of pressure upon it, or by both causes combined; and in either case the upper portion of the structure falls in a shower of fragments, partly into the interior of the portion left standing, and partly on the ground beside its base.

It is obvious that, in order that the stability of a chimney may be secure, no bed-joint ought to tend to open at its windward edge; that is to say, there ought to be some pressure at every point of each bed-joint, except the extreme windward edge, where the intensity may diminish to nothing; and this condition is fulfilled with sufficient accuracy for practical purposes, by assuming the pressure to be an uniformly varying pressure, and so limiting the position of the centre of pressure F, that the intensity of the leeward edge, E, shall be double the mean intensity.

Chimneys in general consist of a hollow shell of brickwork, whose thickness is small compared with its diameter; and in that case it is sufficiently accurate for practical purposes to give q the following values:

For square chimneys, $q = \frac{1}{3}$;

For round chimneys, $q = \frac{1}{4}$;

$$\text{For other shapes, } q = \frac{\text{Moment of Inertia}}{2Fe^2}$$

F = area of section.

e = distance of outer fibre from neutral axis.

The following general equation, between the moment of stability and the moment of external pressure, expresses the condition of stability of a chimney:

$$(50) \qquad HP = (q - q')\,Wt.$$

This becomes, when applied to square chimneys;

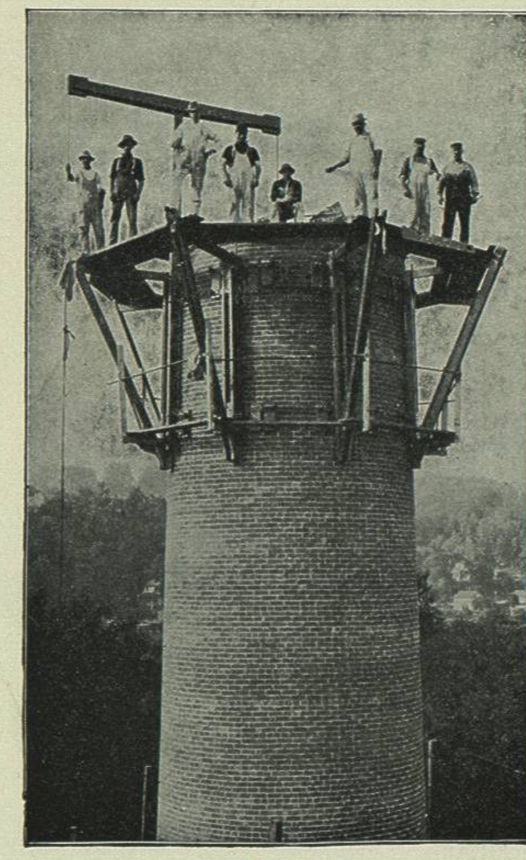
$$(51) \qquad HpA = (\tfrac{1}{3} - q')\,Wt;$$

and when applied to round chimneys;

$$(52) \qquad \frac{HpA}{2} = (\tfrac{1}{4} - q')\,Wt.$$

The following approximate formulæ, deduced from these equations, are useful in practice:

Let B be the mean thickness of brickwork above the joint



ILLUS. No. 17.

A BRICK CHIMNEY STAGING. CHIMNEY—PLUME & ATWOOD MANUFACTURING COMPANY, THOMASTON, CONN.

150 feet high, 9 feet outside diameter at top.

DE under consideration, and b the thickness to which that brickwork would be reduced if it were spread out flat upon an area equal to the external area of the chimney. That reduced thickness is given with sufficient accuracy by the formula:

$$(53)\quad b = B\left(1 - \frac{B}{t}\right),$$

but in most cases the difference between b and B may be neglected.

Let w be the weight of a unit of volume of brickwork; being on an average 112 lbs. per cubic foot, or, if the brick are dense, and laid very closely, with thin layers of mortar in the joints, from 115 to 120 lbs. per cubic foot should be used. Then we have approximately

(54) for square chimneys, $W = 4wbA$;
(55) for round chimneys, $W = 3.14wbA$;

which values, being substituted in previous equations, give the following:

(56) for square chimneys, $Hp = (\frac{4}{3} - 4q')\,wbt$;
(57) for round chimneys, $Hp = (1.57 - 6.28q')\,wbt$.

These formulæ serve two purposes, first, when the greatest intensity of the pressure of the wind, p, and the external form and dimensions of a proposed chimney are given, to find the mean reduced thickness of brickwork, b, required above each bed-joint, in order to insure stability; and secondly, when the dimensions and form and the thickness of the brickwork of a chimney are given, to find the greatest intensity of pressure of wind which it will sustain with safety.

The shell of a chimney consists of a series of divisions, one above the other, the thickness being uniform in each division, but diminishing upward from division to division. The bed-joints between the divisions where the thickness of brickwork changes (including the bed-joint at the base of the chimney) have obviously less stability than the intermediate joints; hence it is only to the former set of joints that it is necessary to apply the formulæ.

Another generally accepted equation and statement in relation to the stability of a brick chimney-shaft is: that the total wind pressure against a chimney multiplied by one-half of the height of the chimney divided by the weight of the shaft above the section considered should be equal to or less than one-sixth of the outside diameter at the section considered. If $\frac{1}{6}$ then the maximum pressure at any point in the circumference will be double the average pressure.

Rankine's calculations upon the stability of the outer core of a 455½ feet chimney at Glasgow, Scotland,* are as follows:

TABLE No. 24

Divisions of chimney.	Height above ground.	External diameter.		Thicknesses.		Greatest pressure of wind consistent with security. Lbs. per square foot.
	Feet.	Feet.	Inches.	Feet.	Inches.	
V	435½	13	6	1	2	77
IV	350½	16	9	1	6	55*
III	210½	24	0	1	10½	57
II	114½	30	6	2	3	63
I	0 to 54½	35 to 40	0 to 0	2	7½	71

* Joint of least stability.

Fifty-five lbs. is but 4 lbs. above the highest noted wind pressure in the west of England.

The external diameter of the foundation of this chimney is 50 feet.

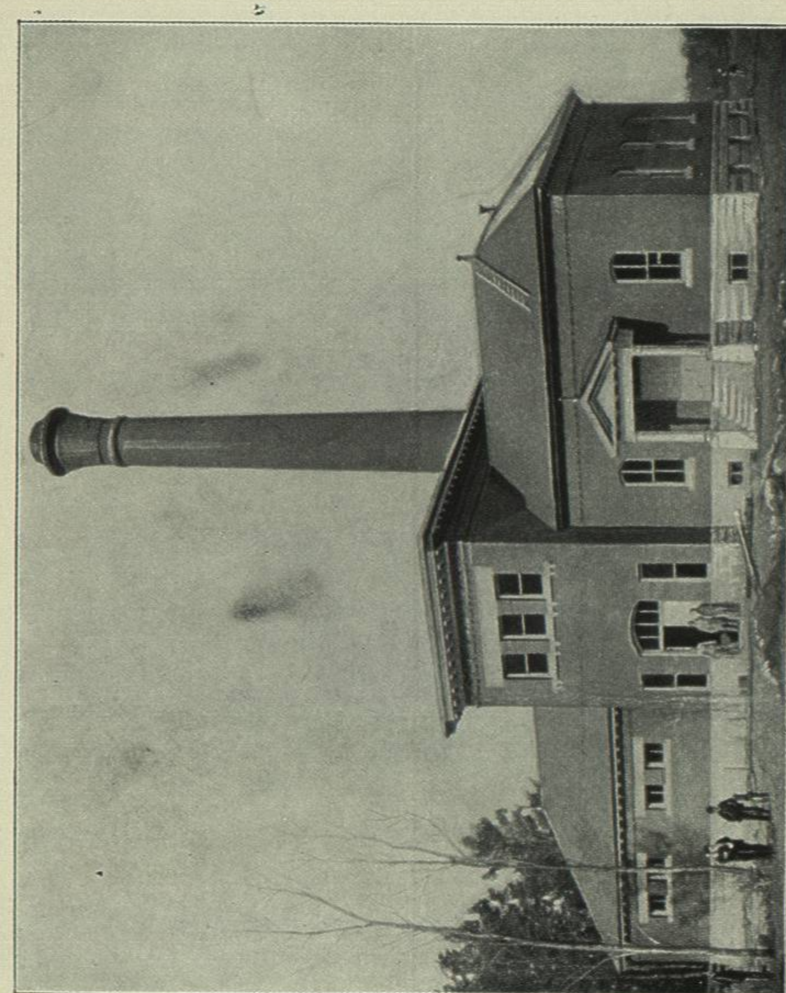
GENERAL NOTES.

Material.—All material entering into the construction of a chimney, its connections, and foundations should be of the best obtainable of their respective kinds. This applies even more forcibly to steel chimneys.

Progress.—Foundations for brick chimneys should be laid up a month before the superstructure is built to allow the mortar to set thoroughly and harden; after this the shaft should be erected at from three to five feet of height per day, and the walls should be trued up or plumbed every three feet in height with the greatest care.

Weather.—Brick chimneys should be commenced and fin-

* The foundation of this chimney has a depth of 20 feet and a diameter of 50 feet.



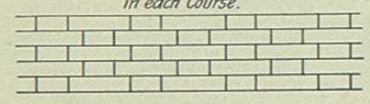
ILLUS No. 18.
PUMPING STATION, WATER WORKS, MANCHESTER, N. H.

ished in the spring or summer months ; take advantage of fine days, and do not lay brick at frosty or freezing temperatures.

Bonding.—In England some chimneys are laid up in Flemish Bond ; some in half brick bond, twice as many stretches as in Old English Bond. In the United States a great many chimneys are laid up in a bond made of one course of headers to five or six courses of stretchers, as shown.

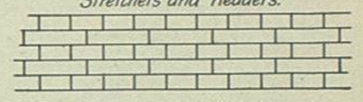
Often in large brick chimneys, an iron band or hoop, such as ¼ by 2 inch or 3 by 3 inch T-iron is laid within the brick wall at intervals of three to five feet, having a continuous circumference, which is very good practice when the walls are over eight inches thick.

Alternate Stretchers and Headers in each Course.



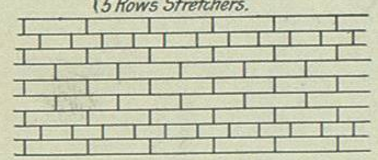
Flemish Bond

Alternate Courses of Stretchers and Headers.



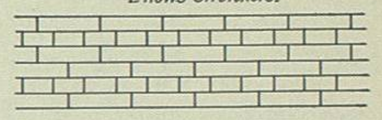
Old English Bond.

{1 Row Headers, 5 Rows Stretchers.



Usual Bond.

2 Rows Stretchers.



Old English Bond.

Mortar.—It is customary in brick chimneys to use a lime mortar for the inner shell until within a few feet of the top, where cement mortar is used because of its strength of adherence ; the outer shell being laid up in mortar of lime, cement, and sand.

The practice of some engineers is to build a ring of chimney about eight feet high laid up in cement mortar, alternating with a similar ring laid up in lime mortar, thereby gaining greater strength and tenacity.

Chimneys which are used to convey the gaseous products of chemical reactions are laid their whole height in cement mortar; the interior surface of the flue laid up as true and smooth as it is possible to make it, and all joints entirely filled.

English refuse-destructor chimney constructed for the Hornsley Local Board (England) for use in connection with its sanitary depot for treatment of house refuse.—*American Gas Light Journal.*

Principal Dimensions.

	Feet.	Inches.
Total height, bottom of foundation to top of capping	244	0
Height from ground line to top capping	217	0
Outside diameter at ground surface	18	3
Inside diameter at ground surface	12	3
Outside diameter at top, under capping	8	6
Inside diameter at top, under capping	6	3

The bricks used in its construction were good London stocks, 9 by $4\frac{1}{2}$ by $2\frac{3}{4}$ inches, and the work throughout is laid in English bond, with Dorking lime mortar in the proportion of three Thames sand to one of lime. No grouting was used in any part of the construction. The foundation bed is clay, 27 feet below ground line. On this a block of concrete was formed, 39 feet square, and $16\frac{1}{2}$ feet deep, composed of six parts Thames ballast to one of Portland cement.

The brick footings in the cement are 33 feet square at base, and built up to ground line, which is 10 feet 6 inches from top of concrete bed, with regular offsets of $2\frac{1}{4}$ by $6\frac{3}{4}$ inches.

The shaft proper, starting from top of footings, is built up in six sections, commencing at the base:

	Feet.	Inches.		Bricks.
First section	30	0	by	4
Second section	34	6	by	$3\frac{1}{2}$
Third section	34	6	by	3
Fourth section	37	0	by	$2\frac{1}{2}$
Fifth section	37	0	by	2
Sixth section	21	0	by	$1\frac{1}{2}$
Seventh (cap)	23	0	by	2
	217	0		

The cap portion, which is constructed in white-glazed and blue Staffordshire bricks, is ornamented with a circular cast-iron capping weighing 2,200 lbs., cast in six segments, and bolted together by internal flanges, and forms a very good finish to this tall shaft.

ILLUS. No. 19.
QUEEN LANE PUMPING STATION, PHILADELPHIA, PA

A fire-brick lining, or inner shaft, is built up to a height of 60 feet, the lower 30 feet in 9-inch, and the upper in 4½-inch work set in fire-clay.

An annular space of 15 inches is left at the base, between the fire-brick lining and the main shaft, to admit of expansion in the fire-brick.

The top of lining nearly touches the main shaft, which is corbelled over to fire-brick lining to prevent any deposit accumulating in the annular space.

Cast-iron inlets 9 by 6 inches are provided at ground level to admit cold air, and to prevent the inrush striking the fire-brick lining; a 4½-inch brick pier, 2 feet high, is built between the two shafts.

Two rings at the base and one toward the top, of hoop-iron bonding, $\frac{3}{16}$ by 1½-inch, are built in main shaft, about every 3 feet 6 inches in height.

The connection between flues of boilers and furnaces with main shaft is made by an arched flue opening, 9 feet by 3 feet 3 inches at the base, and a soot door is also provided, whereby access can be obtained to the inside of shaft when required.

The time occupied in building this shaft was a little over five months, commencing in July and finishing in December, 1888.

The bricklaying was continued all through the foggy weather in the latter month, although the workmen could not see the ground through the fog below.

A lightning conductor is fixed to the shaft, composed of two copper tapes or bands, 1¼ by ⅛ inch, winding spirally around the outer circumference to underside of cap, where they are connected to a ring encircling the shaft, and from thence to 6 copper rods, 1-inch diameter, which are carried to a height of 4 feet above the cap, and the rods terminate with crow-feet ends. The tapes are joined at a distance of about 40 feet from the base, north of the shaft, and 18 feet below the ground level, and terminate in a copper earth-plate 3 feet by 2 feet by ½ inch.

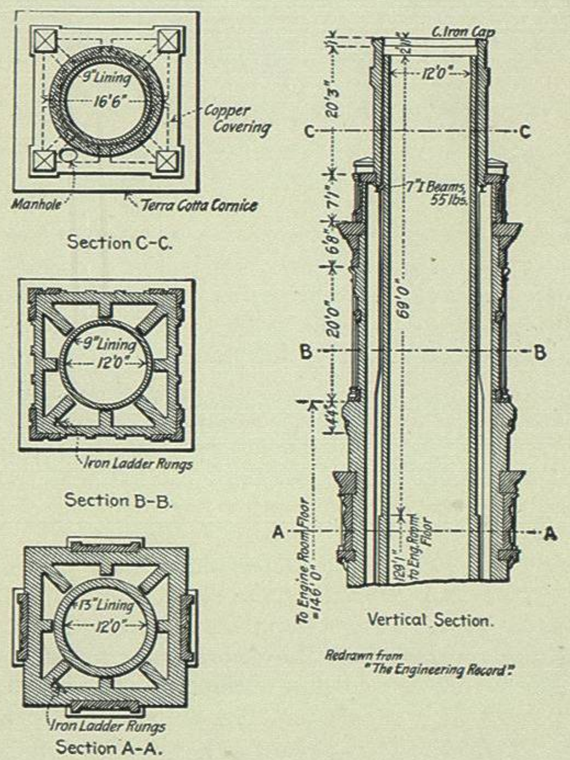
Outside scaffolding was used, and no accident whatever occurred during the construction. The shaft forms a conspicuous landmark to the surrounding locality, and dwarfs all other similar structures for miles around.

Queen Lane Pumping Station, Philadelphia, Pa., completed in 1896, is a brick chimney with a very elaborate exterior casing, as may be seen from the engraving shown.

The flue is 12 feet in diameter, perfectly straight.

Height, 200 feet above ground.

The foundation is 24 feet below grade level, and its bottom course 37 feet square; the base of chimney above grade is 24 feet square.



ILLUS. No. 20.

QUEEN LANE PUMPING STATION, CHIMNEY SECTIONS.