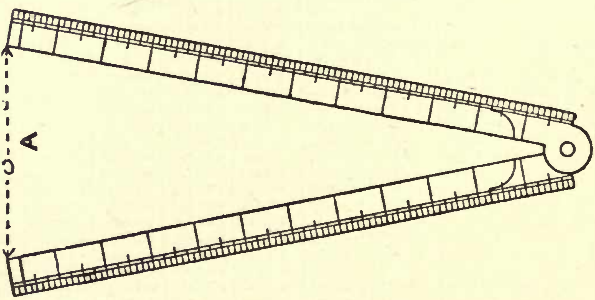


FIG. 53.

Opening in Inches.	Angle. Deg.	Angle. Mins.	Opening in Inches.	Angle. Deg.	Angle. Mins.
1	4	47	13	65	35
2	9	34	14	71	22
3	14	22	15	77	22
4	19	12	16	83	37
5	24	1	17	90	12
6	29	0	18	97	12
7	33	54	19	104	41
8	38	57	20	112	53
9	44	3	21	122	6
10	49	15	22	132	53
11	54	34	23	146	48
12	60		24	180	

It is frequently required to know the superficial area of a retort, in order to arrive at the make of gas per superficial foot. Supposing we have a single 10 feet long retort 20″ × 13″, as in Fig. 54, and we wish to know its superficial

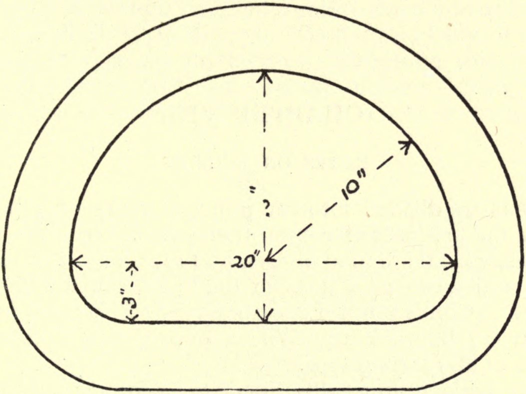


FIG. 54.

area. We have first of all the circumference of half a circle 20″ in diameter, or 3·1416 × 20 ÷ 2 = 31·41 inches, plus half a circle 6″ in diameter at the corners, or 3·1416 × 6 ÷ 2 = 9·425 inches, plus 20″ − 6″ = 14″ flat bottom of the retort, making a total of 54·83 inches. This multiplied by 10 feet (length of retort) gives 45·7 square feet as the superficial area of the retort.

CHAPTER VIII.

NOTES ON BOILERS.

BOILERS are divided into two principal types—(1) those in which the products of combustion pass through the tubes or flues, called fire-tube boilers, and (2) those in which the water and steam pass through the tubes, called water-tube boilers. Cornish and Lancashire boilers belong to the first type; Babcock and Wilcox boilers may be taken as typical of the second type.

The boilers principally used in gasworks are either Cornish or Lancashire. The Cornish boiler has one internal cylindrical flue extending the whole length of the boiler, the furnace being in this flue, at its front end (Fig. 55). The Lancashire boiler has two internal cylindrical flues extending the whole length of the boiler, the

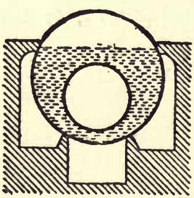


FIG. 55.

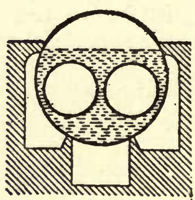


FIG. 56.

furnaces being, also, in these flues, at the front ends (Fig. 56).

In addition to cylindrical boilers of the types mentioned, water-tube boilers are sometimes employed. Of these, special mention may be made of the Babcock and Wilcox. This consists, essentially, of a series of inclined steel tubes, connected at their ends to what are known as "headers," which lead to a large horizontal steam drum situated over the tubes, as shown in Fig. 57. Each vertical row of tubes is zigzag, so that the products of combustion shall come well into contact with the heating surfaces. Also, each vertical row of tubes is connected to a box at each end,

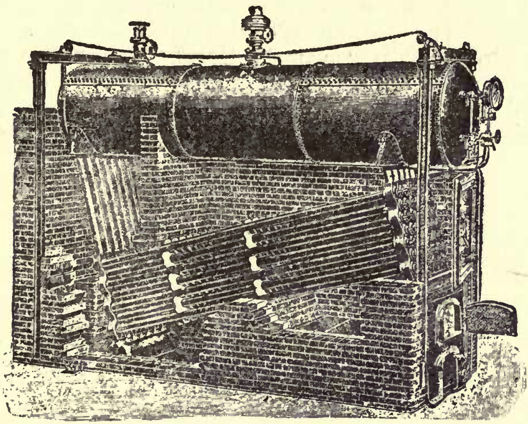
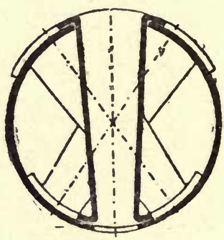


FIG 57.

these boxes being connected to the main steam drum by rising tubes, all tubes being expanded into their respective holes. The outer holes in the headers, opposite the tube ends, are fitted with plugs, or doors, somewhat in the manner that mudholes are sometimes fixed. The back headers are connected to a mud drum at their lower ends, in which most of the sediment collects, and which can be periodically blown out. The whole boiler is suspended from two beams resting on four pillars, and the brick setting is built up round the boiler (Fig. 57). The mountings are similar to those of an ordinary cylindrical boiler, the whole of the front being of cast iron. The water in the tubes, as it becomes heated, rises along the tubes and headers into the steam drum, the water in the drum at the same time descending to the back headers and thence into the tubes.

The advantages of this type of boiler are its great power of withstanding pressure (on account of the small diameter of the steam drum and tubes) and the great facility with which it can be transported, and erected in cramped positions. The amount of space occupied for a given steam production is also small.

An important part of a Lancashire boiler is the Galloway tube, shown in Fig. 58. Galloway tubes add very much to the strength of furnace tubes and flues. They increase



Galloway Tubes.
FIG. 58.

the heating surface, and that very effectively, and they also promote a better circulation of the water. They are generally riveted to the flue, as shown in the illustration, although they are sometimes welded in. Galloways Limited, of Manchester, the patentees and makers of these tubes, make them in all lengths up to 4 feet 6 inches. Up to a length of 2 feet, the diameters of the upper and lower ends are 8 inches and 4 inches, respectively. For lengths over 2 feet and up to 2 feet 3 inches the diameters are 9 inches and 4½ inches, and for lengths over 2 feet 3 inches the diameters are 10½ inches and 5½ inches.

DIMENSIONS OF CORNISH BOILERS.

(As made by Galloways Limited, Manchester)

Diameter of Shell.		Length of Shell.	Diameter of Furnaces.		Number of Cone Tubes.	Heating Surface.	Water Evaporated Per Hour.
Ft.	Ins.	Ft.	Ft.	Ins.		Sq. Ft.	Lbs.
4	0	10	2	1½	2	142	800
4	0	12	2	1½	2	169	1,000
4	0	14	2	1½	2	196	1,200
4	6	10	2	4½	2	158	900
4	6	12	2	4½	2	189	1,100
4	6	14	2	4½	2	219	1,300
5	0	12	2	7½	2	208	1,300
5	0	14	2	7½	3	247	1,400
5	0	16	2	7½	3	281	1,550
5	0	18	2	7½	4	320	1,700
5	0	20	2	7½	4	354	1,850
5	6	16	2	9	3	300	1,700
5	6	18	2	9	4	342	1,850
5	6	20	2	9	4	378	2,000
5	6	22	2	9	5	420	2,150
6	0	18	3	0½	4	370	2,000
6	0	20	3	0½	4	409	2,200
6	0	22	3	0½	5	455	2,400
6	0	24	3	0½	5	492	2,600
6	6	22	3	3	5	497	2,600
6	6	24	3	3	5	539	2,800
6	6	26	3	3	6	588	3,000
7	0	24	3	6	5	580	2,900
7	0	26	3	6	6	632	3,150
7	0	28	3	6	6	677	3,300
7	0	30	3	6	7	730	3,450

Dimensions of Standard Lancashire Boilers.

(As made by Galloways Limited, Manchester).

Diameter of Shell.		Length of Shell.	Diameter of Furnaces.		Number of Cone Tubes.	Heating Surface.	Water Evaporated Per Hour.
Ft.	Ins.	Ft.	Ft.	Ins.		Sq. Ft.	Lbs.
5	6	14	2	1½	2	318	1,600
5	6	16	2	1½	2	362	1,800
5	6	18	2	1½	4	415	2,000
6	0	16	2	4½	2	398	2,100
6	0	18	2	4½	4	457	2,400
6	0	20	2	4½	4	508	2,700
6	0	22	2	4½	4	557	3,000
6	6	20	2	7½	4	559	3,000
6	6	22	2	7½	4	615	3,400
6	6	24	2	7½	6	680	3,800
6	6	26	2	7½	8	745	4,200
7	0	24	2	9½	6	726	4,200
7	0	26	2	9½	8	794	4,600
7	0	28	2	9½	8	852	5,000
7	0	30	2	9½	10	922	5,500
7	6	28	3	0½	8	924	5,500
7	6	30	3	0½	10	1,001	6,000
8	0	30	3	3	10	1,071	6,700
8	0	32	3	3	12	1,151	7,200
8	6	30	3	6	10	1,151	7,800

The Galloway boiler, externally, resembles a Lancashire boiler. It contains two furnaces, which lead into a broad flue, in the form of a bent oval in cross section, this being traversed by a large number of Galloway tubes, and having on its side several pockets. The furnace gases flow to the the back of the boiler, where they divide, and return by side flues to the front end, where they re-unite, and flow along a bottom flue to the flue leading to the chimney.

DIMENSIONS OF STANDARD GALLOWAY BOILERS.

(As made by Galloways Limited, Manchester).

Shell.			Furnace.				No. of Cone Tubes.	Heating Surface.	Water Evaporated Per Hour.
Dia.		Length.	Dia.		Length.				
Ft.	In.	Ft.	Ft.	In.	Ft.	In.		Sq. Ft.	Lbs.
5	6	14	2	1½	5	8	9	310	2,100
5	6	16	2	1½	5	9	12	364	2,400
5	6	18	2	1½	6	2	14	412	2,700
6	0	16	2	4½	5	10	14	412	2,600
6	0	18	2	4½	6	4	15	461	3,000
6	0	20	2	4½	7	0	17	514	3,400
6	0	22	2	4½	7	4	20	574	3,800
6	6	20	2	7½	6	2	20	584	3,800
6	6	22	2	7½	7	0	21	636	4,200
6	6	24	2	7½	7	4	24	700	4,600
6	6	26	2	7½	7	4	27	766	5,000
7	0	24	2	9½	6	10	28	775	5,000
7	0	26	2	9½	7	6	30	838	5,500
7	0	28	2	9½	7	10	33	905	6,000
7	0	30	2	9½	8	6	35	968	6,500
7	6	28	3	0½	7	10	33	983	6,700
7	6	30	3	0½	8	6	35	1,052	7,200
8	0	30	3	3	9	6	38	1,120	8,000
8	0	32	3	3	10	2	40	1,180	8,400
8	6	30	3	6	9	6	40	1,211	9,000

The following may be taken as a typical performance of a Lancashire boiler, when working under a high standard of efficiency:—

Coal burned per square foot of grate area per hour	10 lbs.
Water evaporated per lb. of coal - - -	10 ,,
Total coal burned per hour - - - - - -	528 ,,
,, water evaporated per hour - - - -	5,280 ,,
Steam (dry) - - - - - - - - -	98 per cent.
Efficiency of boiler - - - - - - -	70 ,,
Flue gases (CO_2) - - - - - - -	11 ,,
,, (O) - - - - - - - - -	8 ,,
Total products of combustion - - - - -	100 volumes.
Total air in excess - - - - - - -	72 ,,

The cost of boilers may be taken as being, Lancashire £13, 10s. per square foot of grate area; water-tube (Babcock and Wilcox), £14, 10s. per square foot of grate area. The cost of setting Lancashire and Cornish boilers may be taken at from £3 to £5 per square foot of grate area, according to size.

The horse-power of a Cornish or Lancashire boiler can be approximately obtained by multiplying the grate area by 4. This will give the horse-power which will be developed by the boiler when supplying an engine consuming 30 lbs. of steam per hour, or requiring 4 lbs. of coal per I.H.P. per hour. A lower steam consumption or higher evaporative duty from the coal would give a corresponding higher power for the boiler.

The quantity of heat generated in a boiler depends upon the amount of fuel burned in a given time, and this, in turn, depends upon the size of the grate upon which the fuel is burned; from which it follows that the heating surface of a boiler is directly related to the area of the grate.

The principal points to be kept in view in the setting of boilers are easy access to flues, for examination and cleaning; reduction of amount of brickwork in contact with the plates to the minimum, so as to have as much of the plates as possible exposed and to prevent harbouring of moisture; arranging for the deflecting and distributing of the gases in such a manner as to obtain the greatest useful effect therefrom, and at the same time obviating, as far as practicable, unequal expansion and contraction of the shell without checking the draught. In modern practice the usual method is to support, or seat, the boiler on special fireclay blocks, so that it is supported on a narrow surface on each side, the surface in contact with the plates varying from a mere circular ridge, in the case of Poulton's patent seating blocks, up to $3\frac{1}{2}$ and 4 inches wide, when ordinary blocks are used. The blocks are shaped so as to support the weight of the boiler without crushing and to give the greatest amount of room in the side flues and conduct away from the plates any moisture which may run down the sides of the boiler. The flue covers are also made of special arched fireclay tiles. On leaving the boiler the products of combustion should first flow under the bottom of the boiler, splitting at the front end and then flowing along the side flues to the back and from there to the chimney. By this means the bottom and sides of the boiler are maintained at a more equable temperature than if the gases passed through the side flues first. The top of the side flues should not be above the level of the furnace crowns, and care should be taken that the seating blocks and flue covers are not in contact with the longitudinal seams of the shell. The front cross wall should be clear of the L iron of the shell, and be recessed so as to leave room for the elbow pipe to the blow-off cock to expand and contract, and also to make the shell accessible for examination. Sharp angles and sudden enlargements in the flues should be avoided. Firebrick should be employed in the facing of the flues; the mortar employed should be made of fireclay, no lime mortar being used. The boiler should have a fall, so that it is $1\frac{1}{2}$ inches lower at the front end than at the back, in order to allow of its being thoroughly drained at the blow-off cock when being emptied.

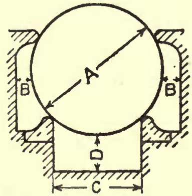


FIG. 59.

The following gives the sizes of flues which will be found suitable, A being the diameter of the boiler, and columns B, C and D giving the sizes of the flues, as in Fig. 59 :—

A.		B.	C.		D.	
Ft.	Ins.	Foot.	Ft.	Ins.	Ft.	Ins.
3	6	1	1	9	1	9
4	0	1	2	0	1	9
4	6	1	2	3	1	9
5	0	1	2	6	2	0
5	6	1	2	9	2	0
6	0	1	3	0	2	3
6	6	1	3	3	2	3
7	0	1	4	0	2	6
7	6	1	4	3	2	6
8	0	1	4	6	2	6
8	6	1	4	9	2	9

CHAPTER IX.

BUILDING CONSTRUCTION.

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[Originally read before the Eastern District of the Scottish Junior Gas Association, and now revised for publication.]

A YOUNG man at the beginning of his professional career is confronted with many conflicting ideas and unknown possibilities. The author has, therefore, endeavoured to present in this paper a few of the many things with which one can only become fully acquainted through practice and almost daily contact; drawing largely for the purpose on his experience in connection with the construction of buildings designed to accommodate plant for the manufacture of gas at Granton gasworks, under Mr. W. R. Herring. He trusts that the notes herein set forth may prove useful to young engineers, who may some day have to take in hand the construction of works of a similar character.

The first point the author would wish to emphasize is the necessity for the young engineer to become a competent draughtsman, so that he can place his ideas on paper in an intelligent and comprehensive manner. This is sadly neglected by many, but if thoroughly acquired brings its own reward.

The author will endeavour to give a brief description of the construction of a building from foundation to ridge, in as simple and elementary a way as he possibly can, so that anyone who may not have directed his attention to this subject hitherto may derive some benefit.

Excavations.

The foundations of a building constitute its main stay of life. Given a good solid foundation, other things being also first class, you get a correspondingly sound building, free from cracks, settlements, etc. ; and exactly the reverse may be looked for where the foundation is faulty. In preparing for a foundation, great care should be exercised in thoroughly testing the soundness and solidity of the ground, and, besides this, personal supervision should be given to the work as the tracks are cut, seeing that much depends on the nature of the bottom obtained. Soft pockets may be met with, in which case a deeper track should be cut over the area affected. This will also cause water to accumulate in the trenches. Rock may be encountered, and where met with can either be adopted for the foundation, where it lies below the required level, or tracks can be cut or blasted through the solid, as circumstances require.

Boulder clay may be come upon, and, generally speaking, where this is of a blue or grey colour, well sprinkled through with whinstone or sandstone boulders, it will make a satisfactory foundation. In such cases a much lighter foundation of concrete or stone can be used, always keeping in view the height and weight of the buildings to be carried. However, each individual case requires special consideration.

Running sand should be carefully looked after, and where met with prompt measures should be taken to close timber the sides of the cutting, to exclude it, and pumping or hand bailing resorted to, to keep the tracks free from water. Where running sand is encountered it often becomes necessary to increase the width of the foundation, in order to spread the superimposed weight of the walls, etc., over a greater area, and thus practically form what is known as a floating foundation.

Another method adopted in soft and unstable ground is the use of piles. These are invariably of greenhart, and should be shod at the points with iron. Piles are, as a rule, driven by machine, and where the head shows signs of fracture through the constant striking, an iron band or cap should be fixed to prevent the wood pulping. After the piles have been driven home, a staging is formed on the heads ; this can either be of wood, or steel beams. The whole is then covered with concrete, on which the superstructure is reared.

In open cuttings for foundations of walls, tanks, etc., the sides must be timbered as the excavation proceeds, in order to guard against a possible cave in. In the case of a drain running alongside the foundations of a newly erected building, the excavations should be taken out in short lengths and timbered immediately. It will be found advantageous to leave in such timber, as to remove it when the excavation is only partially filled in may cause a settlement in the adjoining foundations. In some instances one must leave the timber in the cuttings instead of removing it as the excavations are filled in, as, for example, in a case of tunneling under roadways, etc., for pipes. The labour and risk involved in the removal of such timber is not worth its value. In trench work, also, where the track passes through running sand, or ground with much water in it, always leave in the timber.

Foundations.

Assuming that the trenches are cut and a good solid bottom obtained, the next operation is the filling in, or building of the foundations themselves. Foundations are generally composed of stone, brick or concrete. Where stone is adopted, large stones for preference should be used, and a thorough cross or through bond made as they are laid in the trenches. All stones should be laid on their natural beds. In some cases the rough stone foundation is brought up to a general level with a light layer of concrete mixed in the proportion of 8 to 1. This is not always done, but, where carried out, improves and strengthens the foundation, by binding in the various stones.

Another class of foundation consists of simply widening the lower part of the wall with offsets of brick. The first course of brick is laid on the bottom of the open track from side to side, all round. Offsets are then taken off the next courses, thus reducing the width until the foundation reaches the desired level. The wall is then started directly above this. In such a case, where the wall is, say, 20 feet high (built 10 feet high of $18\frac{1}{2}$ inch work, the remaining 10 feet being 14 inch work), the first course of brick in the foundation would be 3 feet broad, and reduced by stepping to take the $18\frac{1}{2}$ inch wall at the desired level. The steps or intakes are usually $2\frac{1}{4}$ inches at a time.

Foundations of concrete are adopted in preference to the above method. The concrete is mixed either by hand or machine, according to circumstances, and well rammed into the trenches and beaten down. Where a thick foundation, consisting of a number of layers is being put in, the surface of each layer must be left rough, so that the following layer may adhere firmly to the already set concrete in the previous layer. This also applies to any portion of the work left in an unfinished state, say at the end of a day, to be continued on the following morning. The foundations should, in every case, be well beaten down to the level required, and left as uniform in surface and level as possible, ready for the stone or brick walls. In a concrete foundation where the finished level comes above the ground level, timbering can be employed to enclose or encase the concrete. Another method successfully adopted is to build $4\frac{1}{2}$ inch common brick casing from the ground level up to the desired height and then fill in with concrete.

In foundations where smooth inner faces are required, (such as walls of basements or sunk flats), this can be obtained in the following manner:—The tracks are cut as has been already explained, and the inner face is lined with wood boards laid parallel with the cutting. These boards (where only a moderately smooth face is required) can be left as they come off the saw, but where a smooth face is imperative, the boards must be dressed. If the faces of the boards are rubbed over with soft soap before the concrete is run in, the best results will be obtained. When the trenches are filled in and the concrete set, the general excavation inside the foundation is taken out and the timber recovered and removed, thereby exposing the concrete face. Any flaws, air holes, rough parts, etc., are then dressed off and finished by hand.

Damp Proof Course.

After the foundation has been successfully put in, the next operation is the laying of a damp proof course. A damp proof course to be of any use should be laid at or as near the ground level as possible, and extend over the full thickness of the wall. There are various types of damp proof courses, and each one has its own merits. Felt treated with asphalt can be obtained in rolls of various widths and lengths, and is largely used. Asphalt melted and run on over full thickness of wall and dressed off with sand on top while soft, is another method. A mixture of tar and pitch is also used; and some prefer a plain layer of cement $\frac{1}{2}$ inch to $\frac{3}{4}$ inch in thickness, laid on over the full width of wall.

Brickwork Walls.

The next operation is the building of the walls. Brick is the material generally adopted in gasworks construction, and therefore these notes are confined to this class of work. The brickwork can either be of common work all through, or faced with special pressed face brick, according to the design of the building.

There are many bonds in which a wall may be built, but, for all practical purposes, a wall built with three courses of stretchers to one of headers will be found to give satisfaction for ordinary work. For work where great strength is required, the author would advocate the English bond, which consists of courses of stretchers and headers alternately. This bond derives its strength from the large number of headers through the wall.

Bricks should be uniform in shape and size, having the arrises sharp and true. They should be hard burned, of even colour, and free from warps and fire cracks. All bricks before being built should be well wetted. This removes the dust and prevents the moisture from the mortar being absorbed too quickly.

In starting the brick wall above the foundations, two methods can be adopted. (1) Where a good scarcement of, say, 9 inches is allowed in the concrete or stone foundation, the wall can be begun at its full thickness immediately ahove the foundation. (2) Brick footings may be built. Irrespective of bond, the footings are laid in the same way, all bricks as far as possible being laid as headers. The bottom course of footings is generally twice the thickness of the wall above. The offsets in footings should not exceed $2\frac{1}{4}$ inches at a time per course. In building walls bonded three or more courses of stretchers to one of headers, where the face is of terra cotta or pressed facing brick backed up behind by common brick, it is advisable to use bonding irons to tie in the wall, such bonding irons filling the place of headers in the stretcher courses. Bonding irons are also used in the construction of hollow brick walls, and serve the same purpose here. All brickwork exposed to the weather should have the outside joints pointed and drawn in with a key.

Arches in brick, whether semicircular, elliptic or straight, require to be built with special arch bricks, made to the radius required, where the face work is of terra cotta or pressed brick. Arches through common work, as over door openings, window openings, etc., may be cut from common stretchers. Care should be taken not to remove the wood centres from underneath arches until they are properly set.

Bricks vary in size, but the common standard is generally 9 inches long by $4\frac{3}{8}$ inches to $4\frac{1}{2}$ inches in breadth by 3 inches to $3\frac{1}{8}$ inches in depth. Where the face work is built with terra cotta, enamel, or pressed facing bricks, the common bricks must be less in depth than such facing bricks, the reason being that common bricks require a much heavier bed than pressed facing bricks. If the common and face bricks were equal in depth, they, on being built, would show much too heavy joints in the face brick.

No part of a wall should be raised more than 3 feet higher than the surrounding parts at one time. If this is not attended to the chances are that difficulty will be experienced in keeping the wall equal in height and level. The interiors of thick walls should be laid as carefully as the interiors of thin walls. The tendency is to overlook good work throughout the wall, when it happens to be a thick one. In thin walls care should be taken to see that all joints are battered clean through, and not merely tipped. Only bricks of good shape, well burned, and having true arrises, free from cracks, etc., should be used in building. Uneven surfaces cause thick joints, which are undesirable. The surface of the bricks should be rough enough to form a key for the mortar to adhere to.

In cases where a brick wall is to be plastered on direct, the joints are sometimes raked out, and in others left rough, with the snugs projecting to form a key for the plaster. This is usually done in interior walls or gables, partitions, inner faces of hollow walls, etc. The inner faces of all outside walls to be plastered are strapped and lathed. Where flues pass through brick walls, it is advisable to render the insides of all such flues with a coat of lime. In many cases fireclay vent linings are used, and in cases where great heat occurs, all flues should be built with fire-brick set in fireclay. Faulty joints will let out smoke, and are difficult to locate and repair, especially in dwelling houses, in the construction of which the rendering of all flues or lining them with fireclay vent linings is an absolute necessity.

Where steel or iron beams rest, or are let into walls for support, a stone template should be placed under the ends or bearing parts of such beams. Where the load carried by the beam is a moving one, or vibration is likely to occur, through the floor supporting machinery, an extra precaution is necessary, namely, to cover the top or bearing surface of such templates with a sheet of lead. This allows the beam to slip in the case of any deflection, or through expansion or contraction owing to differences of temperature. Where steel or iron work is connected or let into a wall (such as ends of joists, girders, etc.), a pocket should be left round the ends of such joists, etc., large enough to allow a clear space for expansion of at least 2 inches, and if this clearance can be increased (especially where great heat is likely to affect such iron or steel work) to, say, 4½ inches, so much the better.

All window or door openings through brick or stone walls have checks or reveals to take the standards and window sashes. In brickwork, the general ingoes for windows is 4½ inches, with a 2¼-inch or 4½-inch check for sash. Door ingoes are generally 4½ inches to 9 inches deep, and the check 2¼ inches, to take the standards. For hung sash windows, the check must not be less than 4½ inches; but for dead fixed sashes 2¼ inches is ample. For door openings through which much traffic passes, it is advisable to build the jamb corners with either 2¼-inch or 4½-inch radius bullnose bricks. If the jamb corners are built with ordinary square bricks, the chances are that they will be chipped or worn away in a short space of time. Lintels of brick, wood, stone, iron or steel, according to the span of opening, and weight of walls above, are provided over all openings.

Where the floor is of wood, ventilation should be provided for under same. This can be done by leaving out a brick, or building in a perforated brick, where required. The general way is to build in a checked and perforated stone having a cast-iron grating in front. Ventilation openings should always be provided in both front and back walls, in order that the air current may travel under the whole floor area. Where a wood floor is laid immediately above a rough concrete under floor, the method described may be used, care, however, being taken to perforate the joists with 1¼ to 1½-inch holes here and there in their length, in order that the air current can get free passage below each set of wood joists.

Enamel bricks require greater care in laying, and all joints should be uniform and of equal thickness. Enamel bricks should be jointed with putty lime.

STONEWORK.

In most buildings where brick is the principal material used for the walls there is usually a certain amount of stonework required. There are various methods and styles of finishing and working stone. Stone can either be hand or machine wrought. Where dressing machines are employed large quantities of material can be handled expeditiously. Cornices, string courses, mullions, jambs, sills, lintels, etc., can be worked on the machine direct from the rough stone; and only such stones as are odd in shape, circular, triangular, etc., are worked by hand.

When designing the building the heights of the stones should be worked in even with a given number of courses of brickwork. All stonework should be laid on its natural bed. Sills, cornices, copes, and, in fact, all stonework projecting from the general face of the building should be weathered. All lintels over doors and lintels and sills of windows should have at least 6 inches wall-hold on each side of the opening. Where the jambs of doors and rybats of windows are of stone they can either be made in one or several long stones, or built in courses. In any case the stone requires to be checked for the door standards and window cases. The stone chosen should be free from clay pockets and iron, close in grain, and of a uniform colour. All stones showing traces of iron on the face after being worked should be rejected, as if used the iron will only run with the weather and cause discolouration.

JOINER WORK.

In most buildings connected with a gasworks proper joiner work does not come prominently forward. The preliminary joiner work in an ordinary building consists of laying the joists and sleepers for carrying the floors, and setting in position all door standards through the partition walls. These joists and sleepers are built into the walls at the required level, and where the span is too great to enable single lengths to be used they are lapped and supported on the partitions of the rooms beneath, or on dwarf walls, and run through in one or more sections. Where joists rest on top of brick partitions a wall plate or runner of wood should be provided and bedded on the brickwork. Such wall plates should in all cases be the full width of the partition, and not less than 1¼-inch in depth. This also applies where sleepers rest on a dwarf wall, or the scarcements of outside main walls. Wall plates are also provided where the rafters of a wooden roof meet the wall head. In cases where the partitions on the ground floor are far apart (such as in shops) the joists of the upper floors are usually carried by steel beams, and all such beams are placed so as to carry the partitions of the upper floors, where such partitions are of brick. In some cases, where the ground floor consists of one or more large apartments, it is found necessary to construct a steel and concrete floor throughout, at the first floor level, and on this floor is built direct the brick partitions and walls of the upper floors.

Sleeper joists are usually of white wood and vary in size. The ordinary size is 6½ inches by 2½ inches, ranging according to the span to be bridged to 9 inches by 3 inches. Joists also vary in size from 6 inches and 8 inches by 2 inches, 9 inches by 3 inches, to 11 inches by 2 inches, according to the span. In better class work redwood sleepers and joists are adopted. All joists and sleepers are laid at 18-inch centres. In cases where a very rigid floor is required it becomes necessary to dwang the joists. This is accomplished by wedging in between the joists cross-wise pieces of boarding the full depth of the joists. These dwangs stiffen the joists and obviate any side play or sagging. There are various other methods of dwanging a floor, but this is the one usually adopted. Care should be taken to guard against the ends of joists being built into walls through which any flues pass, and where this cannot be avoided it is necessary to encase the ends of all such joists in fireclay joist covers. When a hearth has to be formed a bridle is run between the joists on each side of the opening, into which all intermediate joists are run and housed. A brick arch is built from the inner face of the bridle to the main wall, on top of which the hearth is laid in concrete.

No flooring boards should be laid until the deafening of floors is set and dry. All ceilings should be brandered. Branders are $1\frac{1}{4}$ inches by 1-inch and nailed crosswise to the joists at 14-inch centres, and to these in turn is nailed the lath. All interior faces of outside walls should be strapped. Straps are $1\frac{1}{4}$ inches by 1 inch and fixed at 14-inch centres. The wall is either dooked to receive the straps, or provided with bond timbers to which the straps are nailed direct. The grounds behind skirtings and base plates, shelves, etc., are usually $2\frac{1}{4}$ inches by 2 inches where the walls are strapped and lathed, and $2\frac{1}{4}$ inches by $\frac{3}{4}$ inch where the walls are plastered on direct and are fixed to dooks or bond timbers, as described. Grounds are usually fixed $\frac{3}{4}$ inch to 1 inch below the top of skirtings or bases, and bevelled on top side to afford a key to the plaster. Corner beads should be run up all corners. They are usually about $\frac{3}{4}$-inch to $\frac{7}{8}$-inch diameter. By their use sharp and square corners likely to be chipped are avoided in the plaster work.

The flooring, whether of white wood or red wood, should be well seasoned and perfectly dry. Flooring differs in size from 6 inches and 7 inches broad to 3 inches broad by $1\frac{1}{8}$ inch thick. All flooring should be tongued and grooved. A movable board should be left in the flooring, fixed by screws, at any place where water or gas pipes, electric or bell wires, etc., lie.

Roofs.

There are various classes and styles of roofs. The purpose for which a building is to be used, together with the span to be covered, may be generally taken to decide the class of roof required. Roofs are built of steel and wood, and often a combination of both is adopted. Roofs can be slated, tiled, asphalted, or covered with corrugated iron, as desired. Concrete is used largely where a roof is required to be fireproof.

The common inverted Λ-shaped roof is most in use

Under favourable conditions this shape of roof, when constructed of wood, answers for a span up to 35 or 40 feet. Any greater span (if built in wood) would be both heavy and expensive, and this is to be avoided. Large spans are usually divided into two or more sections, each having a roof to itself and supported by girders, which in turn are carried on cast-iron or steel columns. Another way is to form the main principals of steel, in the shape of a semicircle or elliptical arched girder. These girders are in turn braced and tied longitudinally by box girder purlins, and diagonally by tees, channels or flats. Overhead, and supported by the principals and box girder purlins, are erected the rafters, pitched to suit angle of roof.

In a roof to be slated two methods may be adopted :—(1) Angle steel slate laths $1\frac{1}{4}$ inches by $1\frac{1}{4}$ inches by $\frac{3}{16}$ inch to $\frac{1}{4}$ inch thick can be bolted or riveted to the rafters at $10\frac{1}{2}$-inch centres (which is the maximum pitch for 24-inch slates). These angle steels form a rest for the slates, which are attached thereto by copper wire. This will be found a very satisfactory way of slating a roof which is exposed to fire, great heat, or corrosive fumes, such as will be met with in a boiler house or retort house. (2) From eaves to ridge angle steel ears may be bolted or riveted to the rafters at 2 feet to 2 feet 6 inches centres. To these angle ears, and running longitudinally to the rafters, are fixed wooden purlins of 4 inches by 2 inches, 5 inches by 2 inches, or larger, as required. The necessary piends, ridges and ridge rolls, are fixed in position, the whole roof being then covered with $\frac{5}{8}$-inch or $\frac{3}{4}$-inch sarking or boarding closely jointed. Such sarking or boarding can be laid either vertically or diagonally, as required. Occasionally the roofs are covered with $1\frac{1}{8}$-inch tongued and grooved flooring in place of sarking.

Where a flat roof is to be covered with asphalt, it is necessary to place on the top of the rafters, or cross bearers, what are known as taper pieces, in order that the water may have a run to back and front from the centre. Where a flat roof is covered with lead or zinc, rolls are provided and nailed to the sarking.

It is customary to cover all roofs (slated on wood) with roofing felt tacked to the sarking, and overlapped at joints.

FINISHINGS.

The finishings consist of doors, windows, stairs, architraves, facings, skirtings, linings, shelving, flooring, etc. Doors are framed and panelled or lined, and should have all the rails and munters morticed and tenoned into the stiles. Windows are also framed, and the sashes should be morticed and tenoned. In the case of sash windows the countercheeks (or meeting rails between top and bottom sashes) should always be bevelled, to exclude wind and rain. All sills should be of oak, and have a good weathering. In better class work it is customary to secure the ends of all tenons with ¼-inch diameter oak pins, driven through the stiles or rails and cut off flush. In putting together doors, window sashes and in fact all bound work, the tenons should be glued and wedged firmly into the mortices with wedges of hardwood. Stiles and rails in doors and window finishings, panelling, etc., are grooved to receive the panels.

Stairs, whether straight or wheel, should have the ends of all treads and risers raggled into the stringers. Underneath the bottle or face of tread is placed a small cavetto moulding. The average height or rise of a step is 6 inches to 6½ inches for an easy stair, and the width of the tread should not be less than 10 inches from face of riser to outside of bottle. The balusters can either be of iron or wood, and surmounted by a hand rail of mahogany or birch.

In no case should the finishings be fitted up until the plaster work is thoroughly dried.

Flooring is either of red or white wood; and joists, sleepers, rafters, sarking, door standards, partition standards, etc., of white wood. Windows should be of red wood and the sills of oak. All bound work for internal finishings, such as doors, window scuntions, soffets, and breasts, dado panelling, facings, achitraves, etc., should be of yellow pine. Butternut is now largely used for this class of work. Lining, whether beaded or V jointed, may be of white or red wood, and is also run from pitch pine. Stair stringers should be of red wood, and the risers and treads of pitch pine. Balusters, stringer plates and stair finishings generally, are of yellow pine. It is imperative that the wood from which the finishings are intended to be made be well seasoned and thoroughly dry, as otherwise it will split, shrink and warp. All timber of whatever nature should be free from large or loose knots, shakes, cracks, sap, and blue wood.

Drainage.

The drainage of a building is of vital importance. In the first place, the drain should have a good fall to the main sewer. Some advocate $\frac{1}{8}$ inch fall to each 3 feet length of pipe, and others $\frac{1}{4}$ inch per pipe. Fireclay drains, whether 4 inch or 6 inch diameter or larger, are universally spigot and faucet. Fireclay drains should be jointed with cement mortar, and, as the work proceeds, tested by means of the smoke test for leakages before the trenches are filled in. All w.c.'s connected to the drain should be trapped by means of an S.P.A. trap aired to the surface, and the same applies to baths, sinks, tubs or basins discharging into the drain. All rainwater conductors should be provided with a Hart trap at foot of conductor, which will prevent any soil from the roofs finding its way into the drain. Inspection eyes and bends should be provided at all turns or bends in the drain, as well as at intervals on the straight portions, in order that the drains can be easily cleaned from end to end in case of a choke. Inspection eyes and bends are usually set in a small manhole provided with a lifting grating at surface, and in such positions as to be easily accessible at all times.

Where drains pass under the floors of a building, the pipes used should be of cast-iron jointed with lead, and should any drains be likely to have any heavy weights passing over or on top of them, all such drains should have the pipes jacketed in concrete

Plumber Work.

The plumber work consists of fitting up rhones, conductors, flashings, cisterns, w.c.'s, baths, washhand basins, tubs, sinks, hot and cold water supplies, gas pipes and fittings, zinc and lead work in connection with roofs, etc. All rhones should be of cast-iron, whether of moulded or half-round pattern. The area of roof fixes the size of rhone necessary to carry off all water, but a 4-inch to 5-inch half-round rhone will be found to meet any ordinary requirement. Rhones when half-round in shape are fixed with galvanized or japanned iron straps, shaped to pitch of roof and circle of rhone. These straps are nailed along the eaves to the sarking boards at from 2 to 3 feet centres. The joints of rhones should be made with red lead and small brass bolts and nuts. Drop pieces are cast on the rhones, to which are attached the down pipes or conductors. Where the eaves project, knees from the drop pieces are provided, and connected to the conductors in the usual way.

Moulded and ornamental cast-iron rhones are made in lengths of about 6 feet each, having sockets cast on one end for jointing purposes. Some prefer to use moulded rhones at the wall head, and the general way is to screw each length to a wooden plate fixed to ends of roof rafters for this purpose. Conductors vary in size and shape. The ordinary standard is 3 inches, 3½ inches to 4 inches when round, and 5 inches to 6 inches by 4 inches when rectangular. Conductors are fixed to the wall by means of wrought-iron straps driven into the joints of stone or brickwork. The joints are spigot and socket, and made with rope yarn and red lead. Rectangular conductors are fixed by means of specially made ears, which are fixed to the wall by means of bolts run in with lead.

Where waste water from a sink, washhand basin, or bath, is connected up on the outside to a conductor, a branch must be provided in the proper position on such conductors to receive the connection. The final attachment is made with a drawn lead branch of same diameter as conductor and equal in thickness to 7 lb. lead. An offset on conductors (below the rhone) is fixed to enable the pipe to be carried above the rhone a distance of 2 feet to 2 feet 6 inches. This is for ventilation, and the open upper end of pipe is closed by a wire basket. Care should be taken that all such ventilation pipes are carried well above the level of windows, dormers, or skylights.

All lead S. or P. traps in connection with sinks, baths, wash tubs or basins, should be provided with an air pipe led direct to outside air, and the open end provided with a brass perforated grating. Sinks, wash tubs, basins, etc., in good work are made of fireclay, enamelled in various colours outside and in. Baths are of cast-iron or zinc, enamelled outside and in or finished in porcelain. Fireclay enamelled baths are also to be had. W.c.'s can either be of wash out or wash down pattern, and are fitted up in the manner already described for baths, sinks, etc., each having the necessary ventilation pipes. Soil pipes from w.c.'s serve their purpose direct to the drain, nothing else being connected up to them but the closets. Soil pipes are also carried above the eaves, as has been already described, for ventilation purposes. Each w.c. is provided with a 3-gallon galvanized iron syphon cistern fitted up on cast-iron brackets, with the necessary pull and chain, valve, copper ball cock, etc. Sinks, basins, wash tubs, baths, etc., should be open and easily reached, and it is a mistake to cover them with linings or other wood finishings.

Where the drains from any source pass under a floor the pipes should be of cast-iron jointed in lead. Water supply cisterns are lined with lead, weighing 6, 7, or 8 lbs. per square foot, according to the size of cistern. All pipes in connection with the water and gas supply should be led from the main direct to cistern or meter by the shortest route possible. The hot water supply from boiler to cistern should be $\frac{3}{4}$-inch diameter pipe weighing 10 lbs. per yard. Cold water supplies are either $\frac{1}{2}$-inch or $\frac{3}{4}$-inch, weighing 7 and 10 lbs. per yard.

It is well to see that all cisterns have a stop-cock easily accessible between them and the main, also lever-weight valves in connection with the hot and cold supply from cistern to boiler, sink, bath, etc., fixed in a convenient position and properly labelled or engraved.

All boilers should be provided with a connection to an expansion pipe, at least 1¼-inch diameter, of malleable iron double welded, which, in turn, is connected to a drain. This expansion pipe runs the whole height of building and is carried through roof. A ¾-inch scour pipe is taken from boilers to outside of building and connected to a conductor, or a separate main scour pipe is run up outside of building into which all minor scours are led. This scour pipe is connected to drain at bottom, and carried above the roof. A stop-cock should be provided between the boiler and main scour pipe. All boilers should be frequently scoured out. All cisterns should also be regularly scoured out. Scour and overflow pipes are also provided from cisterns, connected to a conductor, or led so as to discharge into a bath. The latter is preferable, as any discharge can readily be seen.

In some cases the supply pipes and connections to and from the cistern for both hot and cold water are made throughout in ¾-inch diameter double welded malleable iron pipes, and all joints and connections are screwed. This makes a good sound job, and little trouble is caused through bursts, etc.

Lead flashings at rhones, round pipes, etc., passing through a roof, skylights, dormers, ridges and piends, etc., are made of 6 to 7 lb. lead. Ridges and piends are made to afford a sufficient lap over the slates, and are beaten close to ridge and piend rolls, and secured with lead-headed nails. Ridges and piends are also made in zinc, and secured with straps spiked through the ridge and piend rolls. Flashings of lead at chimneys, etc., are let into a raggle cut in the stone or brickwork, and secured with lead plugs, all open spaces being pointed up with cement or mastic, on completion of work.

Lead coverings for flat roofs are laid in sheets, the lead being dressed over wood rolls fixed to the sarking, and pinned through rolls in position. Zinc is laid in the same manner, except that the sheets do not lap over rolls, being merely dressed up sides of same for a distance of 1½ inches. Over this upstand is slipped a zinc roll cap, sprung into position. The spring of the roll cap against the upstands makes the joint water-tight.

PLASTER AND CEMENT WORK.

The plaster work comprises deafening floors and partitions, plastering walls and ceilings, running cornices, etc. Cement work consists of laying floors, hearths, pavements in granolithic, cementing walls of staircases, etc. Plaster work for walls, partitions and ceilings, should be put on in three separate coats, and the space behind all skirtings, base plates, etc., should be filled up flush with the finished plaster above. This latter work is called pugging, and is done when the first coat of plaster is placed on the walls. On any walls to be covered with wood lining, it is advisable to first render such walls with one coat of plaster.

Deafening a floor is accomplished as follows :—On top of deafening boards, fixed between the joists, is run a coat of plaster. When this has set and dried, a layer of dry lime riddlings or engine ashes, 2½ to 3 inches deep, is laid on, and covered with another coat of plaster. This upper coat should be carefully examined, and all cracks filled up. All spaces between the joists and walls should be carefully filled up.

The plaster for the first and second coats on walls, etc., for ordinary work is composed of best lime shells, mixed with clean, sharp pit or fresh water sand. The sand must be free from salt, or other impurities, and mixed in the proportion of 1 measure of lime shells to 3 measures of sand, with the necessary quantity of water and 1 pound weight of well-washed ox hair to every 3 cubic feet of plaster, all thoroughly mixed and well beaten up. This plaster should be prepared at least six weeks before being used. The finishing coat is prepared from 1 part of sifted putty lime run fine to 2 parts of well-washed white sand. The putty lime is run from best white lime shells.

Ceilings and cornices should be gauged and run with stucco. Gauged plaster is composed of 3 measures of lime to 1 measure of pure stucco.

Cornices are run by means of a mould known as a slipper, having on the face a zinc profile cut to contour of cornice moulding. Cornice dentils and enrichments are cast in moulds and fixed in position on cornice with stucco. Cornices are run when the second coat of plaster has been applied to the walls and ceilings.

The surface of first coat plaster is marked criss cross all over to afford a key or grip for the second coat. Second coat plaster is brushed vertically with a hard fibre brush, or the scores on face are put on in circles; either method gives the key for the finishing coat. The finishing coat is left perfectly smooth. Three-coat plaster measures in thickness $\frac{3}{4}$-inch. Plaster should be finished plumb, smooth and straight, free from cracks, water marks, blisters, etc.

Slater Work.

Slates vary in colour according to the quarry from which they are obtained. The general colours are bluish grey, grey, purple and green. The sizes of slates vary according to the class of work for which they are required. Slates can either be nailed to the sarking direct, or prior to the roof being slated the whole of the sarking can be covered with roofing felt, well lapped at joints and tacked to sarking, on top of which the slates are laid in the ordinary manner and nailed to sarking. Slates can also be fixed by copper wire to steel purlins. For sloped roofs covered with sarking, slates should be laid with a cover or lap of $3\frac{1}{2}$ inches at the eaves, and this cover or lap is gradually diminished to $1\frac{1}{2}$ inches at the ridge. Every third course should be shouldered with haired lime and double nailed with galvanized iron nails weighing 10 lbs. per bag. The first course of slates at eaves should be a double one. Exposed ends of slates should be bedded and pointed with portland cement.

Raggles are usually pointed with mastic, and joints in skews pointed with portland cement.

Asphalt Work.

In covering a flat roof with asphalt, it is first necessary to cover the sarking with felt or jute cloth, on top of which the asphalt is run. Asphalt, when laid on concrete roofs, is run on direct to the concrete. Asphalt for ordinary work is usually $\frac{3}{4}$ inch to 1 inch in thickness and is run on in two layers.

Glazier Work.

The glazier work of a building is decided by the character of the structure. In ordinary work the glass mostly employed is polished plate-glass, 16 to 21 ounce sheet-glass, rough, rolled plate-glass, obscured glass, both plate and sheet, muranese glass, leaded lights, etc. Polished plate-glass is $\frac{1}{4}$-inch to $\frac{3}{8}$-inch thick, and is much used in shop windows and show-cases, offices, etc., or situations where a perfectly clear vision is desired. Sheet-glass is $\frac{1}{8}$-inch thick for 16 ounces and $\frac{3}{16}$-inch or so for 21 ounces, and is employed in all ordinary glazing, such as windows, fanlights, doors, etc., in dwelling houses. Rough rolled plate-glass is used in windows, etc., where clear vision is not of importance, such as warehouses, factories, etc. This glass is usually $\frac{1}{4}$-inch thick, and can be procured in lengths to suit all ordinary purposes. It is specially adaptable for glazing cupolas, skylights, roof, etc. Wire woven glass is also extensively used in glazing roof, cupolas, skylights, and almost any kind of overhead work. It is similar to the rough rolled plate-glass but has wire netting encased in the heart of each sheet. The advantages are greater strength, and if, for instance, in the case of a factory roof glazed with this glass a pane or panes should be accidentally broken the wire prevents the broken glass from falling, and risk of accident is avoided. Obscured glass is inserted where privacy is desired. Muranese glass is figured, stamped with a pattern, rippled, etc., and is much used in screens, fanlights, doors of vestibules, etc. Leaded lights answer the same purpose as muranese, and often appear in the windows, etc., of churches, etc., filled with stained glass.

APPENDIX.

Bricklayer's Memoranda.

1 rod of brickwork = 272 superficial feet of standard thickness.
1 ,, ,, = 408 feet superficial, 1 brick thick.
1 ,, ,, = 306 cubic feet, viz., 235 cubic feet of bricks and 71 cubic feet of mortar.
1 ,, ,, = $11\frac{1}{3}$ cubic yards.
1 ,, ,, requires 4,300 stock bricks laid in mortar.
1 ,, ,, ,, 5,370 ,, ,, laid dry.
1 ,, ,, ,, 1 cubic yard of stone lime and $3\frac{1}{2}$ yards of sand.
1 ,, ,, ,, about 126 gallons of water to slake the lime and mix the mortar.
1 ,, ,, weighs about 14 tons.

To reduce brickwork from superficial feet of 9 inches thick, or 1 brick, to standard thickness, deduct $\frac{1}{3}$rd.

To reduce brickwork from cubic feet to superficial feet of standard thickness, deduct $\frac{1}{9}$th.

1,000 stock bricks stacked = 56 cubic feet.
32 bricks laid flat will pave one square yard.
48 ,, ,, on edge will pave one square yard.

Number of bricks in a cubic yard = 384.

Weight of 1,000 firebricks, about $3\frac{1}{4}$ tons.

A bricklayer's hod measures 16″ × 9″ × 9″ and will hold 20 bricks and nearly $\frac{1}{2}$-bushel of mortar.

A square of slating = 100 feet superficial.

1,200 slates = 1,000.
120 ,, = 100.

The following are the sizes of the principal slates in ordinary use:—

Doubles	13″ × 6″
Ladies	15″ × 8″
Countesses	20″ × 10″
Duchesses	24″ × 12″

Safe Working Stresses.

COMPRESSION (DIRECT).

Per Square Inch.

Rolled steel, 7·5 tons; wrought-iron, 6 tons; cast-iron, 7·5 tons; rivets (bearing stress), 9 tons.

	With Grain.	Across Grain.
Oak	900 lbs.	800 lbs.
Yellow pine . . .	1,000 ,,	600 ,,
White ,, . . .	800 ,,	400 ,,
Spruce	800 ,,	400 ,,

Per Square Foot.

Concrete (Portland cement 1, sand 2, ballast 5)	= $13\frac{1}{2}$ tons.
,, (,, ,, 1, ,, 2, ,, 4)	= 15 ,,
Blue bricks in cement	16 ,,
Stock ,, ,, ...	6 ,,
,, ,, mortar	4 ,,
Granites	65 to 150 ,,
Sandstones	25 ,, 100 ,,

TENSION (PER SQUARE INCH).

Rolled steel, 7·5 tons; wrought-iron, 6 tons; cast-iron, 1·5 tons; yellow pine, 1,200 lbs.; white pine, 800 lbs.; spruce, 800 lbs.; oak, 1,000 lbs.

SHEAR (PER SQUARE INCH).

Steel web plates, 4 tons; steel bolts, 3 tons; cast-iron, 1·5 tons.

	With Grain.	Across Grain.
Yellow pine . . .	70 lbs.	500 lbs.
White ,, . . .	40 ,,	250 ,,
Spruce	50 ,,	320 ,,
Oak.	100 ,,	600 ,,

WEIGHT OF A LINEAL FOOT OF FLAT BAR IRON (IN LBS.).

Breadth in Inches.	Thickness in Fractions of an Inch.							
	1/8	3/16	1/4	3/8	1/2	5/8	3/4	1
1	0·42	0·63	0·84	1·26	1·68	2·09	2·51	3·36
1 1/8	0·47	0·70	0·94	1·41	1·88	2·35	2·82	3·77
1 1/4	0·53	0·78	1·05	1·57	2·09	2·61	3·14	4·19
1 3/8	0·58	0·86	1·15	1·73	2·30	2·88	3·45	4·61
1 1/2	0·62	0·95	1·26	1·88	2·51	3·14	3·76	5·02
1 5/8	0·67	1·02	1·36	2·04	2·72	3·41	4·09	5·45
1 3/4	0·74	1·10	1·47	2·20	2·93	3·67	4·40	5·87
1 7/8	0·79	1·17	1·57	2·35	3·14	3·93	4·71	6·29
2	0·83	1·25	1·68	2·51	3·35	4·19	5·03	6·71
2 1/8	0·89	1·33	1·78	2·67	3·56	4·45	5·35	7·13
2 1/4	0·94	1·41	1·88	2·82	3·77	4·71	5·66	7·15
2 3/8	1·00	1·49	1·99	2·98	3·97	4·97	5·98	7·97
2 1/2	1·04	1·57	2·09	3·15	4·18	5·23	6·29	8·39
2 5/8	1·10	1·65	2·20	3·29	4·39	5·49	6·60	8·81
2 3/4	1·15	1·73	2·30	3·44	4·60	5·76	6·91	9·22
2 7/8	1·20	1·81	2·41	3·62	4·82	6·03	7·24	9·65
3	1·25	1·89	2·51	3·77	5·03	6·29	7·55	10·07
3 1/4	1·36	2·04	2·72	4·09	5·45	6·81	8·18	10·91
3 1/2	1·46	2·20	2·93	4·40	5·86	7·33	8·80	11·74
3 3/4	1·57	2·35	3·14	4·70	6·28	7·85	9·43	12·57
4	1·67	2·52	3·35	5·02	6·70	8·38	10·07	13·42
4 1/4	1·78	2·67	3·56	5·34	7·11	8·90	10·69	14·25
4 1/2	1·89	2·82	3·77	5·65	7·53	9·42	11·32	15·09
4 3/4	2·00	3·00	3·98	5·96	7·95	9·94	11·94	15·92
5	2·10	3·15	4·19	6·28	8·37	10·47	12·57	16·76
5 1/4	2·20	3·31	4·40	6·59	8·79	11·00	13·20	17·61
5 1/2	2·31	3·45	4·61	6·90	9·21	11·52	13·83	18·45
5 3/4	2·41	3·61	4·82	7·22	9·63	12·04	14·46	19·28
6	2·52	3·78	5·03	7·53	10·05	12·57	15·06	20·13

WEIGHT OF A SUPERFICIAL FOOT OF PLATES OF DIFFERENT METALS (IN LBS.).

Thickness. Inches.	Iron.	Steel.	Brass.	Copper.	Lead.	Zinc.	Thickness. Inches.	Thickness. Millimetres.
1/16	2·5	2·6	2·7	2·9	3·7	2·3	0·0625	1·59
1/8	5·0	5·2	5·5	5·8	7·4	4·7	0·125	3·17
3/16	7·5	7·8	8·2	8·7	11·1	7·0	0·1875	4·76
1/4	10·0	10·4	11·0	11·6	14·8	9·4	0·25	6·35
5/16	12·5	13·0	13·7	14·5	18·5	11·7	0·3215	7·94
3/8	15·0	15·6	16·4	17·2	22·2	14·0	0·375	9·52
7/16	17·5	18·2	19·2	20·0	25·9	16·4	0·4375	11·11
1/2	20·0	20·8	21·9	22·9	29·5	18·7	0·5	12·7
9/16	22·5	23·4	24·6	25·7	33·2	21·1	0·5625	14·29
5/8	25·0	26·0	27·4	28·6	36·9	23·4	0·625	15·87
11/16	27·5	28·6	30·1	31·4	40·6	25·7	0·6875	17·46
3/4	30·0	31·2	32·9	34·3	44·3	28·1	0·75	19·05
13/16	32·5	33·8	35·6	37·2	48·0	30·4	0·8125	20·64
7/8	35·0	36·4	38·3	40·0	51·7	32·8	0·875	22·22
15/16	37·5	39·0	41·2	42·9	55·4	35·1	0·9375	23·81
1	40·0	41·6	43·9	45·8	59·1	37·5	1·0	25·4

WEIGHT OF A LINEAL FOOT OF ROUND AND SQUARE BAR IRON (IN LBS.).

Breadth or Diameter in Inches.	Round Bars.	Square Bars.	Breadth or Diameter in Inches.	Round Bars.	Square Bars.	Breadth or Diameter in Inches.	Round Bars.	Square Bars.
1/4	0·164	0·209	1 1/4	4·09	5·25	3	23·60	30·07
5/16	0·256	0·326	1 3/8	4·96	6·35	3 1/4	27·70	35·28
3/8	0·369	0·470	1 1/2	5·90	7·51	3 1/2	32·13	40·91
7/16	0·502	0·640	1 5/8	6·92	8·82	3 3/4	36·89	46·97
1/2	0·656	0·835	1 3/4	8·03	10·29	4	41·97	53·44
9/16	0·831	1·057	1 7/8	9·22	11·74	4 1/4	47·38	60·32
5/8	1·025	1·305	2	10·49	13·36	4 1/2	53·12	67·63
11/16	1·241	1·579	2 1/8	11·84	15·08	4 3/4	59·18	75·35
3/4	1·476	1·879	2 1/4	13·27	16·91	5	65·58	83·51
13/16	1·732	2·205	2 3/8	14·79	18·84	5 1/4	72·30	92·46
7/8	2·011	2·556	2 1/2	16·39	20·87	5 1/2	79·35	101·03
15/16	2·306	2·936	2 5/8	18·07	23·11	5 3/4	86·73	110·43
1	2·62	3·34	2 3/4	19·84	25·26	6	94·43	120·24
1 1/8	3·32	4·22	2 7/8	21·68	27·61	...	...	...

Weight of a Square Foot of Sheet Metals (in Lbs.).

Thickness B.W.G.	Iron.	Brass.	Copper.	Thickness B.W.G.	Iron.	Brass.	Copper.
30	0·50	0·55	0·58	15	2·82	3·10	3·27
29	0·56	0·61	0·64	14	3·12	3·43	3·60
28	0·64	0·70	0·74	13	3·75	4·12	4·34
27	0·72	0·79	0·83	12	4·38	4·81	5·08
26	0·80	0·88	0·92	11	5·00	5·50	5·80
25	0·90	0·99	1·04	10	5·62	6·18	6·50
24	1·00	1·10	1·16	9	6·24	6·86	7·20
23	1·12	1·23	1·30	8	6·86	7·54	7·90
22	1·25	1·37	1·45	7	7·50	8·25	8·70
21	1·40	1·54	1·62	6	8·12	8·93	9·40
20	1·54	1·69	1·78	5	8·74	9·61	10·10
19	1·70	1·87	1·97	4	10·00	11·00	11·60
18	1·86	2·04	2·15	3	11·00	12·10	12·75
17	2·18	2·40	2·52	2	12·00	13·10	13·90
16	2·50	2·75	2·90	1	12·50	13·75	14·50

Rules for Measurement of Surfaces and Solids.

To find the circumference of a circle, multiply the diameter by $\frac{22}{7}$ or by 3·1416.

To find the area of a circle, square the diameter and multiply by 0·7854

To obtain the area of a square, rhombus or rhomboid, multiply the base by the height.

To find the area of a triangle, multiply half the base by the perpendicular height.

To find the area of a trapezium, multiply half the sum of two parallel sides by the height.

To find the area of any right lined figure of four or more unequal sides, divide it into triangles, find the area of each and add them together.

For any regular polygon, inscribe a circle, then half the radius of that circle multiplied by the length of one side, multiplied by the number of sides = the area.

To find the area of a parabola, multiply the base by the height by two-thirds.

To find the area of an ellipse, multiply the long axis by the short axis and the product by 0·7854.

Weights, Melting Points, and Expansion of Metals.

Metal.	Weight in Lbs. per Cubic Foot.	Melting Point in Degs. Fahr.	Coefficient of Expansion per Deg. Fahr.
Brass	525	1,700	0·00001047
Copper	540	1,930	0·00000887
Gun-metal	530	...	...
Iron (cast)	450	2,000	0·00000616
,, (wrought)	480	2,900	0·00000657
Lead	710	612	0·00001555
Steel	490	2,500	0·00000680
Tin	455	446	0·0000121
Zinc	437	736	0·00001636

Weights of Various Substances

Name of Substances.	Pounds per Cub. Ft.
Asphalt	150
Bath stone	123
Brick, common hard	125
Brickwork, pressed hard	140
,, London stock	115
Chalk, in lumps	80
Cement, Portland	90
Clay	119
Concrete, ordinary	119
,, in cement	136
Earth, common loam, dry, loose	76
Earth, common loam, dry, moderately rammed	93
Earth as a flowing mud	108
Gneiss, common	168
Granite	170
Glass, crown	157
,, flint	192
Ice at 0° C.	57·2
Lime, quick	53
Limestone, blue lias	154
Masonry, of granite or limestone, well dressed	165
Mortar, hardened	103
Mud, dry, close	80 to 100
Quartz	165·4
Pitch	70
Portland stone	151
Sand, dry pit	100
,, damp	118
,, quartz	170
,, river	117
,, Thames	102
Shingle	88
Slate	175
Tile, common	115
Wood, birch	43·7
,, oak	46·8
,, pine	31·2
,, teak	50
Water at 32° Fahr.	62·418
,, 39° ,,	62·425
,, 50° ,,	62·409
,, 60° ,,	62·367
,, 70° ,,	62·302
,, 80° ,,	62·218
,, 90° ,,	62·119

CIRCUMFERENCES AND AREAS OF CIRCLES. (From 1 to 25.)

Diameter.	Circumference.	Area.	Diameter.	Circumference.	Area.
$\frac{1}{32}$	0·098175	0·00077	$1\frac{13}{16}$	5·69414	2·5804
$\frac{1}{16}$	0·196350	0·00307	$\frac{7}{8}$	5·89049	2·7612
$\frac{3}{32}$	0·294524	0·00690	$\frac{15}{16}$	6·08684	2·9483
$\frac{1}{8}$	0·392699	0·01227	2	6·28319	3·1416
$\frac{5}{32}$	0·490874	0·01917	$\frac{1}{16}$	6·47953	3·3410
$\frac{3}{16}$	0·589049	0·02761	$\frac{1}{8}$	6·67588	3·5466
$\frac{7}{32}$	0·687223	0·03758	$\frac{3}{16}$	6·87223	3·7583
$\frac{1}{4}$	0·785398	0·04909	$\frac{1}{4}$	7·06858	3·9761
$\frac{9}{32}$	0·883573	0·06213	$\frac{5}{16}$	7·26493	4·2000
$\frac{5}{16}$	0·981748	0·07670	$\frac{3}{8}$	7·46128	4·4301
$\frac{11}{32}$	1·07992	0·09281	$\frac{7}{16}$	7·65763	4·6664
$\frac{3}{8}$	1·17810	0·11045	$\frac{1}{2}$	7·85398	4·9087
$\frac{13}{32}$	1·27627	0·12962	$\frac{9}{16}$	8·05033	5·1572
$\frac{7}{16}$	1·37445	0·15033	$\frac{5}{8}$	8·24668	5·4119
$\frac{15}{32}$	1·47262	0·17257	$\frac{11}{16}$	8·44303	5·6727
$\frac{1}{2}$	1·57080	0·19635	$\frac{3}{4}$	8·63938	5·9396
$\frac{17}{32}$	1·66897	0·22166	$\frac{13}{16}$	8·83573	6·2126
$\frac{9}{16}$	1·76715	0·24850	$\frac{7}{8}$	9·03208	6·4918
$\frac{19}{32}$	1·86532	0·27688	$\frac{15}{16}$	9·22843	6·7771
$\frac{5}{8}$	1·96350	0·30680	3	9·42478	7·0680
$\frac{21}{32}$	2·06167	0·33824	$\frac{1}{16}$	9·62113	7·3662
$\frac{11}{16}$	2·15984	0·37122	$\frac{1}{8}$	9·81748	7·6699
$\frac{23}{32}$	2·25802	0·40574	$\frac{3}{16}$	10·0138	7·9798
$\frac{3}{4}$	2·35619	0·44179	$\frac{1}{4}$	10·2102	8·2958
$\frac{25}{32}$	2·45437	0·47937	$\frac{5}{16}$	10·4065	8·6179
$\frac{13}{16}$	2·55254	0·51894	$\frac{3}{8}$	10·6029	8·9462
$\frac{27}{32}$	2·65072	0·55914	$\frac{7}{16}$	10·7992	9·2806
$\frac{7}{8}$	2·74889	0·60132	$\frac{1}{2}$	10·9956	9·6211
$\frac{29}{32}$	2·84707	0·64504	$\frac{9}{16}$	11·1919	9·9678
$\frac{15}{16}$	2·94524	0·69029	$\frac{5}{8}$	11·3883	10·321
$\frac{31}{32}$	3·04342	0·73708	$\frac{11}{16}$	11·5846	10·680
1	3·14159	0·78540	$\frac{3}{4}$	11·7810	11·045
$\frac{1}{16}$	3·33794	0·88664	$\frac{13}{16}$	11·9773	11·416
$\frac{1}{8}$	3·53429	0·99402	$\frac{7}{8}$	12·1737	11·793
$\frac{3}{16}$	3·73064	1·1075	$\frac{15}{16}$	12·3700	12·177
$\frac{1}{4}$	3·92699	1·2272	4	12·5664	12·596
$\frac{5}{16}$	4·12344	1·3530	$\frac{1}{16}$	12·7627	12·962
$\frac{3}{8}$	4·31969	1·4849	$\frac{1}{8}$	12·9591	13·364
$\frac{7}{16}$	4·51604	1·6230	$\frac{3}{16}$	13·1554	13·772
$\frac{1}{2}$	4·71239	1·7671	$\frac{1}{4}$	13·3518	14·186
$\frac{9}{16}$	4·90874	1·9175	$\frac{5}{16}$	13·5481	14·607
$\frac{5}{8}$	5·10509	2·0739	$\frac{3}{8}$	13·7445	15·033
$\frac{11}{16}$	5·30144	2·2365	$\frac{7}{16}$	13·9408	15·466
$\frac{3}{4}$	5·49779	2·4053	$\frac{1}{2}$	14·1372	15·904

Circumferences and Areas of Circles.—*Continued.*

Diameter.	Circumference.	Area.	Diameter.	Circumference.	Area.
4 9/16	14·3335	16·349	8 5/8	27·0962	58·426
5/8	14·5299	16·800	3/4	27·4889	60·132
11/16	14·7262	17·257	7/8	28·8816	61·862
3/4	14·9226	17·721	9	28·2743	63·617
13/16	15·1189	18·190	1/8	28·6670	65·397
7/8	15·3153	18·665	1/4	29·0597	67·201
15/16	15·5116	19·147	3/8	29·4524	69·029
5	15·7080	19·635	1/2	29·8451	70·882
1/16	15·9043	20·129	5/8	30·2378	72·760
1/8	16·1007	20·629	3/4	30·6305	74·662
3/16	16·2970	21·135	7/8	31·0232	76·589
1/4	16·4934	21·648	10	31·4159	78·540
5/16	16·6897	22·166	1/8	31·8086	80·516
3/8	16·8861	22·691	1/4	32·2013	82·516
7/16	17·0824	23·221	3/8	32·5940	84·541
1/2	17·2788	23·758	1/2	32·9867	86·590
9/16	17·4751	24·301	5/8	33·3794	88·664
5/8	17·6715	24·850	3/4	33·7721	90·763
11/16	17·8678	25·406	7/8	34·1648	92·886
3/4	18·0642	25·967	11	34·5575	95·033
13/16	18·2605	26·535	1/8	34·9502	97·205
7/8	18·4569	27·109	1/4	35·3429	99·402
15/16	18·6532	27·688	3/8	35·7356	101·62
6	18·8496	28·274	1/2	36·1283	103·87
1/8	19·2423	29·465	5/8	36·5210	106·14
1/4	19·6350	30·680	3/4	36·9137	108·46
3/8	20·0277	31·919	7/8	37·3064	110·75
1/2	20·4204	33·183	12	37·6991	113·10
5/8	20·8131	34·472	1/8	38·0918	115·47
3/4	21·2058	35·785	1/4	38·4845	117·86
7/8	21·5984	37·122	3/8	38·8772	120·28
7	21·9911	38·485	1/2	39·2699	122·72
1/8	22·3838	39·871	5/8	39·6626	125·19
1/4	22·7765	41·282	3/4	40·0553	127·68
3/8	23·1692	42·718	7/8	40·4480	130·19
1/2	23·5619	44·179	13	40·8407	132·73
5/8	23·9546	45·664	1/8	41·2334	135·30
3/4	24·3473	47·173	1/4	41·6261	137·89
7/8	24·7400	48·707	3/8	42·0188	140·50
8	25·1327	50·265	1/2	42·4115	143·14
1/8	25·5254	51·849	5/8	42·8042	145·80
1/4	25·9181	53·456	3/4	43·1969	148·49
3/8	26·3108	55·088	7/8	43·5896	151·20
1/2	26·7035	56·745	14	43·9823	153·94

Circumferences and Areas of Circles.—*Continued.*

Diameter.	Circumference.	Area.	Diameter.	Circumference.	Area.
14 1/8	44.3750	156.70	19 5/8	61.6538	302.49
1/4	44.7677	159.48	3/4	62.0465	306.35
3/8	45.1604	162.30	7/8	62.4392	310.24
1/2	45.5531	165.13	20	62.8319	314.16
5/8	45.9458	167.99	1/8	63.2246	318.10
3/4	46.3385	170.87	1/4	63.6173	322.06
7/8	46.7312	173.78	3/8	64.0100	326.05
15	47.1239	176.71	1/2	64.4026	330.06
1/8	47.5166	179.67	5/8	64.7953	334.10
1/4	47.9093	182.65	3/4	65.1880	338.16
3/8	48.3020	185.66	7/8	65.5807	342.25
1/2	48.6947	188.69	21	65.9734	346.36
5/8	49.0874	191.75	1/8	66.3661	350.50
3/4	49.4801	194.83	1/4	66.7588	354.66
7/8	49.8728	197.93	3/8	67.1515	358.84
16	50.2655	201.06	1/2	67.5442	363.05
1/8	50.6582	204.22	5/8	67.9369	367.28
1/4	51.0509	207.39	3/4	68.3296	371.54
3/8	51.4436	210.60	7/8	68.7223	375.83
1/2	51.8363	213.82	22	69.1150	380.13
5/8	52.2290	217.08	1/8	69.5077	384.46
3/4	52.6217	220.35	1/4	69.9004	388.82
7/8	53.0144	223.65	3/8	70.2931	393.20
17	53.4071	226.98	1/2	70.6858	397 61
1/8	53.7998	230.33	5/8	71.0785	402.04
1/4	54.1925	233.71	3/4	71.4712	406.49
3/8	54.5852	237.10	7/8	71.8639	410 97
1/2	54.9779	240.53	23	72.2566	415.48
5/8	55.3706	243.98	1/8	72.6493	420 00
3/4	55.7633	247.45	1/4	73.0420	424.56
7/8	56.1560	250.95	3/8	73.4347	429.13
18	56.5487	254.47	1/2	73.8274	433.74
1/8	56.9414	258.02	5/8	74.2201	438.36
1/4	57.3341	261.59	3/4	74.6128	443.01
3/8	57.7268	265.18	7/8	75.0055	447.69
1/2	58.1195	268.80	24	75.3982	452.39
5/8	58.5122	272.45	1/8	75.7909	457.11
3/4	58.9049	276.12	1/4	76.1836	401.86
7/8	59.2976	279.81	3/8	76.5763	466.64
19	59.6903	283.53	1/2	76.9690	471.44
1/8	60.0830	287.27	5/8	77.3617	476.26
1/4	60.4757	291.04	3/4	77.7544	481.11
3/8	60.8684	294.83	7/8	78.1471	485.98
1/2	61.2611	298.65	25	78.5398	490.87

SQUARES, CUBES, SQUARE ROOTS AND CUBE ROOTS.

No.	Square.	Square Root.	Cube.	Cube Root.	No.	Square.	Square Root.	Cube.	Cube Root.
1	1	1·0	1	1·0	44	1,936	6·63325	85,184	3·5303
2	4	1·41421	8	1·2599	45	2,025	6·70820	91,125	3·5569
3	9	1·73205	27	1·4422	46	2,116	6·78233	97,336	3·5830
4	16	2·0	64	1·5874	47	2,209	6·85565	103,823	3·6088
5	25	2·23607	125	1·7100	48	2,304	6·92820	110,592	3·6342
6	36	2·44949	216	1·8171	49	2,401	7·0	117,649	3·6593
7	49	2·64575	343	1·9129	50	2,500	7·07107	125,000	3·6840
8	64	2·82843	512	2·0	51	2,601	7·14143	132,651	3·7084
9	81	3·0	729	2·0801	52	2,704	7·21110	140,608	3·7325
10	100	3·16228	1,000	2·1544	53	2,809	7·28011	148,877	3·7563
11	121	3·31662	1,331	2·2240	54	2,916	7·34847	157,464	3·7798
12	144	3·46410	1,728	2·2894	55	3,025	7·4162	166,375	3·8030
13	169	3·60555	2,197	2·3513	56	3,136	7·48331	175,616	3·8259
14	196	3·74166	2,744	2·4101	57	3,249	7·54983	185,193	3·8485
15	225	3·87298	3,375	2·4662	58	3,364	7·61577	195,112	3·8709
16	256	4·0	4,096	2·5198	59	3,481	7·68115	205,379	3·8930
17	289	4·12311	4,913	2·5713	60	3,600	7·74597	216,000	3·9149
18	324	4·24264	5,832	2·6207	61	3,721	7·81025	226,981	3·9365
19	361	4·35890	6,859	2·6684	62	3,844	7·87401	238,328	3·9579
20	400	4·47214	8,000	2·7144	63	3,969	7·93725	250,047	3·9791
21	441	4·58258	9,261	2·7589	64	4,096	8·0	262,144	4·0
22	484	4·68012	10,648	2·8020	65	4,225	8·06226	274,626	4·0207
23	529	4·79583	12,167	2·8439	66	4,356	8·12404	287,496	4·0412
24	576	4·89898	13,824	2·8845	67	4,489	8·18535	300,763	4·0615
25	625	5·0	15,625	2·9240	68	4,624	8·24621	314,432	4·0817
26	676	5·09902	17,576	2·9625	69	4,761	8·30662	328,509	4·1016
27	729	5·19615	19,683	3·0	70	4,900	8·36660	343,000	4·1213
28	784	5·29150	21,952	3·0366	71	5,041	8·42615	357,911	4·1408
29	841	5·38516	24,389	3·0723	72	5,184	8·48528	373,248	4·1602
30	900	5·47723	27,000	3·1072	73	5,329	8·54400	389,017	4·1793
31	961	5·56776	29,791	3·1414	74	5,476	8·60233	405,224	4·1983
32	1,024	5·65685	32,768	3·1748	75	5,625	8·66025	421,875	4·2172
33	1,089	5·74456	35,937	3·2075	76	5,776	8·71780	438,976	4·2358
34	1,156	5·83095	39,304	3·2396	77	5,929	8·37496	456,533	4·2543
35	1,225	5·96108	42,875	3·2711	78	6,084	8·83176	474,552	4·2727
36	1,296	6·0	46,656	3·3019	79	6,241	8·88019	493,039	4·2908
37	1,369	6·08276	50,653	3·3322	80	6,400	8·94427	512,000	4·3089
38	1,444	6·16441	54,872	3·3620	81	6,581	9·0	531,441	4·3267
39	1,521	6·245	59,319	3·3912	82	6,724	9·05539	551,368	4·3445
40	1,600	6·32456	64,000	3·4200	83	6,889	9·11043	571,787	4·3621
41	1,681	6·40312	68,921	3·4482	84	7,056	9·16515	592,704	4·3795
42	1,764	6·48074	74,088	3·4760	85	7,225	9·21954	614,125	4·3968
43	1,849	6·55744	79,507	3·5034	86	7,396	9·27362	636,056	4·4140

SQUARES, CUBES, SQUARE ROOTS AND CUBE ROOTS—*Continued.*

No.	Square.	Square Root.	Cube.	Cube Root.	No.	Square.	Square Root.	Cube.	Cube Root.
87	7,569	9·32738	658,503	4·4310	94	8,836	9·69536	830,584	4·5468
88	7,744	9·38083	681,472	4·4480	95	9,025	9·74679	857,375	4·5629
89	7,921	9·43398	704,969	4·4647	96	9,216	9·79796	884,736	4·5789
90	8,100	9·48683	729,000	4·4814	97	9,409	9·84886	912,673	4·5947
91	8,281	9·53939	753,571	4·4979	98	9,604	9·89949	941,192	4·6104
92	8,464	9·59166	778,688	4·5144	99	9,801	9·94987	970,299	4·6261
93	8,649	9·64365	804,357	4·5307	100	10,000	10·0	1,000,000	4·6417

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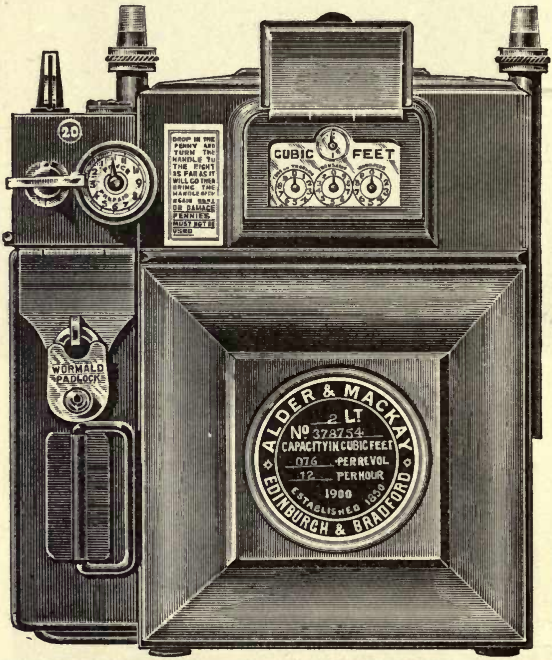

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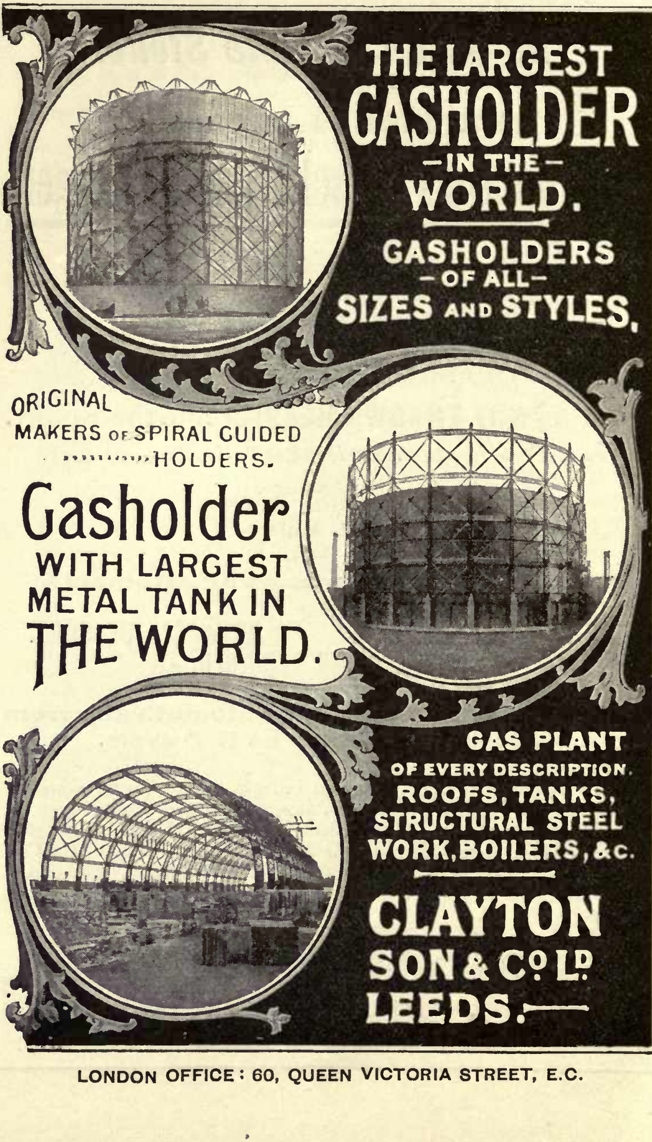

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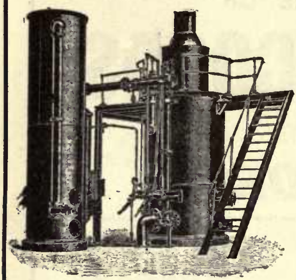

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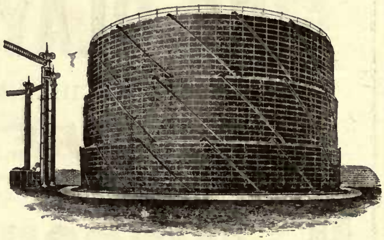

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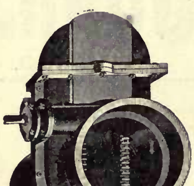

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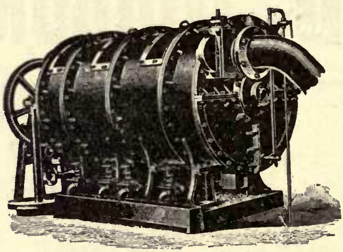

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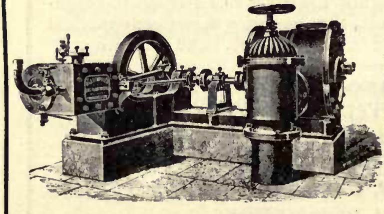

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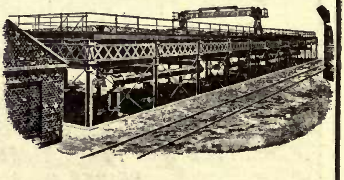

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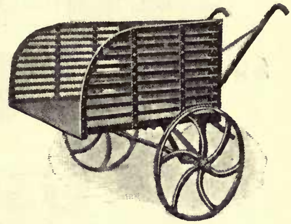

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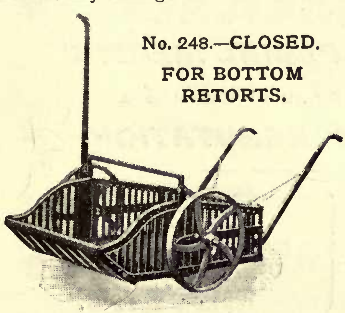

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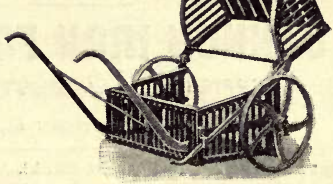

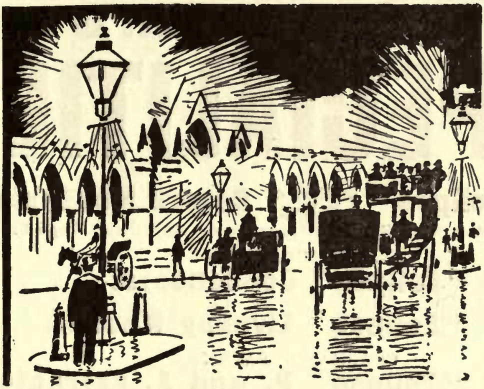

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