chimney the foundation required close piling; the piles were driven 23 feet to 24 feet in depth, and almost in contact with each other; through the stone foundation eight 2½-inch bolts were passed, connecting a circular cast-iron foundation-plate of T-section, 18 inches by 8¼ inches at bottom of stonework, to similar casting upon the top of stone foundation; this top circular ring or base-plate is formed with a projecting flange placed at an angle of sixty degrees to receive plates forming bell-shaped base, 2 feet above ground.

Construction.—The chimney was constructed by inside scaffolding, and built up one plate high at a time; the workmen hanging what is called a "cage" on the plates, to serve as a stand for the "holder on" while riveting the plates *in situ.*

Bell-shaped Base.—The plates forming the base are bolted to the flange of chimney base-ring by ¾-inch bolts, and when completed to a height of 21 feet form a bell-shaped base 21 feet 2 inches diameter at bottom, and 13 feet 6 inches at top.

Shaft.—From the top of bell-shaped base the wrought-iron outer casing is continued to height of 21 feet from below top; from this point the cap is formed as shown in drawing.

Rivets and Riveting.—The plates are all riveted together with a lap of two inches; the constructors used conical-shaped rivet-heads, and the diameter of rivets for this class of work is as near as possible twice the thickness or upward of plate, and the pitch of rivets is 5 diameters.

Ladder.—A wrought-iron ladder is fixed to the outside.

Fire-brick Lining.—A fire-brick lining was built up through the entire height of the chimney, commencing at junction of flues at foundation with a thickness of 18 inches, and finishing at top 5 inches thick. The internal diameter, when finished with lining, is 11 feet, and constant throughout its height; the radiated fire-bricks were of five sizes, purposely made.

Stability.—The chimneys built on this plan are calculated to withstand 50 pounds wind-pressure per square foot with safety; the constructors say the climate of America is dry, and no doubt better for such structures than the climate of England; they believe that no one alive at the present time will see the end of a wrought-iron chimney, lined with brick; the oldest ones in America show no material deterioration. Cost, complete, $13,000.

CHAPTER VII

BRICK CHIMNEYS—THEORY PERTAINING TO SAME, AND EXAMPLES FROM EXISTING STRUCTURES

RULES FOR BRICK CHIMNEYS.

MOLESWORTH'S "Pocket Book" gives the following: "Diameter outside of the base, not less than one-tenth the height; batter of outside, 0.3 inch per foot; thickness of brickwork, one brick from top to 25 feet down; one and one-half brick from 25 feet to 50 feet, etc. If inside diameter exceeds 4 feet at the top, the top thickness should be one and one-half bricks; if less than three feet it may be one-half brick for the first 10 feet down."

The Metropolitan Board of Works Rules for furnace chimney shafts contain this: Brickwork should be at least 8½ inches thick at the top, and for 20 feet below, and must be increased 4½ inches every 20 feet of additional height measured downward. There should be no cornice or projection of more than 8½ inches at the top of the shaft.

Lang gives for thickness of upper wall of chimneys:

If built of ring stone, at least 7.08 inches.

If built of bricks, at least 9.84 inches.

For quadrangular chimneys, ½ brick thickness may be used in upper section, but the chimney must then be built from the exterior, and well braced by scaffolds.

The more steam there is contained in the smoke gases and the cooler they are, the larger the thickness of the upper wall should be chosen.

The old rule that the upper wall thickness should be $\frac{1}{10}$ of the clear width given too thin walls for narrow chimneys, and too thick ones for wide chimneys.

Rather $S_1 = 0.10 + 0.05\ d_0 + 0.0005\ H$ (in metric system). Answer in meters

$S_1 = 3.937 + 0.05\ d_0 + 0.0005\ H$ (in United States measure). Answer in inches

S_1 = thickness, d_0 = clear inside diameter at top, H = height of chimney.

The author would advise making the lengths of each varying thickness 20 to 30 feet,* with an outside batter of 1 in 30 to 1 in 36, and also running the inner core to within a few feet of the top, but not to connect it with the outside shell; in all cases calculate each section for stability, which will also aid in determining the thickness of brickwork.

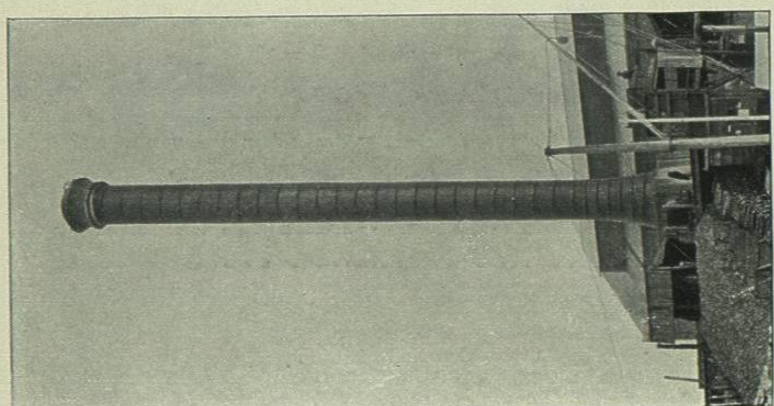
One authority suggests for a brick chimney 100 feet high, an outer shell in three steps, the first 20 feet, 16 inches thick; the second 30 feet, 12 inches thick; the third 50 feet, 8 inches thick—all minimum thicknesses; batter no less than 1 in 36 to give stability. The core should be in three steps of equal height, 12, 8, and 4 inches thick.

Brick chimneys should not be connected in a structural manner with any other structure, owing to both their swaying motion and expansion by heat. A chimney near Marseilles, 115 feet high, was observed to oscillate one foot eight inches; when a sudden gust of wind struck the shaft it would vibrate four or five times before coming to rest. Excessive oscillations are frequently prevented by loading the cap.

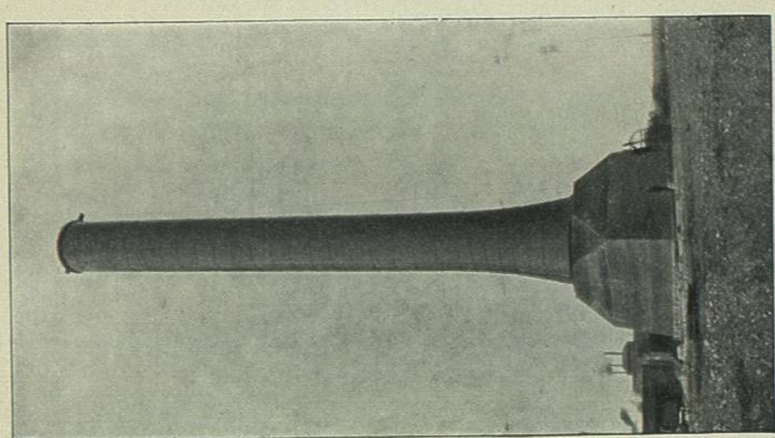
CHIMNEY DESIGN.

M. Bassine—*Engineering News*, April 22, 1897, p. 247—considers a chimney as a vertical beam fixed at the base, and thus determines the limiting conditions of pressure and tension in the different horizontal sections. He recommends an exterior profile with a batter ranging from 33.1 on 1 to 25 on 1, and divides the vertical height into sections of from 16 to 20 feet each, with the thickness of wall constant for each section, and decreasing by 1½ to 2½ inches in each ascending section. He

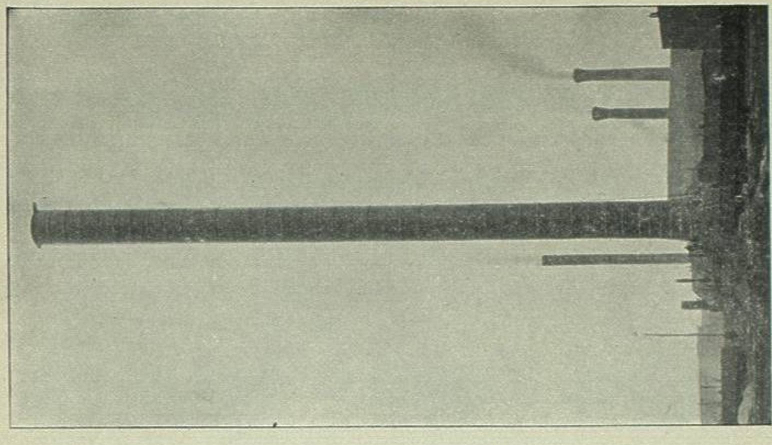
* For chimneys built of common red brick.



ILLUS. No. 13.
THE NASSAU ELECTRIC RAILWAY CO.,
BROOKLYN, N. Y.
Self-Supporting Stack, 12 feet diameter, 165 feet high.



ILLUS. No. 14.
PHILADELPHIA SMELTING AND REFINING CO.,
PUEBLO, COL.
Self-Supporting Stack, 13 feet 8 inches in diameter, by 130 feet high.



ILLUS. No. 15.
MIDVALE STEEL CO., PHILADELPHIA, PA.
Self-Supporting Stack, 11 feet 6 inches in diameter by 200 feet high.

prefers an octagonal base with a height equal to one-fifth of the height of the chimney. The foundation should be a truncated pyramid with a square base, and sides inclined at an angle of at least 45 degrees. The length of the sides of the foundation should vary between $\frac{1}{4}$ and $\frac{1}{3}$ of the height of the chimney.

Stability.—Rankine says: "It had been previously ascertained, by observation of the success and failure of actual chimneys, and especially those which respectively stood and fell during the violent storms of 1856, that in order that a round chimney may be sufficiently stable, its weight should be such that a pressure of wind, of about 55 pounds per square foot of a plane surface, directly facing the wind, or $27\frac{1}{2}$ pounds per square foot of the plane projection of a cylindrical surface, . . . shall not cause the resultant pressure at any bed-joint to deviate from the axis of the chimney by more than one-quarter of the outside diameter at that joint."

The angle of repose for dry masonry and brickwork is 31 to 35 degrees, and the coefficient of friction, 0.6 to 0.7; the coefficient of friction for masonry on dry clay is 0.51; the coefficient of friction for masonry on wet clay is 0.33.

Rankine says: "Towers and chimneys are exposed to the lateral pressure of the wind, which may be assumed to be horizontal, and of uniform intensity at all levels." The inclination of the surface of a tower or a chimney to the vertical is seldom sufficient to be worth taking into account, in determining the pressure of the wind against it.

The greatest intensity of the pressure of the wind against a flat surface directly opposed to it, hitherto observed in Great Britain, has been 55 pounds per square foot. Note, see p. 31, St. Louis, Mo., chimney in tornado; and this result, obtained by observations with anemometers, has been verified by the effects of certain violent storms in destroying chimneys and other structures.

In any other climate, before designing a structure intended to resist the lateral pressure of the wind, the greatest intensity of that pressure should be ascertained either by direct experiment, or by observations of effects of the wind on previous structures.

The total pressure of the wind against the side of a cylinder is about one-half the total pressure against a diametral plane of that cylinder.

Let Fig. 1 represent a chimney of any section, and let it be required to determine the conditions of stability of a given

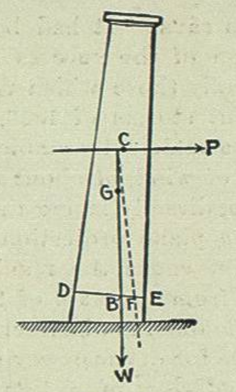


FIG. 1.

bed-joint DE. Let A denote the area of a diametral vertical section of the part of the chimney above the given joint, and p the greatest intensity of pressure of the wind against a flat surface.

Then the total pressure of wind against the chimney will be sensibly:

$$P = pA \text{ for a square chimney;}$$

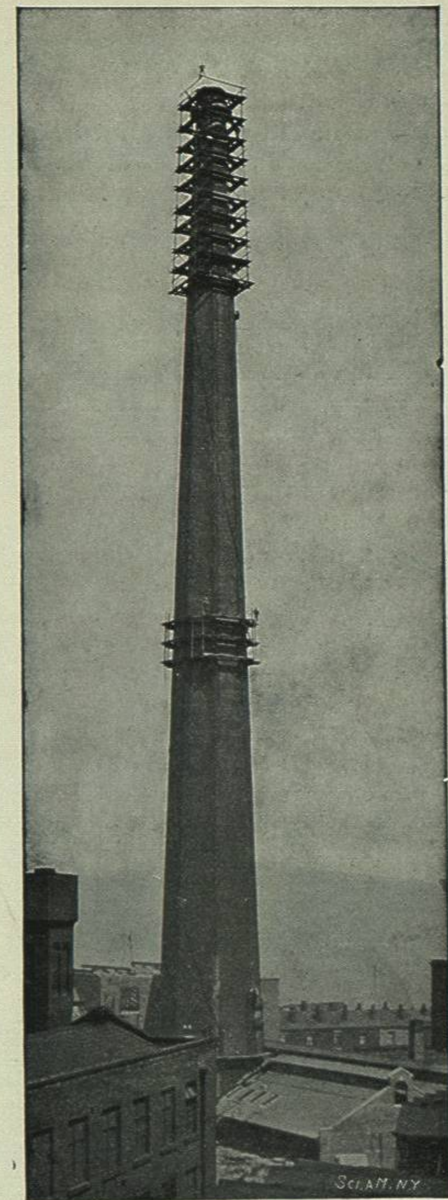
$$P = p\frac{A}{2} \text{ for a round chimney;*}$$

$$P = \tfrac{3}{4}\,pA \text{ for a hexagonal chimney;}$$

$$P = 0.7\,pA \text{ for an octagonal chimney;}$$

and its resultant may, without appreciable error, be assumed to act in a horizontal line through the centre of gravity of the

* In Germany $P = p\frac{2A}{3}$ is used for round chimneys. The most dangerous wind direction for polygon cross-sections is "across corners," because the edge tension becomes the greatest for this direction.



ILLUS. No. 16.

DOBSON & BARLOW CHIMNEY, BOLTON, ENGLAND.

367½ feet high.

vertical diametral section C. Let H denote the height of that centre above the joint DE; then the moment of the pressure is

$$H \times P = HpA \text{ for a square chimney;}$$
$$H \times P = Hp\frac{A}{2} \text{ for a round chimney;}$$
$$H \times P = Hp\tfrac{3}{4}A \text{ for a hexagonal chimney;}$$
$$H \times P = Hp \times 0.7A \text{ for an octagonal chimney;}$$

and to this the least moment of stability of the portion of the chimney above the joint DE should be equal.

For a chimney whose axis is vertical, the moment of stability is the same in all directions.

But few chimneys have their axes exactly vertical, and the least moment of stability is obviously that which opposes a lateral pressure acting in that direction in which the chimney leans.

Let G be the centre of gravity of the part of the chimney which is above the joint DE and B, a point in the joint DE vertically below it; and let the line $\overline{DE} = t$ represent the diameter of that joint which traverses the joint B. Let q' represent the ratio which the deviation of B from the middle of the diameter DE bears to the length t of that diameter.

Then the least moment of stability is denoted by

$$(49) \quad W \times \overline{BF} = (q - q')\ Wt.$$

The value of the co-efficient q is determined by considering the manner in which chimneys are observed to give way to the pressure of the wind.

This is generally observed to commence by the opening of one of the bed-joints, such as DE at the windward side of the chimney.

A crack thus begins which extends itself in a zig-zag form diagonally downward along both sides of the chimney, tending to separate it into two parts, an upper leeward part and a lower windward part, divided by a fissure from each other.

The final destruction of the chimney takes place, either by the horizontal shifting of the upper division until it loses its support from below, or by the crushing of a portion of the brickwork at the leeward side, from the too great concentration