HIGH CHIMNEYS ARE NOT NECESSARY.

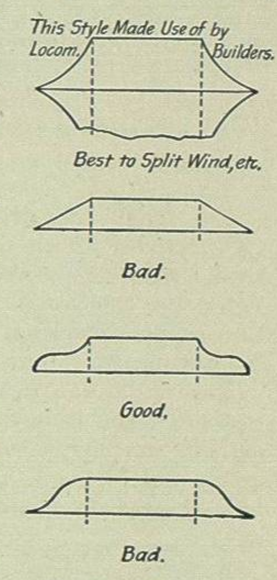
In the language of Professor Wood they are "a monument to the folly of the builders."

While multiple chimneys do not look as imposing as one stately structure, yet better results are often obtained by their use.

A notable example of chimneys in multiple is at the Spreckles Sugar Refinery, Philadelphia, Pa., where five chimneys are used for one plant of 7,500 horse-power of boilers, costing less than one chimney for the combined plant.

The new plant of the Carnegie Steel Company, Bagdad, Pa., is a still more striking example, as shown by Illus. No. 44.

The author has changed one plant from one chimney for two boilers to three chimneys for three boilers, with very beneficial results.



Chimney Top Designs.

STRAIGHTENING A CHIMNEY.

The Standard Concrete Manufacturing Company, Earnest, Pa., have a brick chimney 122 feet high, 11 feet square at the base, with tapering walls, weighing 400 tons; walls 36 inches thick.

The top leaned 45 inches from a vertical line. To sink the side 4½ inches, 10½ inches of brickwork were removed at the foundation from three sides, and square blocks of wood put in their places—brick piers being built 6 inches high so as to leave the 4½ inch space.

The wood was then set on fire and made to burn evenly. As the top gradually swung over, small fissures which appeared on the bottom were filled with steel wedges, to maintain solidity of the walls.

The work consumed one day, the burning of the blocks one hour.—*Engineering News*, vol. xxxvi., p. 160.

CHIMNEY ACCIDENTS.

"The lecture of H. Lütgen, 1884, that in a manner similar to other chimney accidents (see for instance Cordeir's report concerning capsizings in France) all chimneys blown down have broken off either slightly above or below the centre.

"For the granting of an equal steady wind-pressure the upper parts become weak in proportion to the lower part," and "it is well known that in Germany the storm of the year 1876 threw down only such chimneys as were in use among a large number of the same kind and sizes of chimneys" caused by the weakness accompanying the heat from the gases.

A brick chimney with a flue about 5 feet inside diameter by about 160 feet high, being built in a New Jersey city, in 1890, was nearly completed, when struck by an extended severe northeast storm, and though the top was covered, yet the mortar being green, a major portion of the structure came down, so much that an entire rebuilding of the shaft was necessary.

A 200 feet high octagon chimney, with a flue 8 feet in diameter (of the inscribed circle), which had been just completed for the Hoepfner Refining Company, Hamilton, Ont., Canada, collapsed early on the morning of April 18, 1900, necessitating the rebuilding of everything above the foundation.

The apparent cause of this disaster was building the chimney when the lime mortar froze as it was laid, and the consequent expansion was built upon day after day; when the spring sun thawed out the frost the masonry settled and the collapse was the result.

TEARING DOWN OR RAZING A CHIMNEY.

The *Engineering News*, May 17, 1894, gives some details in relation to the successful tearing down of a square brick chimney, 75 feet high, by use of four dynamite cartridges set off at once.

A brick chimney at the Tees Iron Works, Middlesbrough, England, was taken down by using a tight vertical box the cross-section of which was the size of a brick, and dropping the bricks in at the top; when a number had reached the bottom they were removed; the air-cushion provided by the closed box prevented breakage to any considerable extent.—*Engineering*, London, vol. xii., p. 189.

A brick chimney, 160 feet high and 8½ feet square at the base and $4\frac{1}{2}$ feet diameter at the top, was overthrown lately in St. Louis by the use of hydraulic jacks. The chimney belonged to the old Belcher Sugar Refinery, and contained about 200,000 bricks. The chimney was first undermined on one side, and three 10-ton hydraulic jacks were placed in position under the side. A hawser was then fastened about the chimney, 60 feet from the ground, and ropes led from this hawser to crabs placed at a distance of about 100 feet from the chimney. With eight men at each crab and men at the hydraulic jacks, the chimney was slightly lifted and pulled at the same time; the men at the jacks left their posts at the first warning crack, but those at the crabs continued their work until the chimney fell. The top of the chimney toppled over first and the base followed. The work was performed by P. W. Hassatt, contractor.—*Engineering News*, 1899.

STRAIGHTENING A CHIMNEY.

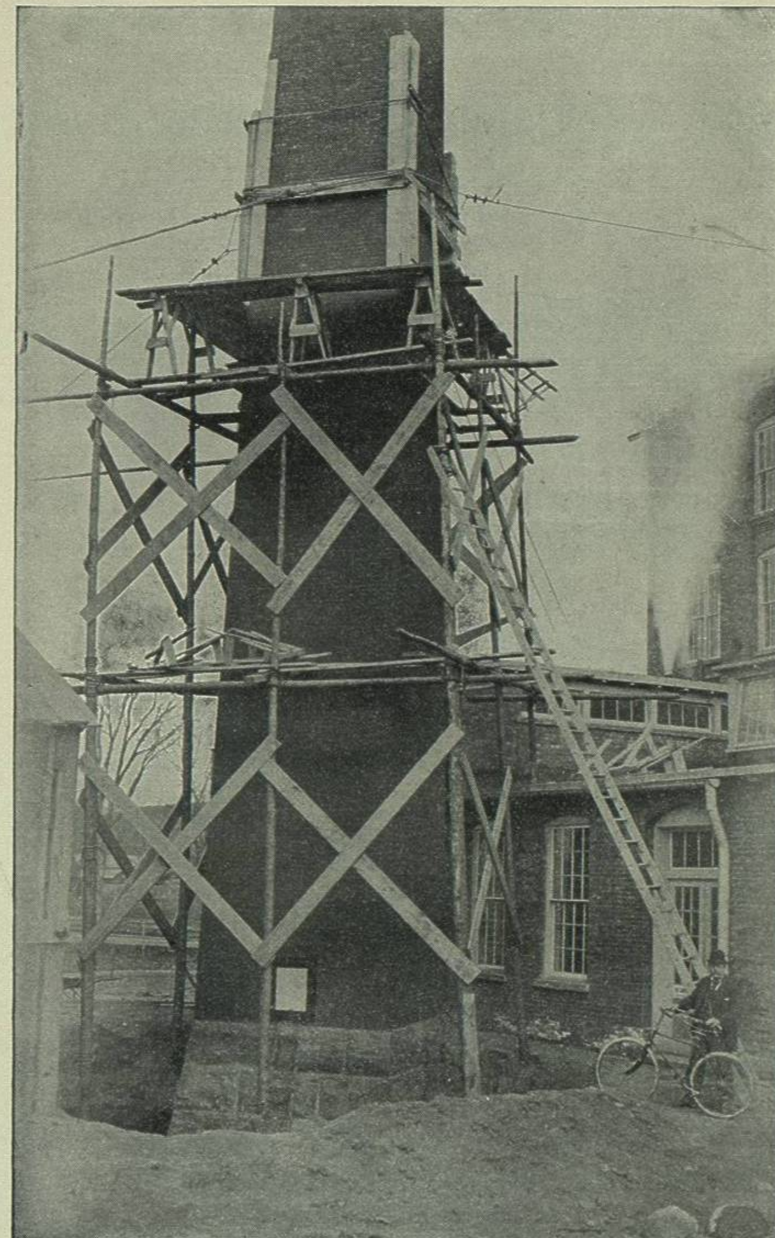
Square brick chimney, 100 feet high, leaning 28 inches, at factory of Ormsby Textile Company, Waterford, N. Y., erected in 1893, located one-third of a mile from the west bank of the Hudson River on north side of outlet of Mohawk River. The underlying rock is shale, irregularly covered by earth.

Chimney is 5 feet 4 inches square at the top, and 9 feet 6 inches square at the bottom, and has a flue 3 feet square; its foundation is 14 feet deep—4 feet by 14 feet square being concrete, and heavy stone-work 10 feet by 14 feet square at bottom, tapering to 9 feet 6 inches at top. Foundation weighs 149 tons, making with chimney 355 tons on 196 square feet of earth, or about 1.8 tons per square foot. — "Transactions of the American Society of Mechanical Engineers," paper dcxi.

This chimney settled in all about 0.598 of a foot. The manner in which it was straightened is described by Mr. J. C. Platt in part as follows:

"The work of straightening the chimney commenced on March 19, 1894. A scaffold was erected, and eight oak timbers, 6 inches by 10 inches by 10 feet, were placed at the corners at the height of 42 feet above the stonework, and $4\frac{1}{2}$ feet below the centre of gravity of the brickwork; the object of the oak timbers being to spread the bearing of the wire ropes over as large a section as practicable.

"Wire ropes were passed around the timbers, and another



ILLUS. No. 47.
ORMSBY TEXTILE COMPANY, WATERFORD, N. Y.

wire rope $2\frac{1}{2}$ inches in diameter with eye in each end, was fastened to the first-mentioned ropes at its upper eye.

"The lower eye was connected with a system of pulleys secured to the dock at the river edge at a distance of 78 feet, and directly opposite the direction in which the chimney leaned, the pulleys being made up of three sets of double and single blocks connected together in series, having three points of fastening to the dock, and having eleven pulleys in a system.

"Cables were also put out from the chimney on each side at right angles to the main cable, and having turn-buckles to tighten them ; also a guard cable in the rear.

"The earth was then excavated on the high side of the foundation nearly one-half way around the bottom of the foundation (to a depth of 13 feet), and the main cable put under strain with the pulleys.

"In the course of three weeks the chimney was brought back about 4 inches.

"Then with a post-hole digger, 8 inches in diameter, eleven holes were sunk vertically in the bottom of the trench around the foundation, principally at the highest point, to a depth of 5 feet 6 inches to 6 feet. At this time the water in the river stood up to within $1\frac{1}{2}$ feet of the bottom of the foundation ; the ground being soft to a depth of 4 feet, it then became very hard, showing that the strata supporting the chimney had been reached.

"No movement or flow of the soil was discovered until the eighth hole was sunk $4\frac{1}{2}$ feet and the tool withdrawn for clearance, when it could only be reinserted readily about 3 feet and headway made very slowly.

"From this removal of the earth there resulted within a few hours a righting of the chimney of 5 inches, increasing to 8 inches by the next morning.

"The slack of the pulling-rope was taken up as fast as the chimney moved, and the rope was kept under strain.

"By tightening up the pulley-rope two or three times a day, in a week the chimney was brought back to $8\frac{3}{4}$ inches.

"In similar manner, the post-hole diggers being reduced to 6 inches diameter, about one-fifth as much more material was removed, immediately followed by righting the chimney to 4 inches, and from that point, after filling the holes with fine broken stone and gravel thoroughly rammed, by continued daily strain on the main cable the chimney was brought back to plumb at the rate of a quarter of an inch per day.

"The turn-buckles in the side cables were occasionally used to control any tendency toward lateral inclination.

"The work has been accomplished without injury to the structure."

Chimneys have been straightened at Louisville, Ky., in a similar manner.

CHIMNEYS FOR FORCED DRAFT.

Chimneys for forced or induced draft should be made of sufficient diameter to carry off the products of combustion; and the writer recommends the top of such chimneys to be at least 15 feet above the top of the boiler-house roof or the roofs of adjoining structures.

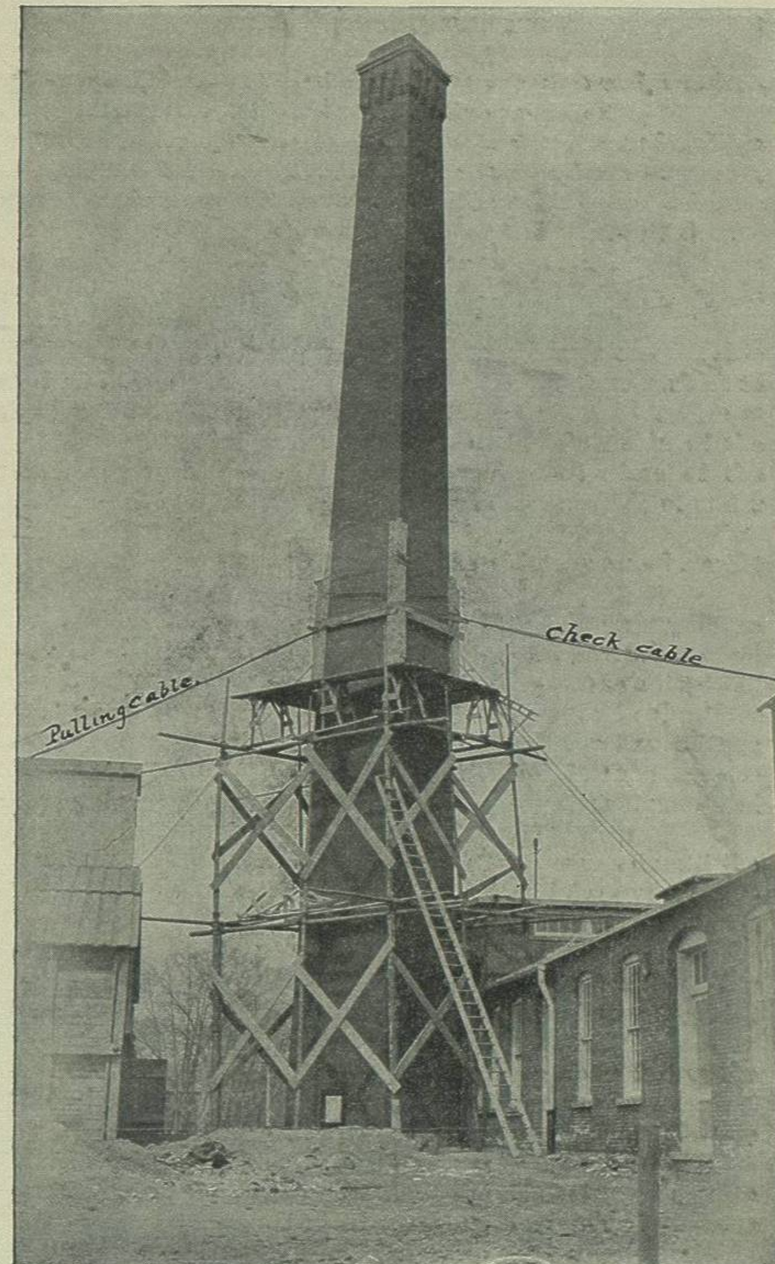
If the greatest diameter of chimney flue, corresponding to the given horse-power or boiler plant, be looked up in the authors' table No. 8 for chimney sizes, it will coincide very closely with present practice, and give abundance of room, so as not to necessitate too high a velocity for the gases.

The above is applicable to either brick or steel chimneys.

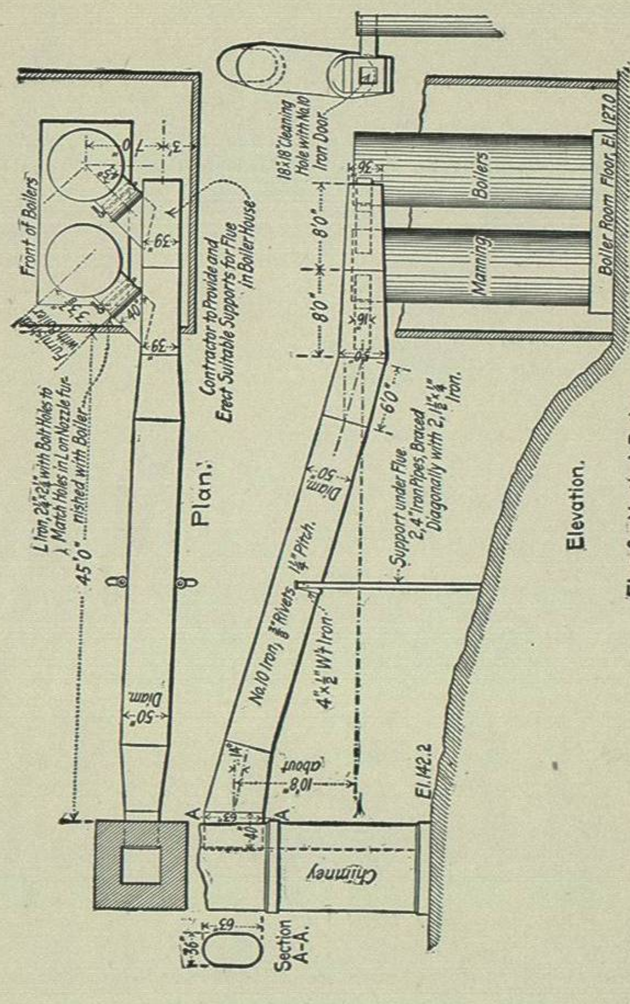
By the use of the fan, high and expensive chimneys are done away with, and the capacity is not as limited as the ordinary chimney, and while the draft of the ordinary chimney is affected by the weather and climatic conditions, forced or induced draft can be regulated so as to be nearly constant in its effects, and there is less waste of heat of the flue gases.

The cheap grades of fuel can be used, in fact anything that will burn at all can be made use of, and money possibly saved, though the interest of the investment must be met, and the running expenses of the draft-producing appliance is never ending.

Provided mechanical draft is an easily applied remedy, unless the flue in the chimney is large enough of area, the results obtained will not meet one's expectations as well as a properly designed chimney; it may be said, however, that



ILLUS. No. 48.
ORMSBY TEXTILE COMPANY, WATERFORD, N. Y.



Flue for Vertical Boilers.
ILLUS. No. 49.

mechanical draft is a necessity in the burning of dust and rice coal and other cheap fine fuel.

FLUES.

In conveying the gases from the boiler furnace to the chimney a flue must be used fitted with an easily swinging damper close to boiler connection, and be made as air tight as possible all of the way to chimney flue.

Having seen that there is less friction in a round than square chimney to the flue gases, we should make the flue round whenever possible, and it is more easily built, while the square flue needs flanged corners or special angle-iron corners.

Round flues for more than one boiler are made tapering from a small size at first boiler to the largest size at chimney.

The area of the flue should be at all sections as large or larger than the total area of tubes emptying in it at that section.

When more than one flue is to connect with a chimney from opposite sides, a partition or deflector is provided so as to separate the two currents of gases, and deflect them upward.

Sometimes one opening is made at least three or four times its diameter above the other flue inlet, without a separator.

Overhead flue connections are of steel sheets, those under ground are sometimes of steel, but often of fire-brick laid in fire-clay and covered with red brick.

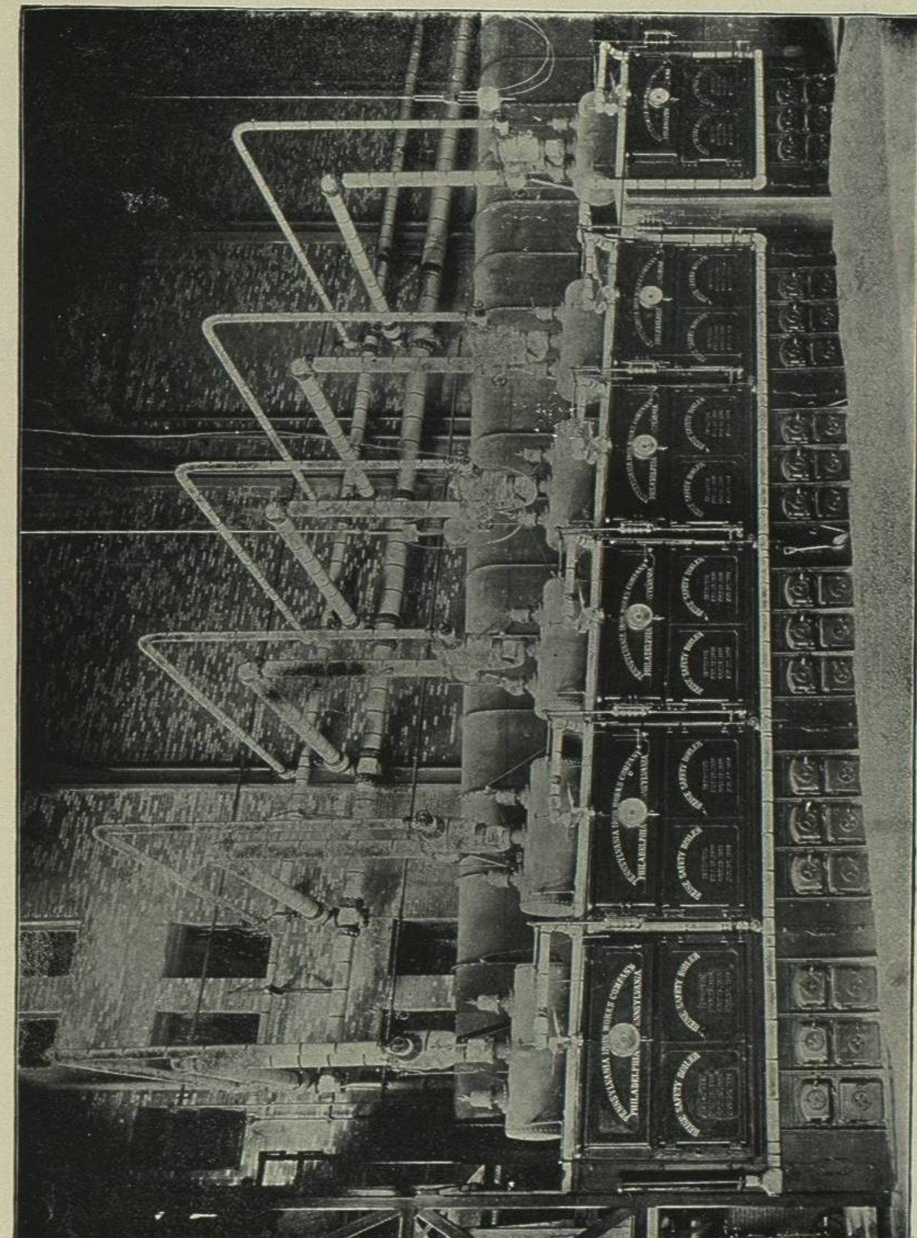
Exposed flues should be protected with hair felt, asbestos board, or some other heat retainer, that all the heat from the gases may be available in the chimney proper for draft.

The effect of changing the length of the flue leading into a chimney 60 feet high and 2 feet 9 inches square is as follows:

TABLE No. 26.

DRAFT POWER—VARYING FLUE LENGTHS.

Length of flue in feet.	Horse power.	Length of flue in feet.	Horse-power.
50	107.6	800	56.1
100	100.0	1,000	51.4
200	85.3	1,500	43.3
400	70.8	2,000	38.2
600	62.5	3,000	31.7



"Helios."

ILLUS. No 50.

FLUE ARRANGEMENT 1,500 HORSE-POWER PLANT OF HEINE BOILERS, PART OF 4,500 HORSE-POWER PLANTS OF BROADWAY AND SEVENTH AVENUE CABLE RAILWAY COMPANY, NEW YORK.

The following table may also be useful.

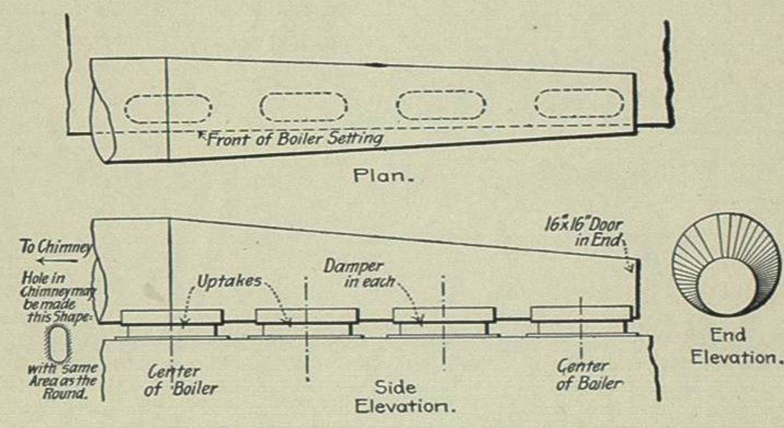
TABLE No. 27.

REDUCTION OF CHIMNEY DRAFT BY LONG FLUES.

Total length of flues in feet....	50	100	200	400	600	800	1,000	2,000
Chimney draft in per cent.....	100	93	79	66	58	52	48	35

In the above the total length from grate to base of chimney must be considered.

When several boilers are connected with one flue, increase size as before noticed.



Flue for Horizontal Return Tubular Boiler.

ILLUS. No. 51.

INFLUENCES OF TURNS AND ELBOWS UPON FLUIDS IN MOTION.*

Let us consider first the influence of abrupt changes of direction and later those of continuous changes, that is to say, of curved pipes.

M. d'Aubuisson has made several experiments on the influence of abrupt changes of direction. In his "Traité d'Hydraulique," p. 513, appears the following:

* Translated from M. E. Péclet's Traité de la Chaleur, by F. R. Low.

"Elbows in conduits, when they are abrupt, augment considerably the resistance to movement. In my numerous experiments on conduits with elbows, seven 45-degree turns reduce the flow one-quarter.

"In these experiments I noticed that the resistance increases, as in water pipes, sensibly as the square of the velocity and nearly as the square of the sines of the angles. Beyond a certain number, however, the resistance even diminished; thus fifteen angles reduced the outflow a little less than seven of the same size. This phenomenon and other circumstances have rendered futile the attempts that I have made to establish, even approximately, the resistance of the elbows. In

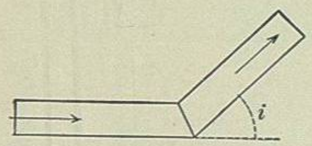


FIG. 1.

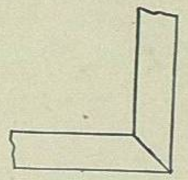


FIG. 2.

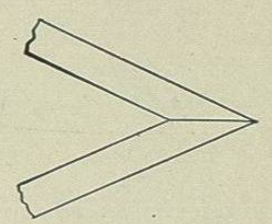


FIG. 3.

practice a bad effect may be avoided by rounding well those curves which it is necessary to make."

According to the experiments made by Dubuat' on water pipes, the resistance of an abrupt change is sensibly represented by $p \sin^2 i$, p being the head corresponding to the velocity of flow, and i the angle which the second pipe makes with the prolongation of the first. For gas which flows under a light pressure, and which in consequence undergoes only insensible variations of density, it was probable that the resistance of the elbows would follow the same law, but it was important to verify this, the more so that in the experiments of Dubuat' the angles i were always between 36° and 56°. As to the singular result found by d'Aubuisson, that from a certain limit the flow increased with the number of angles, it can be explained only by admitting that the joints were not entirely tight.

It results from numerous experiments which I have made on abrupt changes of direction that when the angle i, Fig. 1, of the second pipe with the prolongation of the first is between 20° and 90°, the loss of head is given by the formula:

$$P_1 - p_1 = p \sin^2 i$$

as for pipes carrying water.

P_1 is the head before the elbow,
p_1 is the head after the elbow,
p the head corresponding to the velocity.

For angles between zero and 20 degrees, it will be necessary to consider the elbow as a curved pipe and employ the formula which will be given later.

If the angle was a right angle, Fig. 2, the loss of head would be p, and for n changes at a right angle it would be $n\,p$.

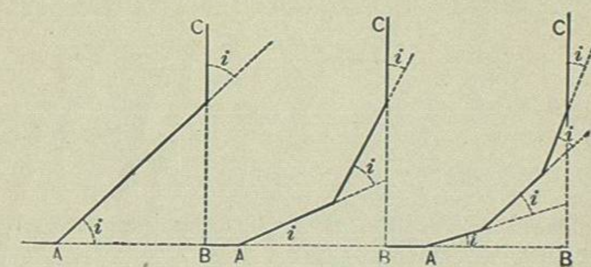


FIG. 4.

For an angle greater than a right angle, as in Fig. 3, the loss of head is uncertain. From some experiments it appears that for the angles made by the second pipe with the prolongation of the first comprised between 110 and 160 degrees, the loss of head would vary from $2p$ to $2.28p$; but these experiments were not sufficiently regular and consistent to justify a great deal of confidence in them. This case, however, rarely presents itself in practice.

The total resistance of the abrupt changes in a circuit being equal to the sum of the resistance of each one of them, if it is imagined that the right angle formed by the two pipes AB and BC, Fig. 4, were replaced by three, four, or five pipes, disposed symmetrically, the angles i being equal, their sum would be equal to 90 degrees, and designating by n the number of angles i, the total resistance would be

$$n\ sin^2\left(\frac{90^\circ}{n}\right).$$

If n be supposed successively equal to

	1	2	3	4
the value of i will be	90°	45°	30°	22° 30′
of which the sines are	1	0.707	0.50	0.382
and the losses of head become	1	1	0.75	0.58

Thus a single pipe cutting a right angle does not diminish the resistance appreciably, and three intermediate pipes do not reduce it quite to one-half.

CURVED PIPES.

The earliest experiment on the flow of fluids in curved pipes was made by Bossut. A pipe of 16.24 metres in length and 27 millimetres in diameter discharged under a head of .325 metre a volume of .0028 cubic metre of water in a minute when it was in a straight line, and .02048 when it was turned upon itself so as to form six well-rounded elbows. It seemed, according to this experiment, that well-rounded elbows had not much influence on the flow, but as the pipe was quite long, the loss of head was in part confused with that which came from friction.

Dubuat made a considerable number of experiments to determine the resistance of curved elbows in water-pipes, and this engineer has been led to a singular explanation of the resistance in question. He maintains that when the water issues from a rectilinear canal, *AB*, Fig. 5, and penetrates into a curved canal, *BCD*, the elementary veins do not follow the curvature of the pipe, but are reflected on its surface, and that the loss of head produced by the curved pipe is due to these reflections of the lines of water. According to his experiments the loss of head would be expressed by

$$0.0123\, v^2 (s^2 + s'^2 + s''^2\ .\ .);\ \text{or}\ p\, 0.24\, (s^2 + s'^2 + s''^2)$$

$s\, s'\, s''$ being the sines of the angles of reflection.

Where the curvature of the pipe is circular, all the angles of reflection are equal, and the above expression becomes

$$p\, n\, sin^2\, i.$$

The angles of reflection are those which correspond to the central vein. D'Aubuisson accepts completely this explanation of the resistance of curved pipes, and the formula of Dubuat ("Traité d'Hydraulique," p. 182). Notwithstanding the authority of these two engineers, such an explanation appears to me to be inadmissible. First, the fluids, liquid or gaseous, do not reflect against the surfaces which they encounter, and in the second place, if this reflection did occur, it would not be the same for all the elementary veins which penetrate into the curvilinear pipe, and for which I think the values of i and n would be different.

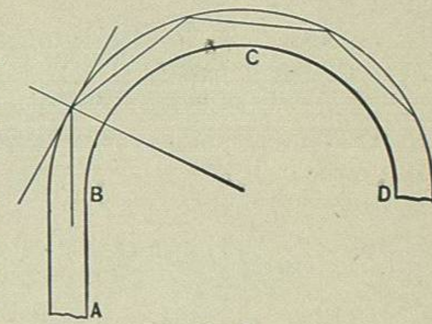


Fig. 5.

I made a great number of experiments to determine the losses of head from rounded elbows, Fig. 6, from which it appears that we shall not be far from truth in considering that the resistance of a curved pipe of constant section is sensibly equal to

$$P_1 - p_1 = \frac{i}{180} p$$

i being the number of degrees of the arc, p the head corresponding to the velocity of flow, P_1 and p_1 the head before and after the curvature. Thus for a semicircle which will bring

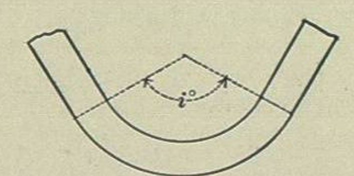


Fig. 6.

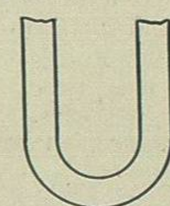


Fig. 7.

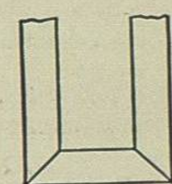


Fig. 8.

the pipe into a position parallel to the initial direction, Fig. 7, we have $i = 180$ degrees, and the loss of head would be p, one-half only of that which would take place if the pipe had taken that direction by two abrupt and successive right-angled changes, Fig. 8. If there were n continuous changes of direction the loss of head would be

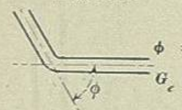
$$P_1 - p_1 = \frac{i}{180} p$$

—*Power*, February, 1900.

Weisbach, from experiments with 1¼-inch pipe (water) found the loss of head to be $h_e = G_e \dfrac{v^2}{2g}$,

$$G_e = 0.9457\, sin^2 \frac{\phi}{2} + 2.047\, sin^4 \frac{\phi}{2}$$

Elbows.—



ϕ =	20°	40°	60°	80°	90°	100°	110°	120°	130°	140°
G_e =	0.046	0.139	0.364	0.74	0.984	1.26	1.556	1.861	2.158	2.434

hence at a 90-degree elbow the whole head due to the velocity is very nearly lost.

Bends.—For curved bends, ○ cross-section, $h_b = G_b \dfrac{v^2}{2g}$,

$$G_b = 0.131 + 1.847 \left(\frac{d}{2r}\right)^2$$

where d = diameter of pipe, r = radius of curvature of bend.

For □ cross-sections

$$G_b = 0.124 + 3.104 \left(\frac{s}{2r}\right)^{\frac{7}{2}}$$

where s is the length of side of section parallel to the radius of curvature, r.

$\frac{d}{2r}$ =	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	○ section.
G_b =	0.131	.138	.158	.206	.294	.440	.661	.977	1.408	1.978	

$\frac{s}{2r}$ =	0.1	0.2	0.3	0.4	0.5	0.6	.07	0.8	0.9	1.0	□ section.
G_b =		0.124	.135	.180	.250	.398	.643	1.015	1.546	3.228	

CHAPTER IX

HOUSE CHIMNEYS

HOUSE-HEATING

SCHUMAN * gives these formulæ for house-heating calculations.

Let A = sectional area of flue in square feet.
V = volume of smoke delivered in cubic feet per second; usually 600 is allowed for V.
K = pounds of coal consumed per hour.
H = height of chimney in feet.
v = velocity of smoke in feet per second.
t = external temperature, average 50°.
t_1 = internal temperature, average 550°.

$$v = 0.08\sqrt{(t_1 - t)H}, \tag{58}$$

$$A = \frac{12.5\,V}{\sqrt{(t_1 - t)H}}, \tag{59}$$

$$V = Av = A\,0.08\sqrt{(t_1 - t)H}, \tag{60}$$

$$H = \frac{156}{t_1 - t}\left(\frac{V}{A}\right)^2, \tag{61}$$

allowing 600 for V, we have

$$A = 0.128 \frac{K}{\sqrt{H}}, \tag{62}$$

$$H = 0.01638 \left(\frac{K}{A}\right)^2. \tag{63}$$

The following table is adapted from the Blackmore Heating and Ventilation Company for hot-air furnaces.

* Manual of Heating and Ventilation, p. 69.