

BRICK CHIMNEY FOR THE METROPOLITAN STREET RAILWAY COMPANY,

NINETY-FIFTH STREET AND FIRST AVENUE, NEW YORK CITY.

Built in 1898.

The ground on which it is built was originally low ground, being covered at one time by the water of the East River, but had been filled in at a later period. A number of borings were made to determine the character of the strata below the earth and ash filling, averaging, respectively, about 10 and 15 feet in depth. Below the filling, blue clay or mud was found to an average depth of 35 feet, beach sand to about 45 feet, fine red sand from 45 to 55 feet, and, from this down, clay was present as far, at least, as 80 feet. Rock was found in one trial at a depth of 125 feet.

In building the foundations, which cover an area of about 85 feet square, the earth and ash filling were removed to a depth of 20 feet below the determined level of the station floor, taken as datum, and piles were driven to a depth of about 40 feet over the entire area. The piles are upon 2-foot 6-inch and 2-foot 3-inch centres, and a total of about 1,300 were driven by means of pile-drivers suspended from derrick booms. At a depth of 40 feet it was found that a 2,500-pound hammer falling 20 feet drove the piles about one inch, on an average. In driving the last 20 or 30 piles, the resistance was so great that they could not be driven over 15 feet. The piles were cut off 1 foot above the top of finished ground, or at a grade of — 19. An immense concrete block was laid upon them, 85 feet square and 20 feet thick, of 1, 3, and 5 Giant Portland cement-concrete. Cement mortar used in the brickwork was made of 1 part Giant Portland cement and 2 parts sand.

It is located close to the wall separating the engine and boiler rooms of the station, and divides the boiler room in two parts. Smoke flues lead from the boilers to the chimney from opposite directions, and as there are three stories in the boiler house upon which the boilers are to be installed, there

are six large openings to the chimney, two on each of the three floors. The chimney is built of two concentric shells, and the outer shell is stiffened by 12 interior longitudinal ribs projecting radially toward the inner shaft and leaving a clearance of $\frac{1}{2}$ inch. The inner shaft has a constant diameter of 22 feet, and the outer dimensions of the stack range from a square base, 55 feet on a side, to a neck of 26 feet 10 inches in diameter, 316 feet above. The cylindrical exterior of the chimney is given a batter of $3\frac{1}{4}$ inches in 10 feet, or 0.312 inches per foot.

The two shells rise from a common brick base resting on the concrete, and are practically a single structure up to a few feet above the smoke-flue openings. These openings are 24 feet 6 inches, one above the other, and 4 feet below the first opening, at the 15-foot elevation, the shaft is lined with an 8-inch thickness of fire-brick to a height of 90 feet, which is about 10 feet above the third-floor opening. Beyond this for 25 feet the fire-brick is only 4 inches thick, and from the 115-foot elevation upward the walls are of common brick. The weakening caused by the openings is overcome by the double-arch construction and the use of tie-beams of channel iron. A 12-inch brick wall, 85 feet high and provided with a buttress divides the lower part of the shaft into two parts, separating the two tiers of smoke-flue openings. The inner shell is built in five sections from the basal thickness of the wall, which is 24 inches, to an 8-inch wall at its top, 340 feet high. The outer shell, as to thickness, ranges from 28 to 16 inches. The fourth section, from the 200 to the 280-foot elevation, is 16 inches thick, as shown, and the wall thickness then becomes 20 inches. The successive gradations of thickness up to this point conform to the requirements of the limiting stresses allowed, but the enlargement is made, aside from providing for the coping, to bring the two shells in closest proximity, so that both may assist in resisting lateral strains. The gap between the two shells near the top of the chimney is protected with an apron of sheet-iron 4 feet wide and provided with a flange at the top imbedded in the brickwork. The top of the chimney is protected with an iron cap formed of 40 cast-iron sectors, bolted one to the other.

They envelop the top brickwork, and are anchored by vertical tie-rods to an annular steel ring about 28 inches in diameter imbedded in the brickwork about 14 feet below the cap. Ten lightning-rods point upward 6 feet above the top of the chimney, and are connected to a copper ring, which is provided with two descending conductors of copper, each 1 by $\frac{3}{8}$ inch in cross section. These conductors are also connected to the iron top. Two other steel rings are also encased near the top, one about 342 feet and another about 313 feet from the base, to prevent any tendency to disintegration resulting from incipient cracks.

The chimney for the station, now practically completed, stands 353 feet above its foundation, and it is, therefore, the tallest chimney in the United States.* Its internal diameter is 22 feet, and in that dimension it is the largest brick chimney in the world. Rankine's formula was used in determining its capacity, and in designing the chimney it was assumed that the wind-pressure would be equivalent to a pressure of about 40 pounds per square foot of diametrical area. The total weight of the chimney is 8,540 tons, and 3,400,000 red bricks were used in the construction.

The drawings show at various elevations the total weight supported, and the corresponding stress per square foot of sectional area. The pressure intensity of the outer shell is on the average greater than that in the interior shaft, being about 9 tons per square foot. The unit load at the concrete base is only 3.5 tons for the whole weight of the chimney.

The chimney was designed by the Engineering Department of the Metropolitan Street Railway Company.—*Engineering Record*, vol. xxxix., p. 53.

* In 1901 it is exceeded in height only by the chimney of the Orford Copper Company, Constable Hook, N. J., which is 360 feet high, see p. 128.



ILLUS. No. 35.

BARBOUR FLAX SPINNING CO., GRAND STREET, PATERSON, N. J.

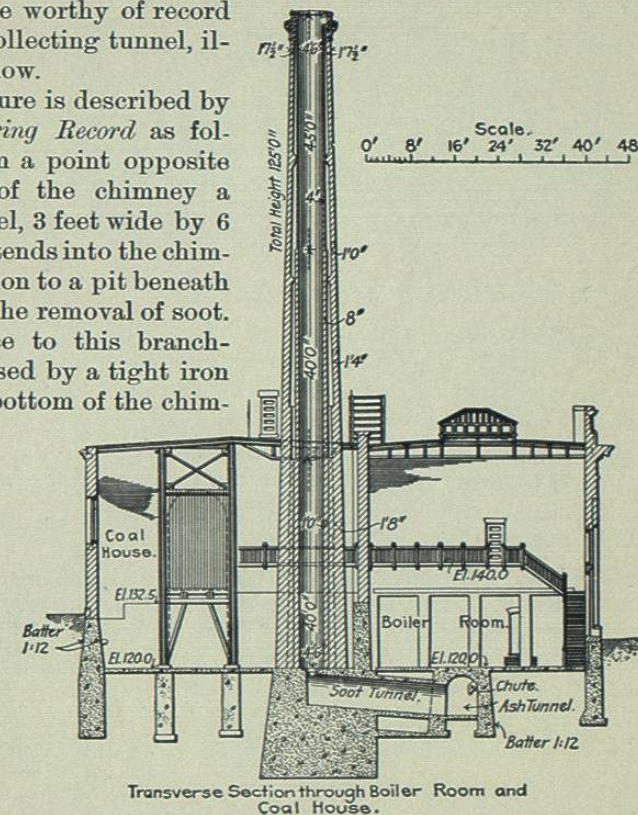
Flue, 6 feet diameter. Height, 175 feet.

THE CHESTNUT HILL PUMPING STATION CHIMNEY.

This chimney, built by the Metropolitan Water Board, Boston, Mass., 125 feet high with a flue $4\frac{1}{2}$ feet in diameter, has a feature worthy of record in its soot-collecting tunnel, illustrated below.

This feature is described by the *Engineering Record* as follows: "From a point opposite the centre of the chimney a branch tunnel, 3 feet wide by 6 feet high, extends into the chimney foundation to a pit beneath the flue, for the removal of soot. The entrance to this branch-tunnel is closed by a tight iron door. The bottom of the chimney is contracted into the form of an inverted truncated cone, whose smaller diameter is 24 inches.

"This opening is closed by a door made of two semi-circular $\frac{1}{4}$ -inch wrought-iron plates, arranged to revolve about a $1\frac{1}{2}$ -inch diameter horizontal steel shaft at the diameter of the circle. By means of pulleys and a chain passing through the walls of the chimney the two leaves of this door can be dropped simultaneously to dump the soot and then be closed again from the coal-house without entering the flue." By this arrangement the chimney draft is not interfered with while removing the soot.



ORFORD COPPER COMPANY'S CHIMNEY.

This radial-brick chimney, 360 feet high, consisting of a single shaft, is now being built (1901) at Constable Hook, N. J., for the Orford Copper Company, to elevate the gases from chemical reactions so high as to be the cause of no harm to the people of the neighborhood.

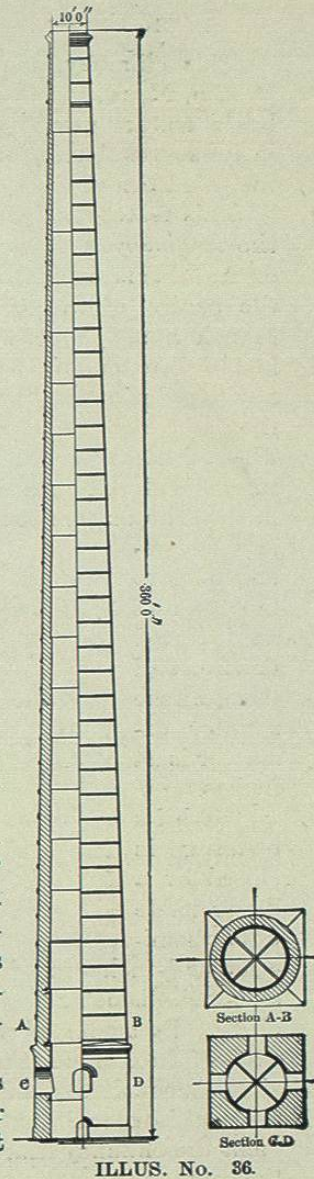
With an internal diameter of 20 feet at the base, and 10 feet at the top, a square exterior for 30 feet above the foundation, the balance of the height is circular in cross-section to the top.

The square portion of the shaft is built of ordinary red brick, the circular part of radial brick (custodis). These radial bricks vary in size from 12 inches radial length at the base, laid in five concentric rows, to 11 inches at the top, in one row, by 4 inches thick (or high).

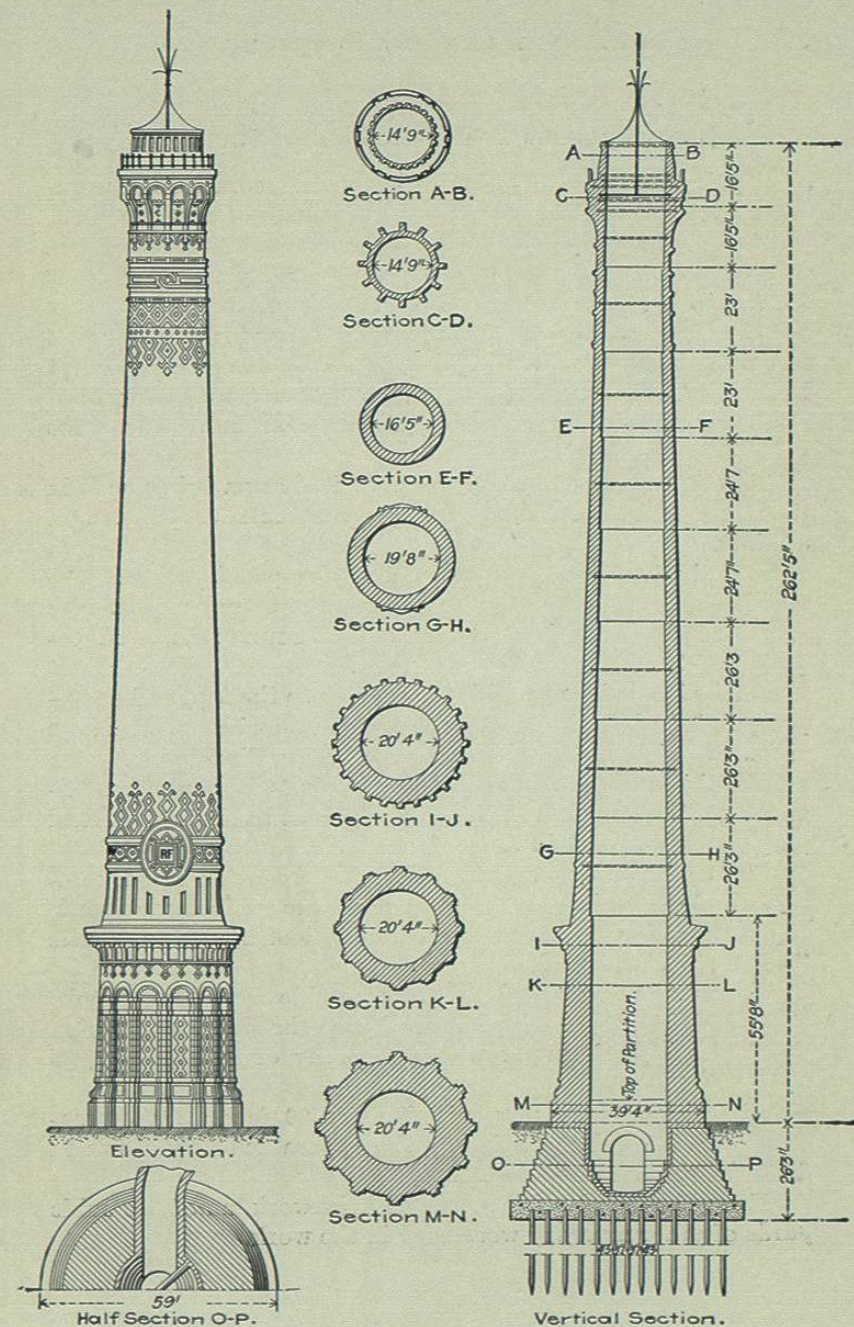
The circular portion is 46 inches thick at the 30-foot elevation, its outside base a taper of 3 inches in 10 feet, the inside being offset 2 inches every $16\frac{1}{2}$ feet. $3\frac{1}{2} \times \frac{5}{16}$ -inch iron bands encircle the brickwork every 8 feet in height, to the cap, which also is made of moulded brick.

The fire brick lining, 42 feet high, intended to resist a temperature of $1,500^{\circ}$ Fahr., is divided into three parts or sections, each carried on corbels at their bottom, and leaving an air-space of 2 inches between the lining and shell. Two partitions, forming an X, deflect the gases upward from four inlets.

The estimated weight of the chimney is 3,475 tons, giving a load of 5.57 tons per square foot on an area of 624.4 square feet at the foundation level.



ILLUS. No. 36.

ILLUS. No. 37.
CHIMNEYS AT THE PARIS EXHIBITION.

BRICK CHIMNEYS AT THE 1900 PARIS EXHIBITION.

A pair of chimneys of white brick, with decorations of terracotta, and brick of various colors, consisting of a single shell, 262 feet 5 inches above the ground, with a flue 14 feet 9 inches at the smallest diameter, were built on the Exposition grounds for furnishing draft to the various steam-boilers.

The sub-foundation of concrete, 59 feet in diameter \times 5 feet thick rests on 133 oak piles, 12 inches diameter \times 23 feet long, driven in circular rows by a hammer weighing 2,650 pounds; above this a stone foundation is built up to the ground-level or nearly so.

Two flues enter each chimney, a diaphragm being built in the chimney a short distance to keep the inlets separate and distinct.

The shaft proper consists of a twelve-panel pedestal $52\frac{1}{2}$ feet high, and a highly ornamented shaft bound together by 0.43×4.75 -inch flat iron bands fifteen in number, bolted together and embedded in the masonry.

An inside ladder provides for access to the top, and a copper-pointed lightning rod at the top, grounded to drainage and waste pipes, is to take care of lightning discharges.

The thickness of the wall at the top is 14 inches to a maximum of 4 feet 5 inches at the cap, $5\frac{1}{4}$ feet at base of cylindrical part and 6 to $9\frac{1}{2}$ feet in the pedestal.

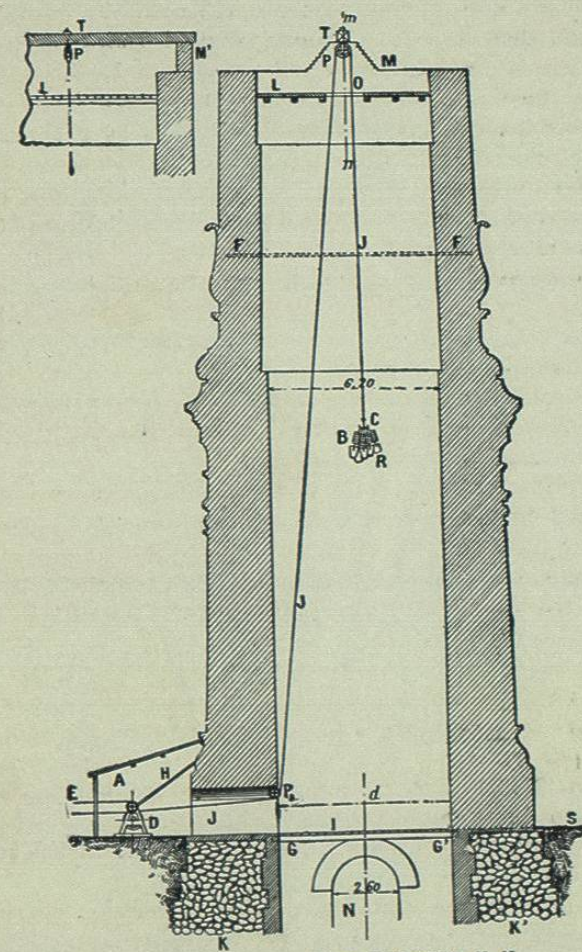
The concrete was 2 parts stone, 1 part mortar, which mortar was 500 pounds Portland cement to one cubic yard of sand. The mortar for the shaft was composed of 1 part hydraulic lime to 2 parts of sand.

The first 92 feet was built from outside scaffolding, above which height a fir-plank platform inside the shaft, from which was hung a platform-car with a capacity of upward of 3,300 pounds.

This timber floor was raised every 20 feet, a five horse-power engine did the hoisting, the apparatus being shown in detail by the cut on page 131.

Three thousand cubic yards of brickwork, and 1,300 cubic yards of other masonry were used in the work.

For more complete description and illustration of these two chimneys see *Engineering Record*, *Steam Engineering*, *Genie Civil* and *Zeits. d. Verein. Deutsch. Ing.*, all of 1890.



ILLUS. No. 38.

ALPHONS CUSTODIS, DUSSELDORF ON RHINE,

as well as other builders, have built a great many round chimneys, using a special moulded radial brick. The brick "are made from pure, thoroughly consistent clay and pressed with water," burned at a heat of not less than 1,500° Fahr. A smooth surface, and a surface which is less porous than is the case with common brick, is thus obtained. These brick are perforated in one direction—vertical, leaving an air-space from top to bottom, which acts as a sort of jacket to the flue, but is not continuous, as the mortar at each joint acts as a separator.

This design of brick adds to the stability of the chimney, by virtue of the less number of joints subject to the weather, and also the better bond which Mr. Custodis says he secures.

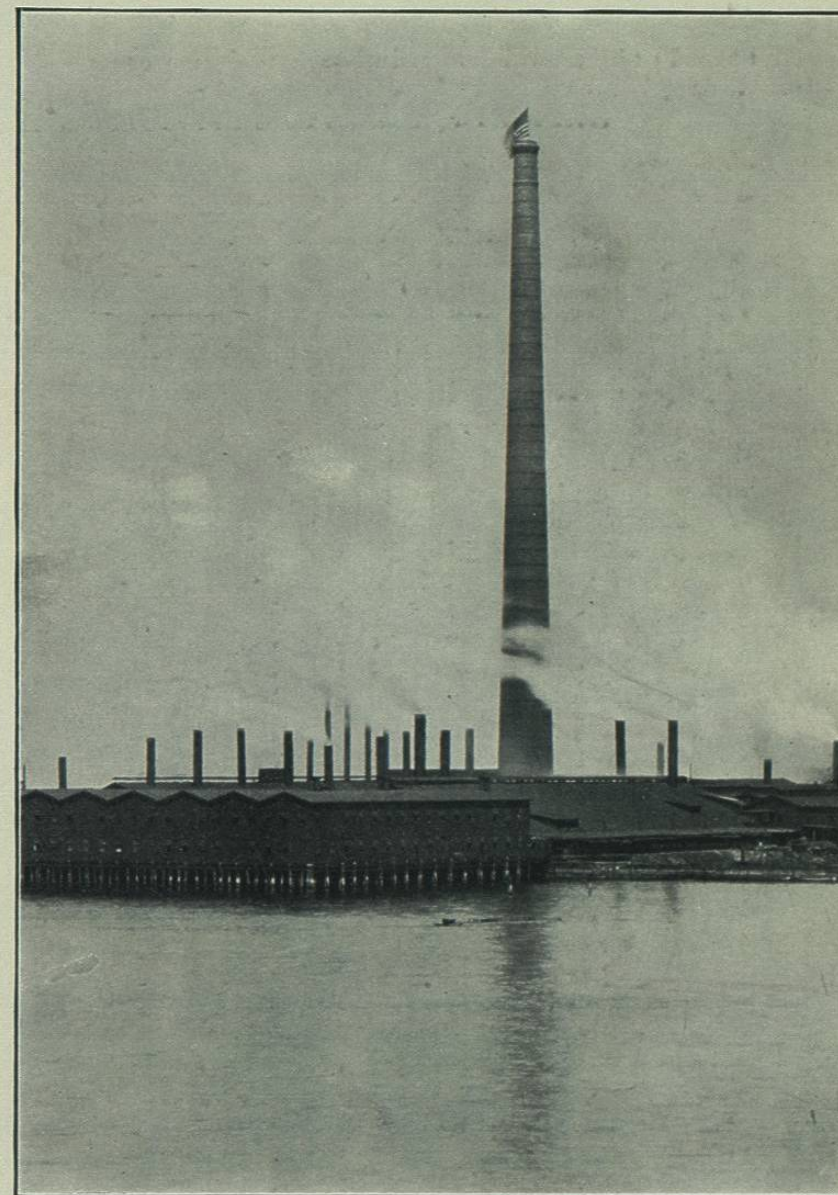


Comparative experiments at the Royal Testing Station for Building Materials in Berlin, with perforated and unperforated chimney bricks, show the following:

1. In unperforated bricks the material possessed the extraordinary compressive strength of 350 kilos per square centimetre (= 4,978 pounds per square inch).
2. In perforated bricks made of the same raw material, the compressive strength was even somewhat greater, 354 kilos per square centimetre (5,035 pounds per square inch), although the sectional area of the holes was included as surface.
3. The adhesive power of cement-mortar used with unperforated bricks amounts to 1.53 kilos per square centimetre (21½ pounds per square inch), while with perforated bricks it amounted to 4.33 kilos per square centimetre (61½ pounds per square inch), or about three times as much.

Illustration No. 39 shows a chimney built in the manner just described and of radial brick.

As it is generally found desirable in a brick chimney to have a central core or flue lined with fire-brick to protect the chimney itself from being destroyed by the varying temperatures within, Mr. Custodis uses the sectional method of building the lining, giving it a uniform thickness, which allows a



By courtesy of *The Staten Islander*, New Brighton, S. I.

ILLUS. No. 39.

ORFORD COPPER COMPANY, CONSTABLE HOOK, N. J.
Designed and built by Alphons Custodis Chimney Construction Company.
Height, 360 feet; inside diameter of flue at top, 13 feet.

section at a time to be repaired; each section can expand vertically according to the heat each section receives; on account of the small lining thickness necessary, this method is very economical.

Because of the superior strength of the bricks used and wall thickness used the diameter at the base of any chimney can be much less than for red brick chimneys, less land occupied, and a less unit load on the foundation.

Chimneys of this type built in the United States, which are over 150 feet high, are in part located as follows:

Bethlehem Steel Company, South Bethlehem, Pa.

(2) 175 feet by 8 feet inside top diameter.

(1) 175 feet by 9 feet inside top diameter.

Yorkville Independent Hygeia-Ice Company, New York City.

Stack 190 feet by 7 feet 6 inches inside top diameter.

New York Shipbuilding Company, Camden, N. J.

200 feet by 8 feet 6 inches inside top diameter.

Great Northern Paper Company, Millinocket, Me.

235 feet by 12 feet inside top diameter.

Manhattan Railway Company, New York City.

(4) 278 feet by 17 feet inside top diameter.

Orford Copper Company, Constable Hook, N. J.

360 feet by 10 feet inside top diameter.