VENTILATION

WILLIAM PATON BUCHAN

To

Professor John Gray McKendrick, M.D., LL.D., F.R.S.

With the author's Compliments

Feby 21st 1891.

W. P. Buchan

VENTILATION

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A TEXT-BOOK

TO THE PRACTICE OF THE ART OF VENTILATING BUILDINGS

WITH A SUPPLEMENTARY CHAPTER UPON

AIR TESTING

BY

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PREFACE.

Of all the requisites for a really healthy and comfortable dwelling, school, hall, or church, &c., none has been so sadly and foolishly neglected hitherto as good Ventilation. Due provision for this important hygienic element is, in the great majority of our buildings, most conspicuous by its absence. Now, however, the public are awakening to the fact that this penny-wise-and-pound-foolish policy is a great mistake, and the demand is everywhere being made for improvement.

Since the writer issued his "Text-Book on Plumbing and House Drainage" in 1876, there has been a wonderful reformation in sanitary practice in these particulars. To aid in completing the work, this companion treatise on Ventilation is now issued, in the expectation that it may be as useful and as successful as its predecessor.

A cheap and popular illustrated practical work on Ventilation—that would be useful alike to the Architect, the Physician, and the Artisan, as well as interesting and instructive to the general reader—has been much desiderated. It is hoped that this little book may help to fill the void, and also be serviceable to the rising generation in our Technical Schools and Evening Classes.

Thanks are due to Mr. P. MacGregor Chalmers, F.S.A.Scot., Architect, Glasgow, for his kind assistance in preparing a large number of the illustrations for the engraver; and to Mr. John Foggie, F.C.S., of University College, Dundee (who acted as assistant to the late deeply lamented Professor Carnelley), for the chapter on Examining the Air of Buildings.

21, Renfrew Street, Glasgow,
January 1*st*, 1891.

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VENTILATION.

CHAPTER I.

INTRODUCTORY.

VENTILATION is in the air in more senses than one. It is being demanded for our schools, churches, halls, houses, and other enclosures where human beings and other animals live, congregate, or work.

Real ventilation means not merely motion of the air, but its removal—carrying off the vitiated air and replacing it with fresh air. In a well-ventilated enclosure, therefore, there will be a constant mass or stream or streams of fresh air coming in at one or more places, while the vitiated air will be going out at some other place or places.

In making provision for carrying out this change of air, it is necessary to remember that it should be done in a way that will not cause discomfort to or produce an evil effect upon the people or animals within the enclosure that is being ventilated. In this relation Professor E. Duncan, M.D., made a very trite remark at a discussion upon ventilation in the Philosophical Society of Glasgow in 1889, viz.: "While science enables us to understand the principles of ventilation, the art of ventilation consisted in the application of those principles, and here the difficulties begin."

The word "draught" calls up unpleasant reminiscences with most people. The Spanish proverb says, "Beware of a cold draught and an angry donkey." Standing or sitting in a draught is sometimes as deadly as swallowing poison. Satisfactory ventilation, therefore, means motion and renewal of the air so as not to produce unpleasant or dangerous draughts.

By the word "air" in this connection is meant the compound mobile fluid that surrounds our earth to a height of forty-five miles or so, and in which we breathe and live, otherwise termed the "atmosphere."

Air is *matter* in a gaseous condition, matter presenting itself in three states, viz., the gaseous, liquid, and solid. Water,* again, which is matter in the liquid state, is formed by the union of the two gases, oxygen and hydrogen, in the proportion by weight of 8 of oxygen to 1 of hydrogen, or in volume 2 of H to 1 of O, oxygen gas being 16 times heavier than hydrogen. We in temperate countries are most familiar with it as a liquid. At and below 32° Fahr. it freezes and assumes the solid state, when it is known as *ice* or *snow*. At and above 212° Fahr. water (at the surface of the earth) boils, and is transformed into the elastic aeriform fluid known as *steam*, which has been converted by human ingenuity into the great servant—or real permanent Hercules—of our race. In the solid form the particles of matter appear to adhere to each other. In the liquid they can roll about freely like bullets, while in the gaseous state the particles appear to repel each other, so that the mass tends to expand indefinitely.

The chemical composition of the atmosphere in 100 volumes or 100 grains of *dry* air may be taken roughly as 21 parts of oxygen and 79 of nitrogen, with a small proportion of carbonic acid, or more exactly as follows, and as is given in "Chambers's Encyclopædia":—

	Volumes.	Grains.
Nitrogen	79·02	76·84
Oxygen	20·94	23·10
Carbonic acid . . .	0·04†	0·06
	100·00	100·00

* In old style the chemical symbol of water was HO; the newer style H_2O or H_2O_2.

† This "0·04" in 100 vols. means 4 in 100 + 100 = 4 parts in 10,000, which is taken as the normal proportion of carbonic acid or CO_2 in the atmosphere.

In addition to the above gases there is always a certain amount of watery vapour in the atmosphere, varying from 4 to 16 grains in the 1,000. Professor McKendrick, M.D., F.R.S., in his work on "Physiology" gives the proportions of the constituents of the atmosphere as follows:—

O	20·93
N	78·19
CO_2	·04
H_2O (vapour) .	·84
	100·00

Traces of ammonia, nitric acid, and of organic matter will also be found in the atmosphere. Ozone, or oxygen in an active or highly electro-negative state, also exists in the air. It is not found in the atmosphere of cities. As ozone is considered a purifier of the blood and health agent, people in bad health are sent to the country or seaside, as the case may be, to inspire ozone. As prevention is better than cure, people again go to the country or seaside for a time each year to brace themselves up and so stave off illness.*

Oxygen and nitrogen may be looked upon as representing the pure air, the principal work of the nitrogen seeming to be to dilute the oxygen; the carbonic acid and other matters found in the air being looked upon as impurities. These impurities consist not merely of bad gases, but also of dust and of low, small organisms and their seeds or spores. Oxygen is an elementary substance, not a compound; it exists in the atmosphere in the free state. It is not chemically combined with the nitrogen in the air, but merely mixed with it.

It has been already stated that air is matter; it must, therefore, have *weight*. This was not understood by the ancients. Aristotle is stated to have weighed a skin or bladder when empty or squeezed close together,

* Sometimes the change is out of the frying-pan into the fire, should the house gone to be damp, or its drainage or water-supply be bad. In some coast houses the air is passable while the windows are open, but with them shut the air in them feels musty and disagreeable.

and when inflated. As he found no difference in the weights, he wrongly concluded that air had no weight. This experiment, unfortunately for Aristotle's credit, was not properly carried out. It helped to mislead men, however, for hundreds of years, or down to the time of Galileo (sixteenth century A.D.).

The simplest experiment is that made by Torricelli in A.D. 1643, which may be explained as follows:—Take a glass tube, hermetically sealed at the one end, and say $\frac{1}{4}$ in. in diameter internally, and 3 ft. long. Fill it quite full of mercury, then stop up the open end firmly with the finger; now turn up the tube and insert its lower end into a vessel containing mercury, as per Fig. 1. When the finger is removed, the mercury will be seen to sink down a little in the tube, until it stands about 30 in. higher than the surface of the mercury in the vessel. This perpendicular column of mercury 30 in. high is prevented from falling down into the vessel by the pressure or counterbalancing weight of the atmosphere. Aristotle's idea that "nature abhors a vacuum," or that she is always able to prevent one being formed, would therefore appear to be wrong, for a vacuum exists inside the glass tube above the 30 in. of mercury.

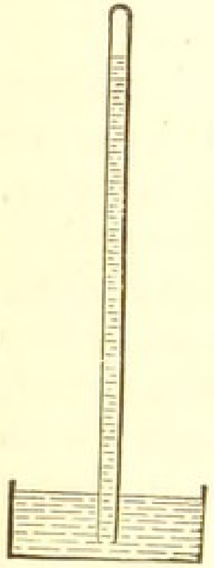


Fig. 1.

As a cubic inch of mercury weighs about half-a-pound avoirdupois, a vertical column of mercury one square inch in base and 30 in. high will weigh about 15 lbs. (more correctly $14\frac{3}{4}$ lbs.). A vertical column of the atmosphere one inch square in base and 45 miles high is the same weight; 15 lbs. to the square inch is therefores known as the pressure of one atmosphere, 30 lbs. of two atmospheres and so on. Previous to Torricelli's experiment Galileo had already discovered that a column of water about 34 ft. high counterbalanced the weight of the atmosphere. He discovered this in connection with the fitting up of some water pumps, which, he found, would not lift the water from a greater depth than about 32 ft. below the under-valve.* The weight of the atmosphere varies, as we see by the rise and fall of the barometer. Water is about 13·59 times lighter than mercury, so that 30 in. × 13·59 gives about 34 ft. for the height of a column of water to balance a 30 in. high column of mercury.

Air is about 800 times lighter than water, and about 10,000 times lighter than mercury. 100 cubic in. of dry air, when the thermometer is at 60° and the barometer 30 ins. weigh 31·074 grains, a cubic ft. of air weighing fully $1\frac{1}{8}$ ozs., or, taking the weight of a cubic ft. of water at 40° Fahr. at 1,000 ozs., the specific gravity of the air at the earth's surface is 1·222 ozs. per cubic ft. Mercury 13,596 oz. Carbonic acid (or carbon dioxide) is as 1529 to 1000 or fully half as heavy again as the ordinary air,† yet owing to the energy inherent in it as per the law of the diffusion of gases, the carbonic acid does not lie at the bottom of the atmosphere, but is, generally speaking, equally diffused through it.

As related in Everett's translation of Deschanel's "Natural Philosophy," Count Berthollet—who died in A.D. 1822, made an interesting experiment which proved how powerfully, even in very unfavourable circumstances, this power or faculty of diffusion acts.‡ He took two globes, as per Fig. 2, and filled one with carbonic acid gas and the other with hydrogen. The

* It is to Galileo that we owe the true scientific method of dealing with all natural phenomena, viz., the method by experiment. Many of the theories of the ancient philosophers, especially of the Platonic school, were based upon mere conceptions—reasoning from a supposed cause to the effect—to which facts had to be accommodated. The Ptolemaic system of astronomy, which held sway until the sixteenth century A.D., is an interesting example of this. The death-knell of many a false theory was sounded when this was exploded.

† Weight of oxygen to ordinary air is as 1.111 to 1, so that it is heavier. Nitrogen again is lighter, being 0·972, and hydrogen lighter still, being 0·069. Hydrogen is one of the lightest substances known, being about 14 times lighter than the same bulk of atmospheric air of equal temperature. Water, which as a liquid is almost incompressible, when boiled expands into steam occupying 1700 times the space of the water, so that a cubic inch of water will give about a cubic foot of steam.

‡ Thomas Graham (of Glasgow), F.R.S., who was born in 1805, wrote "On the Law of the Diffusion of Gases," Transactions of the Royal Society, Edinburgh, 1834. This was after Berthollet's time.

globes were connected together as per illustration, by a small pipe. Although the hydrogen was in the upper globe, yet after a time it was found that half of the hydrogen had gone down into the lower globe and the half of the carbonic acid had gone up into the upper globe. Now as the carbonic acid gas is about 22 times heavier than hydrogen gas, this experiment shows how the power of diffusion overcomes the force of gravity.*

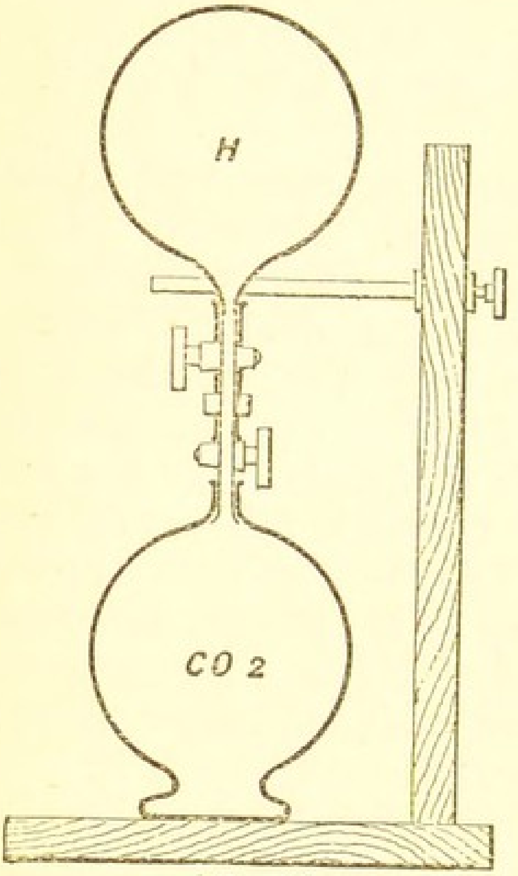


Fig. 2.

This faculty of diffusion causes the carbonic acid at the top of a mountain to be in the same proportion in the atmosphere there as in the fresh air at its base.

The wonderful energy of hydrogen may be shown by the following interesting experiment.

Take a bottle with two mouths and half fill it with water, as per Fig. 3. Then put a tube into each neck, as shown. When a bottle filled with hydrogen gas is placed over the tube at A, so strong a pressure is exerted on the surface of the water, that the water spurts up through tube B.

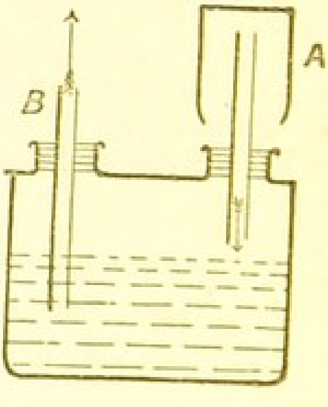


Fig. 3.

Many people, in ignorance of the effect of the continual operation of this law or faculty of diffusion, imagine that because carbonic acid gas is heavier than the general air, that therefore in accordance with the law of gravity it falls to the ground, and as a con-

* It would not do to allow pure oxygen and hydrogen to mix, "these gases forming an explosive mixture when brought together." —*Glasgow Herald*, March 13th, 1890.

sequence, the air, they tell us, at the floor of a room will be worse—or contain more carbonic acid—than that at the ceiling, but this is a pure mistake.

Generally speaking, in occupied rooms, and especially after the gas has been lighted, the worst air is at the ceiling, hence the advisability of drawing it off at that height.

Air as it is exhaled from the lungs has a temperature of about 97°, so it rises upwards. If it can be carried off before it cools and falls again, or by diffusion or currents gets mixed with the general atmosphere of the room, church, school, or hall, then the air of said room or church, &c., will not be deteriorated by it.

In this connection it should be remembered or understood that exhaled air contains about a hundred times as much carbonic acid as fresh air, so that the provision supplied to carry off this large amount requires to be ample, and not in the merely nominal or short allowance style—of a farthing biscuit and half an ounce of beef, and both rather stale, to a hard-worked navvy for his dinner—so often allowed.

In some cases carbonic acid may be generated quicker at the bottom of an enclosure than it can diffuse or get mixed with the atmosphere, as at the bottom of a well, or in a mine, or in a large empty wine or beer vat, but these cases are exceptional. They have to be guarded against, however.

The air in the Grotto del Cane is deadly from this cause, and people have been made insensible or killed by going down into an empty vat, or into a well where the air was bad.

As I write this the newspapers relate that some men have just been killed by going too hastily into a gasometer to work. Some of them saw their mistake when it was too late, they tried to escape, but fell back insensible, and were suffocated.

We might refer to the case of the steamer *Londonderry*, when plying between Liverpool and Sligo. On December 2nd, 1848, she left for Liverpool with 200 passengers on board. Stormy weather came on, and all were ordered below. The cabin for the steerage passengers was only 18 ft. long by 11 ft. wide and 7 ft. high, and into this small space the passengers were crowded. Although there was no provision for ventilation, the captain ordered the hatches to be closed, and even covered over the entrance to the cabin with a tarpaulin. As a consequence the passengers had to breathe the air they exhaled over and over again, consuming the oxygen and supplying its place with carbonic acid, so that their condition shortly became intolerable. A horrible scene of frenzy and violence occurred, many being suffocated. One of the passengers managed at last to force his way on deck and alarm the mate, when it was found that seventy-two persons were already dead, and others dying in torture, all owing to the ignorance of those in authority, who did not understand that people required the atmosphere they breathed to be renewed, and that exhaled air was poisonous.*

It was owing to this consumption of the oxygen and excess of carbonic acid that so many people were suffocated and killed when thrust into the "Black Hole" at Calcutta.

According to Professor McKendrick, animals may breathe an atmosphere containing two or three times the normal amount of oxygen without appearing to be affected. It is not so easy, however, to get an excess of oxygen as of carbonic acid.†

The natural proportion of oxygen in the air is about 20.93 per cent., but when in close rooms and unventilated schools and churches, &c., it is reduced to 20 per cent. the air is very bad. In such circumstances there would be about 1 per cent. of carbonic acid, or twenty-four times as much as there should be. Where many human beings are congregated closely together the air is vitiated, not only by the absorption of oxygen and

* From "Physiology of Common Life," by G. H. Lewes.

† Fifty per cent. of oxygen to fifty of carbonic acid will kill a man although a candle would burn in it. In this case it is the excess of CO_2 that is so deadly.

the giving out of carbonic acid,* but also by certain vicious exhalations from the lungs and bodies of those present, these exhalations being worse from some—as from the drunken or dirty—than from others. It is the same with other animals: bad air, dirt, and damp produce disease; cleanliness and fresh air give health and long life.

We have said that the normal amount of carbonic acid in the atmosphere is 4 parts in 10,000. In occupied rooms it may soon rise to 7 or 8 parts in the 10,000 unless the room is well ventilated. In this condition the air in the room to a person entering it from the fresh air outside feels musty and disagreeable.

Where the carbonic acid is greater (as it too often gets if a large company be present, or the gas lighted), say from 10 parts to 20 parts in the 10,000, the room feels close or very close, as the case may be. This closeness is not caused by the mere presence of the extra amount of carbonic acid, but also by the organic matter and vapours † or products of respiration and transpiration mixed up with it.

Pure carbonic acid to a much larger amount may exist in the air without being offensive, Dr. John S. Billings says, even as much as 150 parts in the 10,000, as in establishments where sparkling mineral waters are bottled, or soda fountains are charged, or in vaults where champagne is bottled, in certain rooms in breweries, or in some celebrated baths and health resorts. These cases of experience with *pure* carbonic acid are exceptional, however.

In making tests as to the purity of the air in build-

* A simple proof that exhaled air contains a large amount of carbonic acid may be had by breathing out through a glass tube into a glass of lime water. The water will at once turn milky by precipitating chalk.

† An excess of vapour in the atmosphere is not agreeable, as is found when walking on a close, damp day. The exercise tends too readily to induce perspiration. In a crowded and ill-ventilated ball-room, after the air has got vitiated by carbonic acid gas and saturated with vapour, a feeling of enervation ensues, which is not favourable to the physical work involved.

ings, the reason why so much stress is placed by chemists upon the presence of an abnormal amount of carbonic acid is, that where an extra quantity of this CO_2 exists there is generally some other deleterious matters along with it, such as organic vapours and offensive suspended particles.

An occupied enclosure that may show good air in daylight may soon possess a vitiated atmosphere when darkness comes on if still occupied and gas lighted, unless sufficient provision exists for carrying off the extra amount of air vitiated by the gas.

According to the late Dr. Wm. Wallace, F.C.S., each person on an average consumes at each inspiration 25 cubic ins. of air and breathes 18 times a minute. This gives 15·6 cubic ft. of air consumed in each hour. The air breathed out or exhaled contains 5 per cent. of carbonic acid gas,* or $22\frac{1}{2}$ cubic ins. out of the 450 exhaled each minute. Now a person may breathe air containing $\frac{1}{2}$ per cent. of carbonic acid with impunity, at least *for a short time*, while a larger proportion is more or less dangerous. Taking $\frac{1}{2}$ per cent. as a basis of calculation, each person requires $2\frac{1}{2}$ cubic ft. of air per minute, or 150 cubic ft. per hour. If a sleeping apartment be taken as containing 1,000 cubic ft., and without means of changing the air, it would—at this rate of $\frac{1}{2}$ *per cent. standard of vitiation*—suffice for one person for $6\frac{3}{4}$ hours, or for two persons for only $3\frac{3}{8}$ hours.

Dr. Angus Smith says a man can only live for a few minutes in air containing merely 17·4 per cent. of oxygen and the carbonic acid up to 3·49; so that in this case of a close room with two persons in it they would have fainted and perhaps be dead in, about, or before 18 hours (see page 26), owing to having consumed about 36 cubic ft. out of the 210 ft. of oxygen

* Having not only reduced the proportion of oxygen from about 21 in the 100 to 16, but also raised the carbonic acid from ·04 per cent. to nearly 5 per cent., so that exhaled air, as we shall see further on, is a deadly poison, whose evil effects in enclosures require to be kept down by carrying it off and by large dilution. See pages 12 and 13.

in the room at first. Their death would be accelerated by re-breathing the vicious air exhaled from the lungs and the vapour from their bodies. This breathing of air with $\frac{1}{2}$ per cent. (or 50 parts in 10,000) of carbonic acid is like beginning to take slow poison. The first dose does not kill; it is only one step, but it is a step in the wrong direction.

A person coming suddenly into an enclosure where the oxygen was reduced to below 18 per cent.* would succumb more quickly than one who was in the enclosure while the oxygen was higher.

A tallow candle may go out, Dr. Angus Smith said, when the oxygen is reduced to about 18·5 per cent.; but he afterwards found (as per page 26) that if the tallow keeps melted the candle keeps in longer, and until the oxygen is less than this—viz., about 15·2 per cent.

If two or three candles are lighted in an air-tight chamber, and fixed at different heights, the highest one, A (Fig. 4), will go out first, as the heat from combustion causes the carbonic acid gas to rise upwards to the top of the enclosure, and take the place of the consumed oxygen.

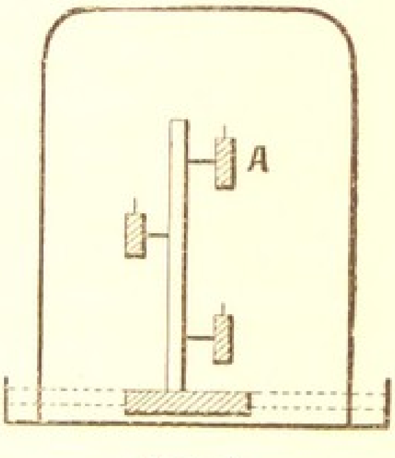


Fig. 4.

In like manner the air in the galleries of badly-ventilated theatres, churches, and halls will be often very much vitiated and disagreeable, while that in the pit or nearer the ground is comparatively pure. The air of a church, which may be pretty good in the forenoon, if badly ventilated, will—by the general diffusion of the air in the interval—feel very bad and stuffy in the afternoon. Some people absent themselves in the afternoon for this reason.

Coal gas is a great spoiler of the air, but its bad

* But to produce the deleterious effect it is implied that the carbonic acid has been raised to about 3 per cent. See page 19.

smell generally acts as a warning when it is escaping. Its smell is felt when there is one part of it in 1,000 of air, and becomes very offensive when it is one in 750 or one in 500. If the gas has been escaping so much as to amount to one part in 11 of the atmosphere, then it explodes on the introduction of a light. Where there is an escape of gas, lights should be kept away and the escape stopped or the gas turned off, and the place well ventilated before a light is admitted.

Each gas jet will vitiate and heat up the air as much as three or four persons,* hence the ventilation provision that may be sufficient before the gas is lighted may be far too little after that. This want of ventilation and the consequent presence of bad air in rooms has a very bad effect upon the health of the inmates, and in many cases when illness sets in tends to retard the recovery of the patient, and in some instances may turn the balance at a critical moment the wrong way and be the cause of death. As there is a great difference in the amount of organic matter in the breath when sweet and when disagreeable, the attendance of a nurse with a bad breath might be a great—though unnoticed—cause of offence to a patient, especially in a badly-ventilated room.

A high standard of purity in the air we breathe should therefore be aimed at, at all times, and especially in the sick and convalescent rooms. It is the exception to find bedrooms with provision for carrying off the vitiated air at the ceiling. This is very short-sighted policy, seeing people spend so much of their time in them. Bad ventilation has a deleterious effect upon the electrical condition of the air, pure air being positively electric, while impure air is negatively electric.

A person to be kept in full health needs 2,000 cubic ft. of air per hour, some doctors say 3,000 ft. per hour. Now, as the cubic capacity of many bedrooms is only

* In the burning of gas a large quantity of sulphur is given off in the shape of sulphurous acid, which changes into sulphuric acid, and besides being hurtful to health is damaging to furniture, books, &c.

about 1,500 cubic ft., or even less, how is 16,000 cubic ft. of fresh air to be supplied for an eight hours' occupancy if there be no provision for ventilation?

The atmosphere of many bedrooms in the morning before their windows are opened to one entering off the fresh air is like that of an ashpit!

Reference has been made to the abnormal presence of carbonic acid gas as a test for the quality of the air in apartments. Another test, especially for the organic matter and vapours exhaled from the lungs and given off from the skin, is that introduced by Dr. Angus Smith, of Manchester, for finding the quantity of albuminoid ammonia which the air contains. Other tests are referred to in special chapter. With the air exhaled from the lungs in breathing there is also sent out a considerable amount of watery vapour, the presence of which is easily proved by breathing upon cold glass, when the vapour condenses into water.* In a well-filled, badly-ventilated hall or church, this vapour may often be seen running down the windows and walls when condensed. In twenty-four hours a man will exhale about 11 ozs. or 19 cubic ins. of water, so that an audience of 1,000 persons in a church or hall will give off in two hours from the lungs and skin about 8 gals. of water, the amount of carbonic acid gas exhaled being about 1,500 cubic ft.,† with which gas is included organic debris from the lungs of the healthy and the unhealthy. In the latter case germs of disease being probably often thrown off into the atmosphere of

* Vapour condenses only on some solid body, large or small, hence in the atmosphere vapour condenses on the dust particles floating in the air. Mr. John Aitken, of Darroch, invented an instrument for enabling an observer to calculate the number of dust particles in a given quantity of air. He read a paper on the subject to the Royal Society of Edinburgh. The process was explained in the *Glasgow Herald* for Feb. 15th, 1890. In actual experiment, Mr. Aitken found the dust particles amount to 3,300 in a cubic inch of clear air in a mountainous district, while in the air of a town they ranged from 160,000 to 2,300,000 in a cubic inch. Fancy inhaling 50,000,000 of dust particles at one inspiration! The value of the nose as a filter will be better appreciated when we know what it saves us from.

† In the carbonic acid exhaled there will be about as much carbon as in ½cwt. of coals.

the place, so that in crowded and unventilated halls, churches, schools, &c., it is well to breathe through the nose, in order to utilise it as a filter. When people meet together to worship God they should consider it dishonouring to Him to do so in an impure atmosphere. When they send their children to school they should show their love for them by insisting that the atmosphere of the schoolroom should be pure and comfortable, and men should have sufficient chivalry, for the sake of their wives and children, as well as common sense for their own protection and well-being, to see that means exist for keeping the air of their houses sweet and healthy. It is only too notorious that in the past all this has been too much neglected, but the demands for improved sanitation now being made augur better for the future.

CHAPTER II.

Opinions and Experiments on Ventilation.

It will be both useful and interesting to quote here the opinions of some of the eminent men who lived in the second quarter of this century, as contained in the "Report from the Select Committee on the Ventilation of the Houses of Parliament," dated A.D. 1835.

George Birkbeck, M.D., in his evidence says, in reference to ventilating a room:—"It must first be known how many persons are to occupy the room. Then what impression they will make upon the atmosphere within it. Then what apertures for admitting fresh air, and what number for allowing exit of foul air, and their area." He would admit fresh air from the external atmosphere, and thinks the atmosphere of a large assembly should be about 60°, but they should not be pestered with streams of air coming in at windows and doors, &c. He proposes passing the air into a room from a large chamber below, where it could be tempered. He objects to cold draughts on the people. "54. What is the speed of a pleasant summer breeze in the open air?—The motion of air moving at the rate of 2 or 3 miles per hour is just perceptible; we call air moving at the rate of 4 miles or 5 miles an hour a breeze; at 10 or 15 a pleasant brisk gale, beyond that it becomes a wind; and when moving at the rate of 50, 60, and 80 miles an hour it becomes a storm, tempest, and hurricane." *

* These designations given by Dr. Birkbeck do not quite accord with what Dr. John W. Tripe said in his address at the meeting of

From $4\frac{1}{2}$ to 6 ft. a second ordinary speed of current up a chimney, or about 3 or 4 miles an hour.

In good ventilation the change of air should take place without being perceptible.

the Sanitary Institute at Worcester in 1889, on "Winds, with some Remarks on their Sanitary Effects." *Inter alia* Dr. Tripe said :—

"The relations between wind velocities and pressure were until lately in a chaotic state of confusion, but, thanks to Mr. Dines and his late father, we now have some definite information on the subject. They erected a whirling machine, driven at various rates by a steam engine. The machine consisted of a long bar, supported by stays, carrying plates of different shapes and sizes, and, for the purpose of comparison, a uniform velocity of 20·86 miles per hour was finally adopted. The result showed that with a velocity of 21 miles per hour the pressure exerted upon a plane area of a fairly compact form is about $1\frac{1}{2}$ lbs. per square foot. As the wind pressure up to a velocity of 70 miles per hour has been found to vary in these experiments as the square of the velocity, the pressure with any intermediate velocity can be readily calculated. If we take the pressure of 1 lb. per square foot as a basis, it is found that a velocity of 17 miles per hour gives this pressure. This varies, however, to a certain but small extent, according to the size and shape of the plate.

"As Beaufort's scale is used not only by seamen, but by most meteorological observers, to express the velocity of the wind, I give the table adopted by the Meteorological Office, and used in the comparison of weather with storm signals, and by captains at sea :—

Force. Beaufort's Scale.			Approximate Velocity. Miles per hour.
0. Calm			0—5
1. Light air, or just sufficient to give steerage way			6—10
2. Light breeze	Or that in which a well-conditioned man-of-war, with all sail set, and clear full, would go in smooth water from	1—2 knots	11—15
3. Gentle		3—4 ,,	16—20
4. Moderate		5—6 ,,	21—25
5. Fresh	Or that in which she could just carry in chase, full and by	Royals, &c.	26—30
6. Strong		Single-reefed topsails and topgallant sails	31—36
7. Moderate gale		Double-reefed topsail jib, &c.	37—44
8. Fresh ,,		Triple-reefed topsails, &c.	45—52
9. Strong ,,		Close-reefed topsails and courses	53—60
10. Whole gale, or that with which she could scarcely bear close-reefed maintopsail and reefed foresails			61—69
11. Storm, or that which would reduce her to storm staysails			70—80
12. Hurricane, or that which no canvas could withstand			80 miles and upwards

Michael Faraday, F.R.S.,* says :—"Airs do not mix so suddenly as is generally supposed, although they inevitably mix if time be allowed." He considered it was not advisable to attempt to restore a vitiated atmosphere by the artificial introduction of oxygen, but rather to draw on the free atmospheric air. "I do not think," he says, "you could restore a vitiated atmosphere. You could restore the oxygen, but you could not take away the deleterious matter which has been communicated to it. The way to do that is *to carry it off bodily*." He prefers the air heated by hot-water pipes or steam. In a large company, where ventilation is deficient, discomfort is felt not merely from the inferior quality of the air but also from effluvia rising from so many persons. A man destroys about a gallon of air per minute, a cubic foot in 6 mins., or 240 ft. in 24 hours, but he should get ten or twenty times that for health.† Faraday also says that when the air is heated to a high degree by metallic or other surfaces, as by Perkins's stove, it requires the vapour of water to be communicated to it.

William Thomas Brande, F.R.S., says :—"In regard to ventilation, the great point is to carry off the foul air, which, I think, is most efficiently done from or near the ceiling, *and to do it in such a way as to*

"There are, of course, serious difficulties, especially in steamships, in noting according to this scale, but observers on land can soon judge as to what place in these scales a wind at a given time should be assigned, but as wind comes in gusts, observations made only from a short period can scarcely be so useful as a continuous record such as that given by Robinson's or other anemometer. Mr. Laughton, however, objects to the velocity fixed for a calm as being too high, and says that anything like 5 miles per hour during a calm would be caused by occasional puffs of wind. Also that the highest is too low, as in tropical cyclones the velocity frequently exceeds 90 or 100 miles, and Mr. Thorn, judging from the damage done in these storms, is of opinion that the velocity often exceeds 120 miles per hour. This estimate agrees fairly well with Greely's statements." Dr. Tripe's paper is published in the "Transactions of the Sanitary Institute," Vol. X.

* Born in 1791, died 1867 (he died poor but honoured).

† This is very much less than medical men now call for, as per page 12, &c.

guard against all possibility of descending currents of cold air."*

Each person may be said to spoil about 18 cubic ins. of air at each respiration, or 21,600 cubic ins. per hour, or about 3,600 cubic ft. in 24 hours.

David Boswell Reid, M.D., F.R.S.E., † prefers fresh air taken in from some height above the ground, where the ground is damp, or where the ground air is otherwise damaged. He would like means taken to cool the incoming air in summer as well as to heat it in winter. With furnaces you can carry the air downwards as well as upwards. Cold air in motion would be called a

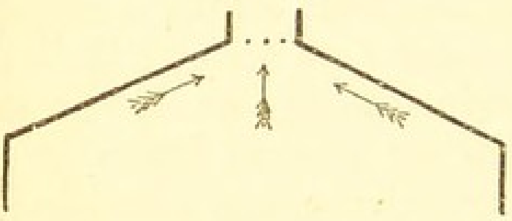


Fig. 5.

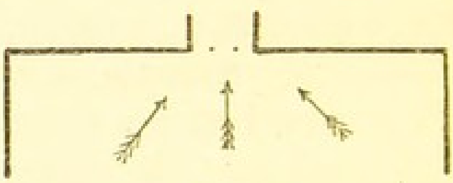


Fig. 6.

draught, while warm air at the same speed would not be objected to.

He says warm air should be *distributed* low down, as one *local* current of hot air might all rise to the ceiling and leave the lower part of the room quite cold.

He prefers a ceiling rising slightly towards the centre, as per Fig. 5, to a flat one, as per Fig. 6.

Dr. Reid prefers the vitiated air to be carried off as it ascends—not to make it descend—considering the former to be the more natural plan.

In his "Special Physiology," Professor J. G. McKendrick, F.R.S., states that Joseph Black discovered carbonic acid gas, or "fixed air," as it was termed in 1754, and three years after found out that it was injurious to animal life, and also that it was produced in the process of respiration. After Priestley had dis-

* This is an idea which Tredgold rather neglected, but which the writer has been carrying out in practice of late years.

† Born in 1805, died in 1863. He went to Washington to undertake the ventilation of military hospitals throughout the States.

covered oxygen in 1774, Lavoisier showed that while the air lost oxygen largely in breathing, it gained carbonic acid to about the amount of the oxygen lost. The air expired also contains a little more nitrogen than that inspired. The amount of aqueous vapour in the air is great when the temperature is high, and small when it is low.

In an occupied room at a high temperature, with the people in it exhaling air containing one-fifth less oxygen and 100 times more carbonic acid than the normal atmosphere, and said exhaled air being also charged with aqueous vapour, and mayhap containing traces of ammonia and carburetted hydrogen, &c.—it is no wonder that the room soon gets disagreeable owing to bad ventilation.

During sleep about 25 per cent. less CO_2 is given off than when up.

It was stated on page 10, that a man might live only for a few minutes in air containing only 17·4 per cent. of oxygen and the carbonic acid gas up to 3·49 per cent., but Professor McKendrick says that if the poisonous carbonic acid gas could be carried off, and its place taken by an inert gas like nitrogen, then when the proportion of oxygen did not fall below 15 per cent., respiration would be normal; from 15 to 7 per cent., respiration would become deep and prolonged; from 7 to 4½ per cent., respiration would be carried on with great difficulty; and below this amount there would be risk of immediate asphyxia. In making this experiment there would be difficulty in preventing the accumulation of the carbonic acid gas, so that inhaling oxygen in this manner is not a likely thing to happen in actual life, and could hardly occur except in some place where gases were manufactured.

Professor McKendrick says further :—"The object of ventilation is not only to introduce fresh oxygen, but to dilute the carbonic acid and other deleterious matters mentioned to their normal amount. Pure air contains of CO_2 about 4 vols. in 10,000. It has been ascertained that air containing 1 vol. per 1,000 (or 10 parts in

10,000) of CO_2 has a sensible odour,* and may be regarded as impure, and it has been established as a principle in ventilation that the amount of CO_2 present ought never to pass 7 per 10,000.

"To dilute CO_2 from ·07 per cent. to ·04 per cent. † would require about 2,000 cubic ft. of pure air per head per hour. A larger quantity is necessary in the wards of hospitals. The practical problem in ventilation is to supply this amount of air, by such arrangements as will secure freedom from colds and draughts.

"Such gases as hydrochloric acid gas, sulphurous acid, nitric acid gas, ammonia, nitrous acid, and chlorine are practically irrespirable, because they produce spasmodic closure of the glottis, and their irritant action has nothing to do with respiratory exchanges. Other gases reach the lungs, and there either interfere with the normal gaseous exchanges, or, entering the blood, combine with one or other of its constituents, or have a poisonous action on the tissues. Under this category we may include carbonic acid, carbonic oxide, sulphuretted hydrogen, phosphuretted hydrogen, cyanogen, and arseniuretted hydrogen. Carbonic oxide, or oxide of carbon, formed during the imperfect combustion of carbon, is a poisonous gas affecting breathing, even when existing in the atmosphere to the small amount of ·001 per cent.,‡ and rapidly destroying life when present to the extent of ·1 per cent. The blue flame that rises from lighted coals or wood is oxide of carbon. It is produced by burning coke, and by badly going stoves."

Dr. Angus Smith's "Air and Rain," published by Longmans, Green & Co., London, is a book that should be read by all who take an interest in the condition of the atmosphere and its relation to health.

* So that, as Dr. Angus Smith says, our senses, such as that of smell, are quite right when condemning the air of crowded rooms as tainted.

† That is from 7 parts in the 10,000 down to 4 parts in the 10,000.

‡ ·001 per cent. = 1 part in 100,000, and ·1 per cent. = 1 part in 1,000.

"Children think a vessel full of air is empty." How many thousands or hundreds of thousands of years did it take to teach men that a vessel with nothing but air in it was really full of something and that something as much real matter as the sand they trod upon?

Dr. Smith says:—We live in air, which flows continually into our blood, hence the state of the air in which we live is bound to have a great effect upon us, which effect is produced by the character of the air, and also by its temperature. The average condition of the air of a place is its climate. Site has an important effect on health. Persons living in a swampy district, and suffering from ague, may be cured by good drainage. Cold and so-called "bracing" weather is death to many. Far more people are killed by cold than by heat.

It was long a popular notion that the colder the water one washed with in winter the better. Dr. B. W. Richardson helped to knock this superstition on the head, and pointed out its cruelty in the case of children. He advocates the mixing of some hot water with the cold, so as to take the chill off. Washing with water at 60° is much more sensible for the majority of people, than using it for that purpose at 40° or less. "The colder the healthier" was only equalled in its absurdity by "the dirtier the saintlier," or "scentlier," as Dr. J. B. Russell suggests.*

Dr. Smith points out the great danger from allowing unwholesome or putrid organic matter to get into the system. In the case of infectious germs the amount in many cases is not, *per se*, what causes evil, but the enormous power possessed of self-multiplication under favourable conditions. So that half-a-dozen may soon develop or increase into millions.

In practice small differences in the normal amount of the oxygen or the carbonic acid may indicate important contamination. It would not be pleasant to

* Another expression was "The clartier the cosier," but all are alike unhygienic, and opposed to the axiom that "Cleanliness is indeed next to godliness."

live in such an atmosphere as indicated by 20·775. 20·6 is the proportion of oxygen marking the beginning of very bad air.

The air of every house is liable to show a diminished amount of oxygen from the normal amount outside, and especially at night when the gas is lighted. A certain amount of diminution from this cause—if not too much —is not so injurious as the presence of a small amount of vitiated air from the house drains or sewers, or other polluted source.

In the following close places Dr. Smith found the carbonic acid very high:—Theatre, ·2734; study at table, with four persons in the room and gas lights and large fire, ·1177; at the ceiling, ·1561. In a school-room, ·0970. In a midden, ·0805. So that the midden, so far as the carbonic acid gas was concerned, was the purest of the lot! * An increase in the amount of carbonic acid gas is much more hurtful if it is accompanied with gases of putrefaction, so the midden gas if so accompanied, as it likely would be, might yet be the most dangerous of the lot to inhale.

When people speak of good ventilation in dwelling-houses, they mean, without knowing it, air with less than ·07 of carbonic acid. In the air of some well-ventilated hospital wards, in or prior to 1872, Dr. Smith found the mean air as follows:—

Day.		Midnight.		Morning.	
Carbonic acid.	Oxygen.	Carbonic acid.	Oxygen.	Carbonic acid.	Oxygen.
Per cent. ·0463	Per cent. 20·92	Per cent. ·0677	Per cent. 20·886	Per cent. ·0694	Per cent. 20·884

On visiting an unventilated law court on one occasion

* The midden had only 8 parts of CO_2 in the 10,000, while the theatre had 27 parts, or more than three times as much.

Regarding this Mr. John Foggie, F.C.S., of University College, Dundee, writes me that he capped this by finding the state of the air the air on entering felt extremely warm and unpleasant, and even after some minutes it was not to be voluntarily borne. The air about 8 ft. from the door a few feet above the floor showed oxygen 20·6500, and at the lantern at the roof about 4.30 P.M., 20·4900. There were a number of people in the court, so that the air was extremely vitiated. Smoking concerts and assemblies are often rendered very unpleasant after a time owing to want of proper provision for ventilation.

Wehrle says:—"It is well known that tallow goes out where oil burns well, and that the common mine lamp goes out when the Argand lamp with the same oil burns clear." Apart from explosion, therefore, the tallow candle would be the safest for testing the air of a well, &c., before going into it or while working in it.

In December last the writer made some experiments by burning candles in a close chamber to see how long they would burn. A pipe, Fig. 7, 6 ins. diameter, close at top and bottom, and 17½ ins. long, and with a small air-tight glass window, had a short piece of tallow candle lighted in it. The candle went out in 1 min. 35 secs. In another trial with fresh air the candle went out in 1¼ mins. The air in the pipe was then renewed and a composite candle tried, which burned 2½ mins. With one ⅜-in. diameter hole at top and the same at bottom the composite candle burnt for 3½ mins. Towards the end the flame would go down as if going out, then it would revive brightly, then fall again, and revive until it finally went out. With two ⅜-in. diameter holes at top and two at bottom the composite candle burnt on but somewhat dull. With only

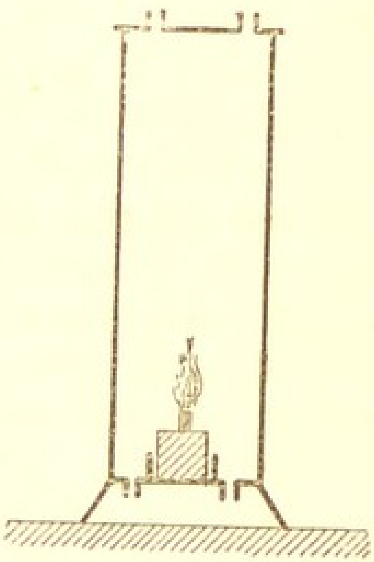


Fig. 7.

in Her Majesty's Theatre at Dundee to be, at half-time, in the gallery, 32 vols. per 10,000 and in the pit over 50 vols. in 10,000. The theatre was crowded. He refers to this as an instance of the exhaled CO_2 not rising; but low roof of pit and currents of air had to do with this.

one hole at top open and two at bottom the composite candle went out in $7\frac{1}{2}$ mins. When a tallow candle tried with one $\frac{3}{8}$-in. hole open at top and two in bottom it went out in from $2\frac{1}{4}$ to 3 mins.

In an experiment with fresh air,* and the vessel or pipe all tight and two composite candles burning, one 4 ins. high and the other 1 in. high, the higher one in one case went out at 55 secs. and the low one at 95 secs. With fresh air and tried again the top one went out at 68 secs. and the low one at 80 secs.

In order to personally test the air in confined places, Dr. Smith made a lead chamber, as per Fig. 8, size about 6 ft. by 4 ft. and 8 ft. high, the cubic capacity being about 190 cubic ft. It had large glass windows, so that a person left in it could easily break out if not let out. The door was made tight by an india-rubber tube being squeezed. With a table and chair and one person in the enclosure, the air capacity was reduced to about 170 cubic ft. His first experiment was by sitting down in the chamber for an hour and 40 mins. This gave 1 per cent. of carbonic acid. There was no certain difference felt for the first 25 mins. The temperature was 45° Fahr., and the air became moist. After one hour the unpleasant smell of organic matter was felt, *as is often perceived in a crowded school.* After one hour the air also felt soft from the moisture in it. This moisture in the air has a tendency to leave the skin and its action unchanged. It allows little evaporation owing to the air being moist already. The disagreeable effects of this are felt on a rainy day, especially if it is also close and warm, when walking. Dry air, again, stimulates the skin because it absorbs moisture. We all know the exhilarating effect of a nice frosty day when the sun is shining. At the end of 100 mins. the air had an unpleasant flavour or smell, and Dr. Smith came out. Three persons then went in at once, and pronounced the air to be very bad. When

* The vitiated air was put out and replaced by fresh for each experiment.

Dr. Smith was in and sitting quietly he did not feel the badness of the air so much, but when moving or walking or causing the air to move he felt the unpleasant

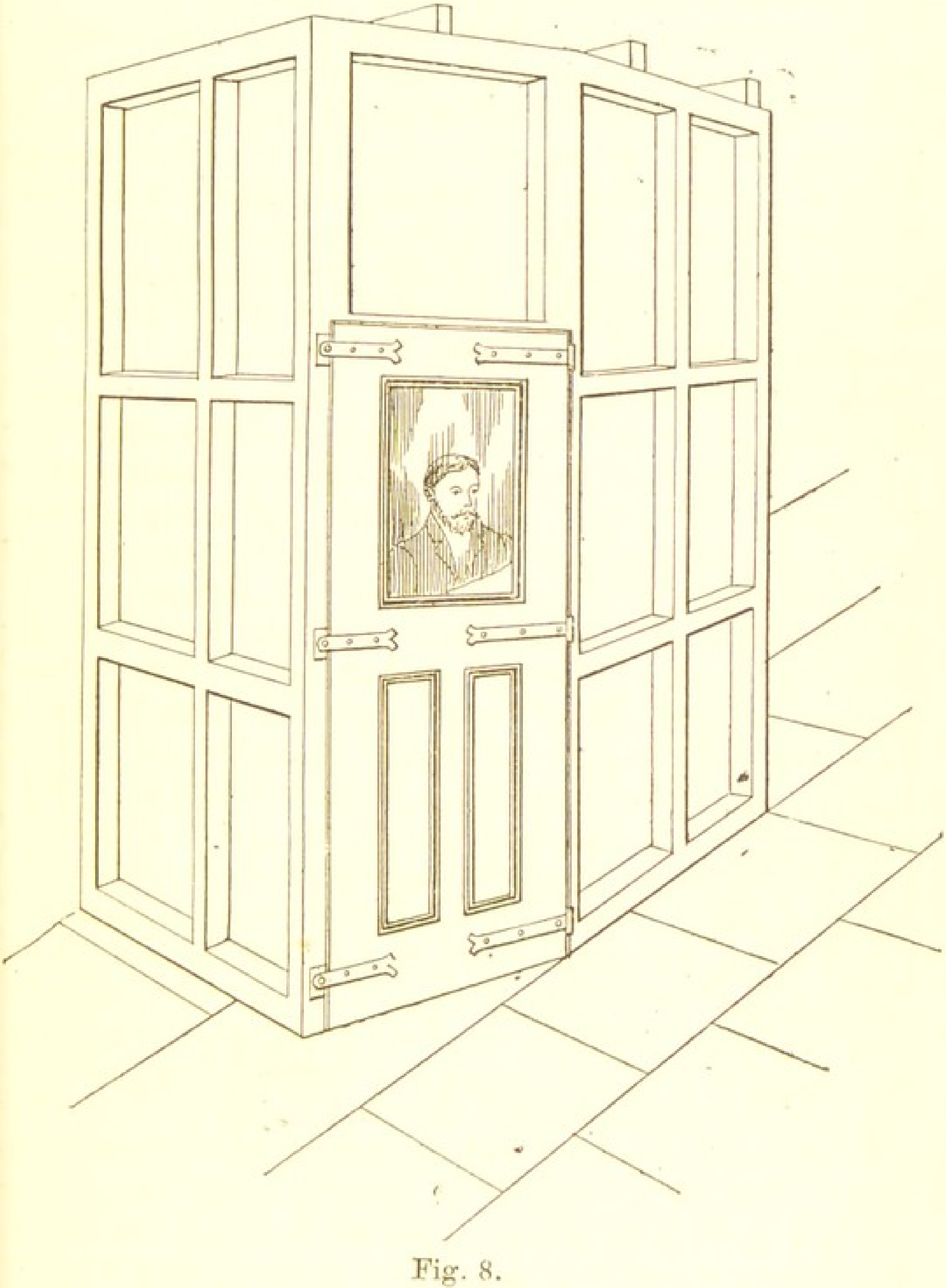


Fig. 8.

quality of the air. In another stay of 160 mins. the air felt very close, oxygen reduced to 19·61 per cent. In an experiment with four miner's candles in the chamber, and no person inside, the candles went out in 5 hours and 10 mins., the carbonic acid being 2·28 and the oxygen 18·80.*

In another experiment with eight candles, one paraffin lamp, and one spirit lamp, all the candles were out in 93 mins. ; the highest first, the paraffin lamp in 98 mins., when the carbonic acid was 2·32 and the oxygen 18·48. The spirit lamp stayed in for 150 mins., when the carbonic acid was 2·45 and the oxygen 18·40. Afterwards gas was lighted, and burned well for a time and then went out Upon entering after the gas went out candles were extinguished as quickly as if dipped in water. Nevertheless Mr. Smith and those with him breathed, but felt very uncomfortable. Upon standing up upon a chair a feeling of faintness ensued. When the gas went out the oxygen was reduced to 17·40 per cent.

Dr. Smith drew the conclusion from these experiments that the senses are no proper or safe guide as to the *degree* of danger. People may get alarmed as much when the carbonic acid is 0·1 per cent. as when it may be about 4 per cent., or forty times as much. After breathing the vitiated air above described for a short time, a great feeling of relief was experienced after coming out of it into the fresh air. Although a man can continue to breathe where a candle, and especially a tallow one, will not burn, the sooner he gets out of that place the safer for him. Some persons, again, will succumb in bad air much sooner than others. A young, healthy lady went into the chamber after the candles had been burning for a time and were threatening to go out, the oxygen

* Although in the chamber of 170 cubic ft. capacity the candles went out as above when the oxygen was reduced to 18·80 per cent., yet upon making some experiments by burning candles in a small tin vessel, 2 ft. high by 9 ins. square, he found the common dip tallow candle to burn much longer, viz., till the oxygen was reduced from 15·2 to 16·2 per cent. In this latter case the tallow remained melted below the burning wick much longer than in the lead chamber experiments, probably because the small 2-ft. high vessel was heated easily by the candle in it. So that the exact point of extinction of a candle will vary with circumstances.

being barely 19 per cent. and the carbonic acid 2·1. There had not been any person in the chamber, so that there was no organic matter in its atmosphere. She stood five minutes perfectly well, and making light of the matter, but she suddenly became white and could not come out without help.

In another experiment with the oxygen 20·19 and carbonic acid to the extent of 3.84 driven into the pure air, two gentlemen got headaches at once, and could only stay in the chamber about seven minutes, while Dr. Smith himself managed to stop in for twenty minutes, but feeling very uneasy. His inspirations were quickened to 26 a minute, as against 20 in his normal condition.

After all these experiments we come back to this, that badly ventilated rooms containing less than 20·7 per cent. of oxygen and ·07 per cent. or more of carbonic acid are very unwholesome, this diminution of the normal amount of the oxygen and increase of the carbonic acid being an indication of the presence of other deleterious matters, organic or otherwise.

In regard to schools, Professor Thomas Carnelley, F.C.S., says the carbonic acid should not exceed 13 vols. per 10,000. He has found it as high as 37·8 in some Scottish schools,* and 35·4 in Parisian ones; while in German schools the carbonic acid has been as high as 57·8 vols. per 10,000—a most disgusting state of matters for both teachers and scholars.

* In one school the head teacher told me that some of the children turned sick at times with the bad air. By "should not exceed 13 vols. per 10,000" is likely meant that this should be the maximum at closing. Less than 13 vols. per 10,000 should be aimed at, however.

CHAPTER III.

SMELL AS A TEST OF IMPURITY.

WHILE Dr. Angus Smith lays considerable stress upon the value of the sense of smell as a safeguard or warning, Dr. Carnelley says the smell of a room is a very unsafe guide as to the state of the ventilation, as said smell depends so much on the temperature and on the hygrometric state of the air.* The air in a room at a comparatively high temperature may smell very much worse than that in one at a lower temperature, although the air in the first case may be purer than that in the second. He does not think that any system of ventilation will keep the carbonic acid down much below 12 vols. per 10,000 in the present overcrowded state of the schools. Even the air of a mechanically ventilated school is not usually free from a certain amount of smell, though frequently so; nor can we expect it to be so with the amount of carbonic acid averaging nearly 12 vols. per 10,000. But care has to be taken to distinguish between a warm feeling on entering a room and a really close stuffy smell, for frequently the one is mistaken for the other.

"A mechanically ventilated school, when the fan is stopped, is worse as regards CO_2, and feels closer than an ordinary school—though it is never so bad as regards micro-organisms, even when the fans have been stopped for a long time." See chapter on Micro-organisms.

In some experiments made by Dr. Smith as to the rise of *temperature*, in the before-mentioned leaden chamber, caused by the presence of a man, and in

* See page 26 *re* Dr. Smith as to the *degree* of danger, and see p. 202.

another instance by a paraffin light burning, he found that in fifteen minutes the air in the middle of the chamber was raised 7° Fahr. by the presence of a man, and 9·5° in one hour, and when the temperature at starting was 44°, in two hours it rose to 54·8° Fahr. With a paraffin lamp and the temperature at start 42·7° Fahr., in fifteen minutes it rose to 44°, in one hour to 46·3°, and in two hours to 47.3°. In these two cases there was no ventilation or change of air in the chamber. The man therefore gave off much more heat than the paraffin lamp. A man gave about double the amount of carbonic acid a sperm or paraffin candle did. Thus a man in an hour produced ·6 of carbonic acid to 100 ft. of air, a candle ·31.

Extra heat relaxes the exertions of both body and mind, especially when the air is saturated with moisture.* When the temperature rises, and organic matter is present, it becomes more offensive with the extra heat. Places that may not feel offensive in frosty weather soon do so after a thaw has set in and the temperature rises if matter to cause offence exists. Putrefaction is facilitated greatly when the thermometer rises to 55° Fahr.

Dr. Smith says :—" It is not right to demand as much air for ventilation on a cold day as on a warm ; it is not right to break the windows of patients in winter, and to tell them that fresh air is better than heat.† The chemical action, and with it the feelings, demand warmth first above all things. It is the very first demand, as no function can go on without it. You may live hours, days, or years in badly ventilated places with more or less discomfort and danger ; ‡ but a draught of cold air may kill like a sword almost instantly. In the railway carriage as well as in the house the great instinct

* At 50° Fahr.—the temperate range—the body, if in motion, may feel warm enough ; but seated, a higher heat, such as 60°, may be more acceptable. Below 55° it may be difficult to keep up the animal heat without exercise or extra clothing.

† People should air their rooms well, however, at all times when not occupied.

‡ Like the dull-burning candle on page 23.

of man is first to be warm enough, and he is quite right."

Had each railway carriage compartment one or more fixed exhaust ventilators *on the roof*, as it ought to have, there would be less necessity of opening windows, to the great danger and discomfort of many passengers. The way in which the majority of the smoking compartments of railway carriages are *not* ventilated is most disgraceful. See special chapter on Railway Carriage Ventilation farther on.

CHAPTER IV.

GASES *versus* GERMS.

DR. SMITH points out that "gases and acids are not of themselves bodies in active chemical change, neither are they organised." They have not the terrible power of self-multiplication that disease-breeding living germs have. A certain amount of mere gas may be inhaled, or a small quantity of a dangerous acid tasted or swallowed, without harm resulting, but it is different with disease germs. Some of these, so small, perhaps, as to be invisible to the naked eye, settling on or coming in contact with a suitable portion of the human body, begin to multiply so quickly as soon to cause disease and then death unless means are taken to kill them. Pasteur's experiments have proved that putrefaction and fermentation are not caused by pure gases, but by organised bodies or germs in the air. Neither putrefaction nor fermentation are the result of merely chemical change, but both are the effect of living organisms.

About three hundred years ago Lord Bacon pointed out the danger from the bad air caused by emanations from human beings, and, *inter alia,* in crowded assemblies, yet although his remarks pointed to the necessity for pure air by ventilation and cleanliness, his voice for long was as that of one crying in the wilderness: men heeded not, and so disease and death ran riot.

Long before Bacon's time the origin of germs was a subject of speculation. Lucretius, in his work, "De Rerum Natura," relates how many living creatures spring from the earth, being formed by rain and the heat of the sun. In the absence of the microscope, and with chemistry still but an undeveloped germ, it was quite excusable to suppose that the low forms of life, to be seen in wayside pools, had originated from the mud. "Protoplasm" had not yet been invented, and it was never imagined that these supposed lowest forms of life were, in fact, comparatively high in the scale. "Spontaneous generation," or the idea that life could originate *de novo* out of dead matter was looked upon both by Greek philosophers and mediæval naturalists as a matter of course. They thought evidence of its truth was patent all around them.

This idea received a shock, however, at the hands of Francesco Redi, a Florentine physician who lived about two centuries ago. He demonstrated that maggots in meat were produced by flesh-flies depositing their eggs upon the meat. Following upon this he propounded the aphorism, "Omne vivum ex vivo" (all life proceeds from life). The philosophers then often got puzzled over the problem whether the egg preceded the animal or the animal the egg? Some time after Redi, a Dutchman named Leuwenhœck, about the beginning of last century, invented a sort of microscope which revealed life as teeming in fields before unknown. Hereupon Needham revived the problem anew, and as, after boiling infusions to kill the living animalculæ in them and sealing up the vessels, he found the infusions inside in a short time teeming with life, he concluded he had proof of life arising *de novo* from dead matter. Upon repeating those experiments more carefully, viz., heating the infusions higher, and sealing the vessels while the boiling was going on, the Italian naturalist, Lazaro Spallanzani, found that the infusions remained inert. Needham's experiments were therefore condemned as being improperly carried out.

More recently the doctrine of spontaneous generation has been upheld by Dr. Bastian, but his experiments have been condemned by Professor Tyndall. It is pointed out that tinned meats are kept wholesome owing to being thoroughly boiled, and sealing them up before any new germs can get into them.

The question is not yet settled, however, for while Professor Tyndall's condemnation of Dr. Bastian's experiments are held by some to have given the spontaneous generation theory its *coup de grâce*, Professor Tyndall does not say so himself. In December, 1885, he wrote to the author :—"I believe now as firmly as I did in 1874 that we have in matter 'the promise and potency of all terrestrial life.' I believe in the nebular theory, and that the life which we now see upon the earth is the development of a power resident in matter before it shaped itself into worlds."

In a postscript the Professor says:—"Do not imagine that I profess to explain the mystery of life. It is insoluble by man."

In the article on "Biogenesis and Abiogenesis," in "Critiques and Addresses," by Professor Huxley, we read, on page 239 :—"So much for the history of the progress of Redi's great doctrine of Biogenesis, which appears to me, *with the limitations I have expressed,** to be victorious along the whole line at the present day."

Professor Romanes, in lately addressing the students of

* Some opponents of Abiogenesis, in quoting this paragraph, very discreetly omit the six words that have been italicised. Now, while this may be doing evil that good may come, it is not altogether honest. The "limitations" are somewhat important, and in Professor Huxley's words (page 238) are partly as follows :—"I must carefully guard myself against the supposition that I intend to suggest that no such thing as Abiogenesis ever has taken place in the past, or ever will take place in the future. With organic chemistry, molecular physics, and physiology yet in their infancy, and every day making prodigious strides, I think it would be the height of presumption for any man to say that the conditions under which matter assumes the properties we call 'vital' may not, some day, be artificially brought together. All I feel justified in affirming is, that I see no reason for believing that the feat has been performed yet." He further goes on to say:—"But expectation is permissible where belief is not, and if it were given to me to look beyond the abyss of geologically recorded time to the still more remote period when the earth was passing through physical and chemical conditions, which it can no more see again than a man can recall his infancy, I should expect to be a witness of the evolution of living protoplasm from not living matter. I should expect to see it appear under forms of great simplicity," &c.

the University of Edinburgh, remarked :—"The present attitude of the scientific world as regards spontaneous generation is not one of disbelief but of expectancy."* The two schools of thought in this connection will be found in latest editions of "Modern Science and Modern Thought," by Samuel Laing, M.P., and "Natural Law in the Spiritual World," by Professor Drummond.

In medical books germs are styled "bacteria," "bacilli," or "microbes." While some germs are hurtful others are innocuous. They are extremely small, requiring a good microscope to see them. Some are one ten-thousandth part of an inch long, others only half that. About four hundred millions of germs would find room, side by side, on a square inch. They are of various shapes; some round, others like rods, and some, styled "spirilla," like corkscrews. These different classes breed each amongst themselves. Different microbes produce different diseases. The yeast plant belongs to the round germs, and is about one three-thousandth of an inch in diameter. It is the cause of fermentation owing to its power of self-multiplication in a suitable medium. Dampness and want of ventilation are favourable to the growth of such fungi as the Merulius lacrymans, which produces dry rot in wood. To eschew dampness, dirt, and bad air, while valuing sunshine, and promoting cleanliness and good ventilation, are amongst the best preservatives against attacks fron disease-breeding germs.

* In the introduction to Lady Claud Hamilton's translation of "Louis Pasteur, his Life and Labours," Professor Tyndall expresses his disbelief in the permanence of the supposed distinction between the organic and the inorganic. And in his Text Book on "Physiology" (page 734) Professor J. G. M'Kendrick, M.D., F.R.S., says of Abiogenesis :—"It is unphilosophical to assert the impossibility of its occurrence now or in some past time. The intimate relations known to exist between physical, chemical, and vital phenomena, depending on the laws of the conservation and transmutation of energy, and the theory of evolutional development, indicate the probability of Abiogenesis, and it is one of the problems of biological science to ascertain the conditions in which this may occur."

See also the *New Review* for March, 1890, in which there is an interesting article on "The Origin of Animals," by Mr. Grant Allen.

CHAPTER V.

Bad Systems of Ventilation; or How Not to do it.

As we have said that ventilation consists in carrying off the vitiated air, while supplying fresh air, we will now consider some of the attempts that have been made to do so.

Firstly, as to carrying off the vitiated air in a satisfactory manner; this has not been found in practice so easy to accomplish as many have imagined. All sorts of mistakes have been made both in the general plans and in details. It will be both interesting and instructive, therefore, to refer to and describe some of these mistakes.

About fifty years ago Mr. Thomas Tredgold recommended the style of provision shown in Fig. 9, but it is not satisfactory. I have had often to condemn it, at schools especially, owing to complaints of inefficient ventilation, and the ceiling openings A and B, intended for outlets, often acting as inlets, and allowing down-draughts of cold air upon the persons sitting underneath. When the wooden or metal valves G and H above A and B were closed the ventilation was stopped.

The louvre-boarded wooden "ventilator" on the ridge might let air in on the one side, as at C, and out at the other, as at D, *up and down*, according to circumstances, all as indicated by the arrows.

A modification of Fig. 9 is shown in Fig. 10, in which, as in some churches, a long opening, L, is left in the centre of the ceiling, in the expectation that the vitiated air from the lungs of the hearers, and from

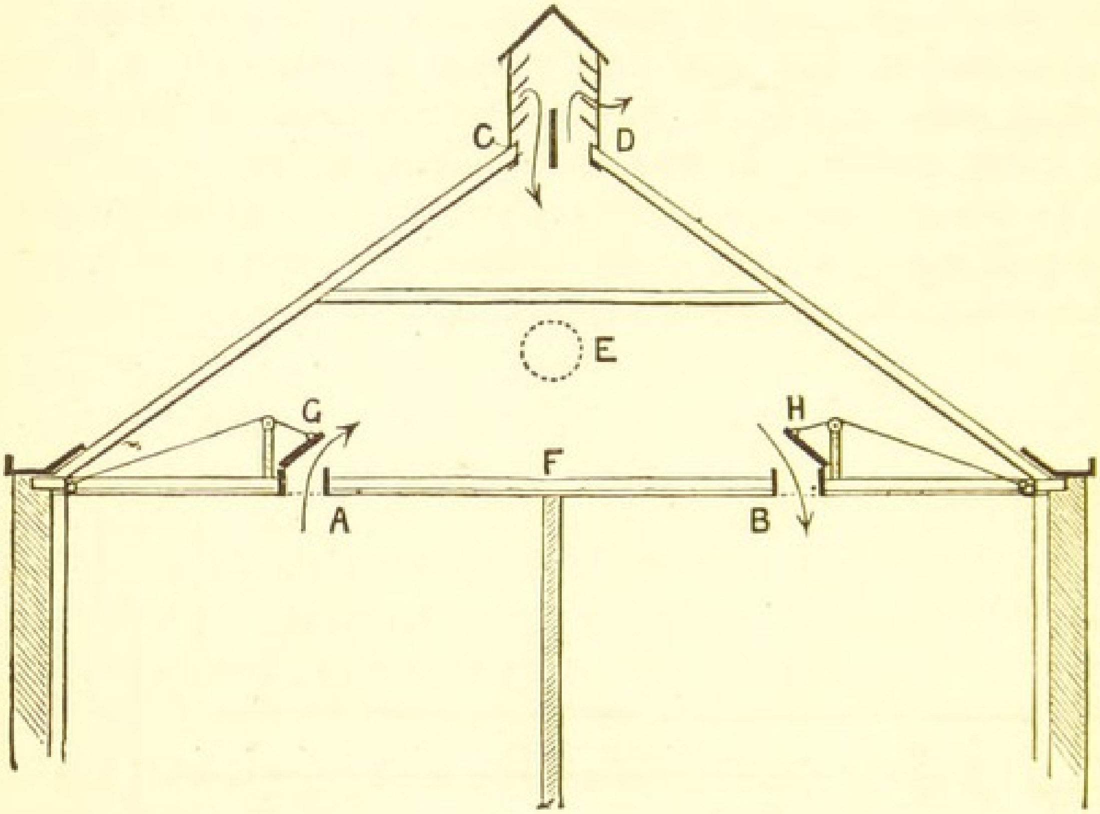


Fig. 9.

the gas when lighted, would all go up through the long opening L, and out at the louvre-boarded side-openings in

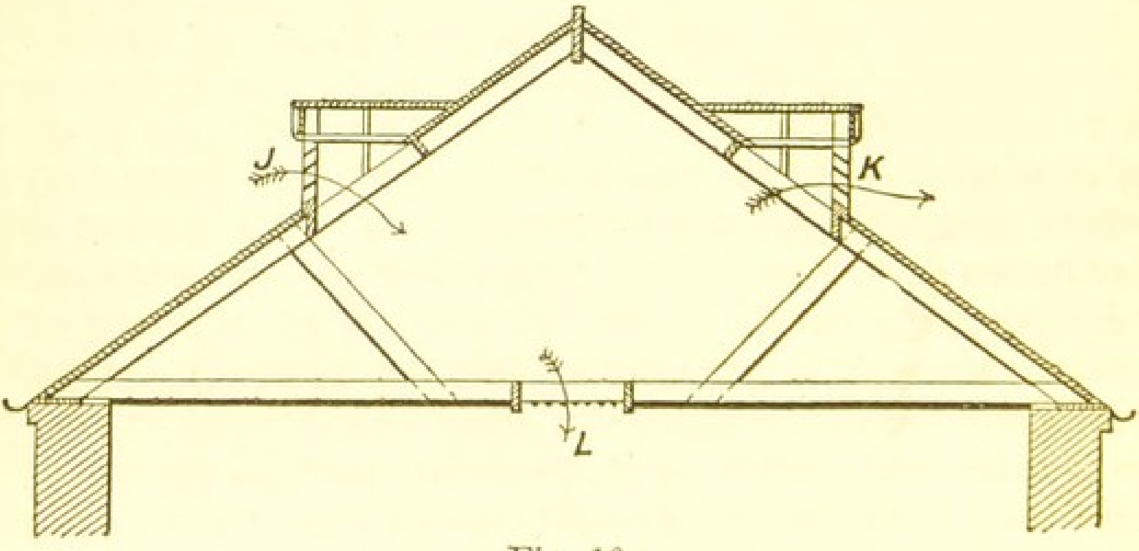


Fig. 10.

the roof J and K. It often happened, however, that the cold air came in at J in sufficient quantity to blow down through the opening L, and also out at K. On account of this the opening L was often pasted up as tightly as possible with brown paper, or otherwise closed, while the openings J and K were boarded up in the inside.

Instead of the openings J and K, Fig. 10, a large round hole, E, Fig. 9, was sometimes made in the stone or brick gables. It was also unsatisfactory.

In other cases the only provision for ventilation was by pulling down or opening the windows at the top. Some days during mild weather, and the direction of

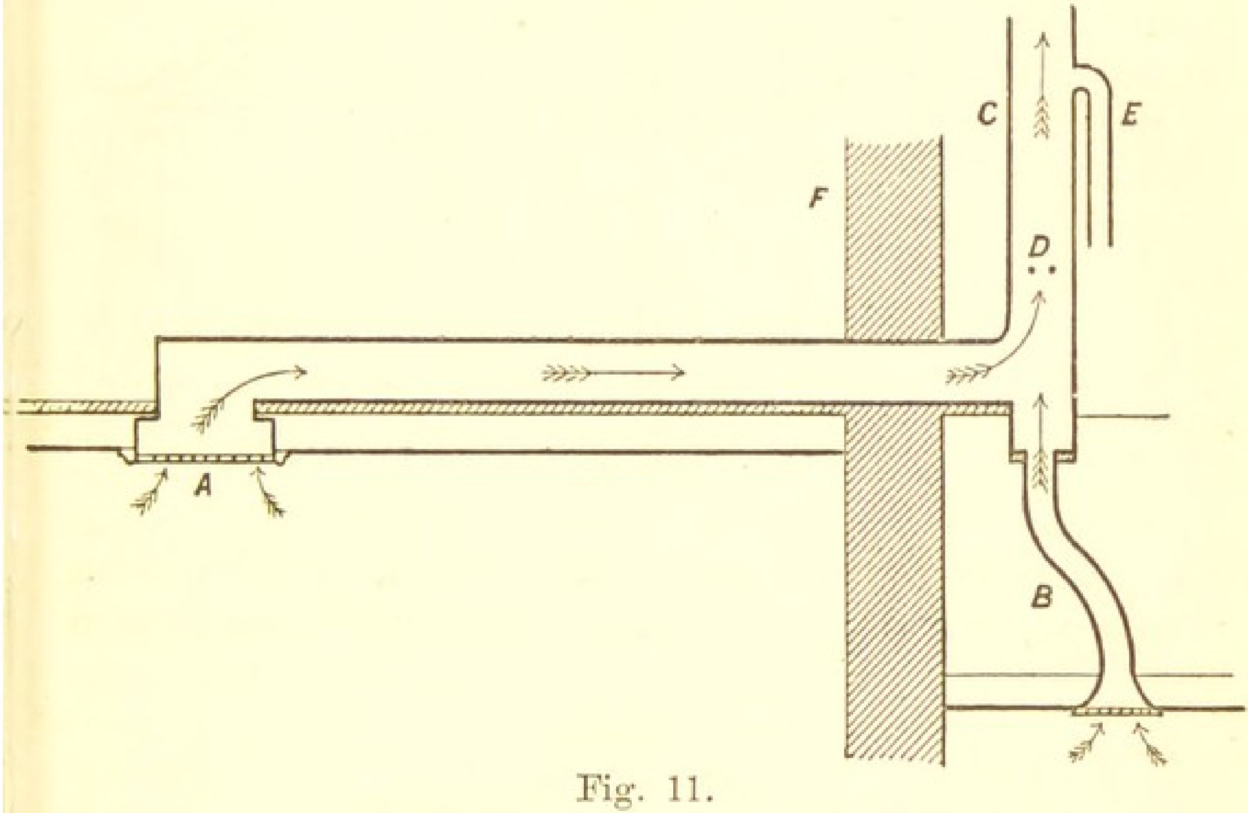


Fig. 11.

the wind favourable, this served pretty well. On other days again, the air came blowing in and down upon the children or persons sitting, in a very disagreeable and dangerous manner. This causes the windows to be often shut, and the ventilation thus entirely stopped. In some cases again, where the plan of the provision for outlet ventilation is good so far, it is often marred by the ventilating outlets or pipes being *far too small*, or some mistake is made in connecting the pipes.*

The sketch in Fig. 11 shows an example of how the

* In ninety-nine cases out of a hundred the outlet ventilating pipes of churches, halls, schools, and other places are too small.

ventilating outlet piping from off the ceiling A of the interior of a church or hall, say, may be spoiled by connecting the pipes improperly, as, *e.g.*, connecting or leading up a pipe B of considerable size, from the staircase into the bottom of the main upcast shaft C. Even with a circle of gas jets at D, which could be lighted in calm, warm weather, to start or increase the up-current in the pipe C,* instead of the air coming from A, as wished, it may come from B, which does no good. The pipe B should therefore be disconnected from the bottom of the shaft C, and if connected to C at all, let it be joined up at E with a much smaller pipe. The effect of closing up the inlet at the bottom of the shaft C would of course be to cause the air to be drawn much better from the ceiling opening A, and so carry out as really intended and necessary the ventilation of the *interior* of the building.

An architect who had carried out the ventilation of a church, about eight years ago, with the pipes A and C only 18 ins. diameter, said recently that if he had to do the same work now he would use a 3 ft. diameter pipe. This is equivalent to admitting that at present the provision for the outlet ventilation is only one-fourth of what it should be. Progress is made by not only admitting past errors, but in also *avoiding them in future.*

Fig. 12 shows a plan often adopted for ventilating halls, &c., but it is very unsatisfactory as the wind blowing up the slope of the roof D often blows in under the umbrella cover C and causes disagreeable down-draughts. This umbrella cover is also a check to the outgoing air.

Fig. 13 is much worse than Fig. 12, as the top of the intended outlets, E and F, being lower than the ridge, the wind blows down all the more readily and strongly.

* The author tested a pipe like C, about 40 ft. high and 18 ins. diameter, on a calm day. The up-current was 160 lineal ft. a minute, but with the gas circle of twelve jets lighted, the current rose to 300 ft. a minute, five minutes after the gas was lighted.

Fig. 14 indicates the principle of McKinnell's ventilator, patented March 26th, 1855. It is formed of two concentric tubes; the inner and higher or longer

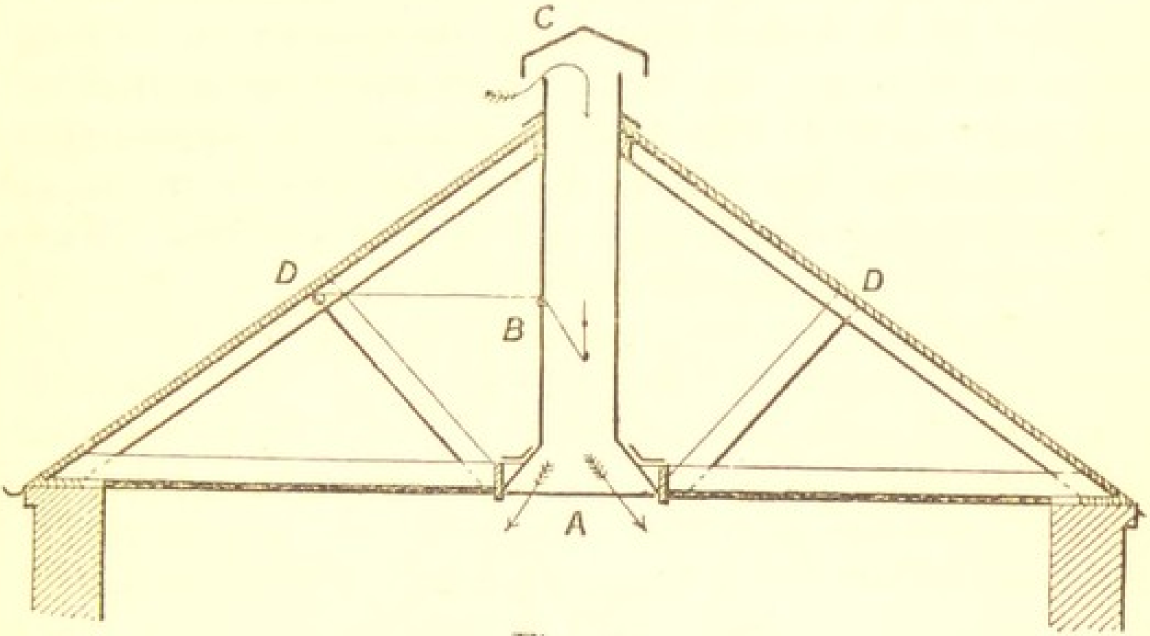


Fig. 12.

one, G, being for the exit of the vitiated air, and the outer, and lower or shorter one, H, being for the admission of fresh air. The broad circular flange, J J,

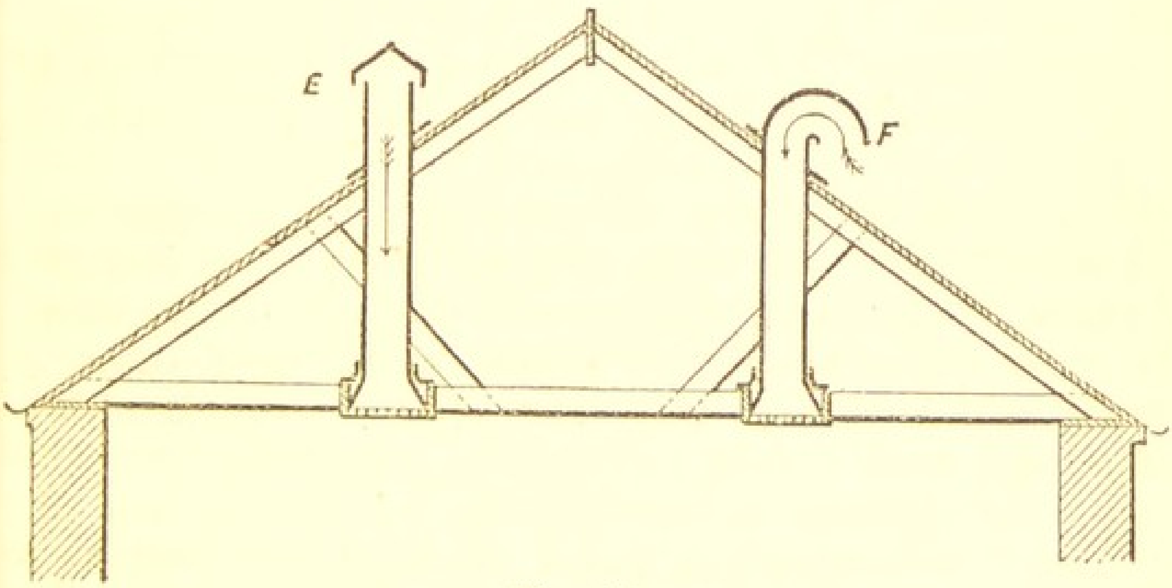


Fig. 13.

which is attached to the bottom of the inner tube, G, is for deflecting the incoming fresh air along the ceiling, K K. In cold weather, however, the air often falls down nearly vertically. Notwithstanding this ventilator being recommended by the late Dr. E. A. Parkes, in his valuable "Manual of Practical Hygiene," I have no hesitation in condemning it as a most dangerous and unsuitable appliance for use in connection with the ventilation of either schools, churches, or halls, &c., where living sensitive persons have to sit under it.

I fear neither Dr. Parkes nor other parties, who have recommended this appliance, have sat below it, as the writer has done, and felt the incoming cold air

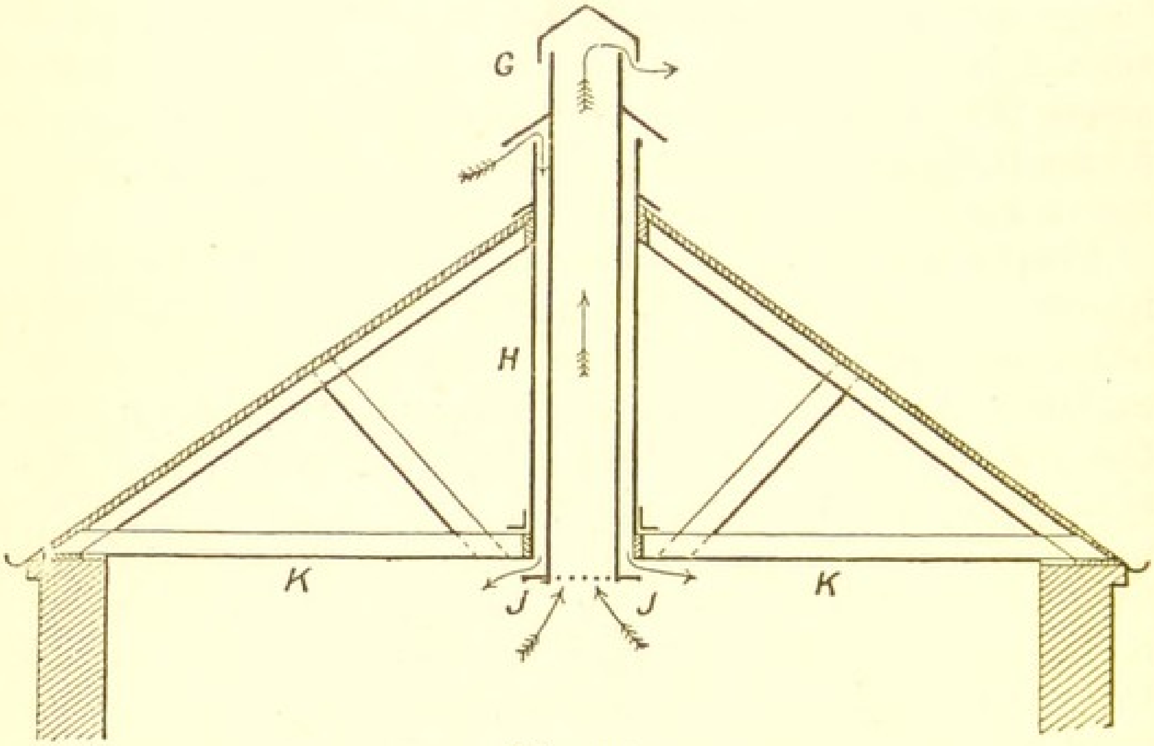


Fig. 14.

blowing down upon them, or they would have referred to it in a different manner. The idea in a climate like ours, of *purposely* admitting *cold* air at the ceiling to blow right down, as, under the conditions, it often would, upon the heads and shoulders of those sitting under it is simply absurd.

The appliance when fitted up is apt to become a manufacturer of influenza and rheumatism, while the approval of it by men like Dr. Parkes simply shows how persons of ability, owing to want of proper consideration, may sometimes make a mistake.

We have heard of "death in the pot," but death from the ventilator may be just as bad.

In a number of schools the only means of ventilation is by the windows, and perhaps, in addition, the chimney of an open fire. Now, as the opening in the grate above the fire is seldom higher than 2 ft. 6 in. or 3 ft., it follows that it is a very bad outlet for the vitiated air, either exhaled from the lungs or produced by gaslights. It is far too low.

If the ceiling is 14 ft. high or more, then the grate or fireplace, as an outlet, is 11 ft. or more too low. Being so low the warm air and carbonic acid from the lungs and gaslights is not carried off quickly, as it should be, but is allowed to accumulate in the space above the grate. This is very bad practice, as it transforms three-fourths of the cubic space of the apartment into a reservoir for bad and vitiated air.*

People are either unaware of the fact, or else they ignore it, that they exhale about 100 times more carbonic acid gas than they inhale, and that this exhaled carbonic acid gas is not only poisonous, but, owing to the organic matter contained in it, much more poisonous than pure carbonic acid gas.

I may here, also, denounce the bad system of ventilation existing in most of our railway carriages, where no means exist for carrying off the exhalations from the lungs of the passengers *at the roof*, but instead there are slits in the sides of the carriages at the top of the doors. Through these slits, while the expired air may sometimes go out so far, it is a fact that the cold air often blows in very strongly, especially upon the windward side of the carriage. This cold air so coming in is not only disagreeable, but it is also often highly dangerous to many passengers sitting in the draught.

Sometimes, again, a person sitting next the carriage window will insist, even in cold weather, upon having it down a piece from the top, quite regardless of the feelings or comfort of his fellow-passengers. Now, if there were one or more proper ventilating outlets *on the roof* (with hit-and-miss valve to open and shut as

* This bad system existed in many of the schools which Professor Carnelley condemned.

wished), there would not be the same excuse for this, and far better and more comfortable ventilation would be got. (See Figs. 141, 142, and 143.)

The reason why bad or non-provision for satisfactory outlet ventilation has been here condemned so strongly is that, whereas the carbonic acid gas in the atmosphere normally is only 4 parts in 10,000, yet *air exhaled from the lungs* contains 4·38 per cent., or 438 parts in 10,000. When exhaled its temperature is about 97°, so that it rises towards the ceiling—as does the heated air from gaslights—*where it ought to be carried off as quickly as possible.*

CHAPTER VI.

Faulty Inlets.

It will be quite *à propos* now to say a few words specially regarding bad styles of admitting the fresh air, in addition to what happened to be made while treating on Fig. 14.

The oldest bad style in modern times is, perhaps, that of simply pulling down the top sash of the window, say six inches, or more or less, from the top, or, perhaps, even lifting it up from the bottom, and allowing the fresh air to blow in as it chose upon the bodies of the children if a school, or their elders if a church or hall, just as if they were so many inanimate statues. If colds resulted from this, these were looked upon as providential dispensations, not to be either guarded against, grumbled over, or fled from, but quietly and thankfully submitted to. If told that this fatalism was foolishness, the sufferer might retort, "Na, na, ye needna' tell me; if folk are to catch the cald they will catch it, dae what they like." Then, tapping his snuff-mull and taking a pinch of Taddy, or biting off a chew of tobacco, Sandy would march off, or turn round with an air as if he had enunciated an axiom.

Quite possibly he might style me a graceless loon for writing thus, but I am not at present thinking so much of the means of grace as of the means of ventilation; and if good ventilation could prevent my friend Sandy from swearing to himself on a cold day, why, good ventilation will have turned out to be itself a means of grace!

In badly ventilated buildings one often experiences a feeling of relief when leaving them. This is not very creditable, *e.g.*, if the building is a church, as it turns what should be a pleasure into a penance. The elders in past times often managed to keep up the attitude of attention by the aid of snuff, if males, or the scent-bottle if females, but we have no record of the millions of kicks and pinches given to the youngsters. At the business meeting of the members of a church, not a hundred years ago, when the subject of the bad ventilation of the church was mooted, even the minister complained, stating that in the pulpit he often felt as if he would be greatly the better of an umbrella to protect hinself from the disagreeable down-draughts; while another sufferer was actually tempted to misquote the psalm—

> "I joy'd when from the house of God
> Go out, they said to me.
> Jerusalem, within thy gates,
> We're sure to poison'd be."

All reasonable grounds for complaints like these should be done away with.*

Another style of bad fresh-air inlets—*if intended for use when room or hall occupied*—is the hinged ones we sometimes see fitted in at the top of the windows and only a little below the ceiling. The incoming air in this case, as in Fig. 15, often comes in and goes along the ceiling the one day, the next day it is deflected down upon the persons sitting a few feet away from the window. It is absurd to bring in fresh air direct from the outside in this manner so high up.† It is not the flies on the ceiling of the room, hall, or church that require the fresh air, but the people sitting near the

* It is usual in many places for the Sunday-school to be held in the Church after the afternoon service. The children then get the full *benefit* of the day's vitiation. In badly ventilated churches the atmosphere the children and teachers are forced to inhale is sometimes very foul. Many pulpits should have a canopy over them to protect the preacher.

† In Fig. 15 style of inlet the air sometimes goes along the ceiling and then falls down upon the people at the opposite side of the room.

floor-level or standing on the floor, so that the fresh air should come in no higher than about 5 ft. 6 in. above the floor, or as much less as circumstances will permit. The inlet may sometimes do well in, on, or at the floor.

Fig. 16 shows a style of window ventilation which I saw adopted for some schools, where the opening of the windows served for both the inlets and the outlets, there

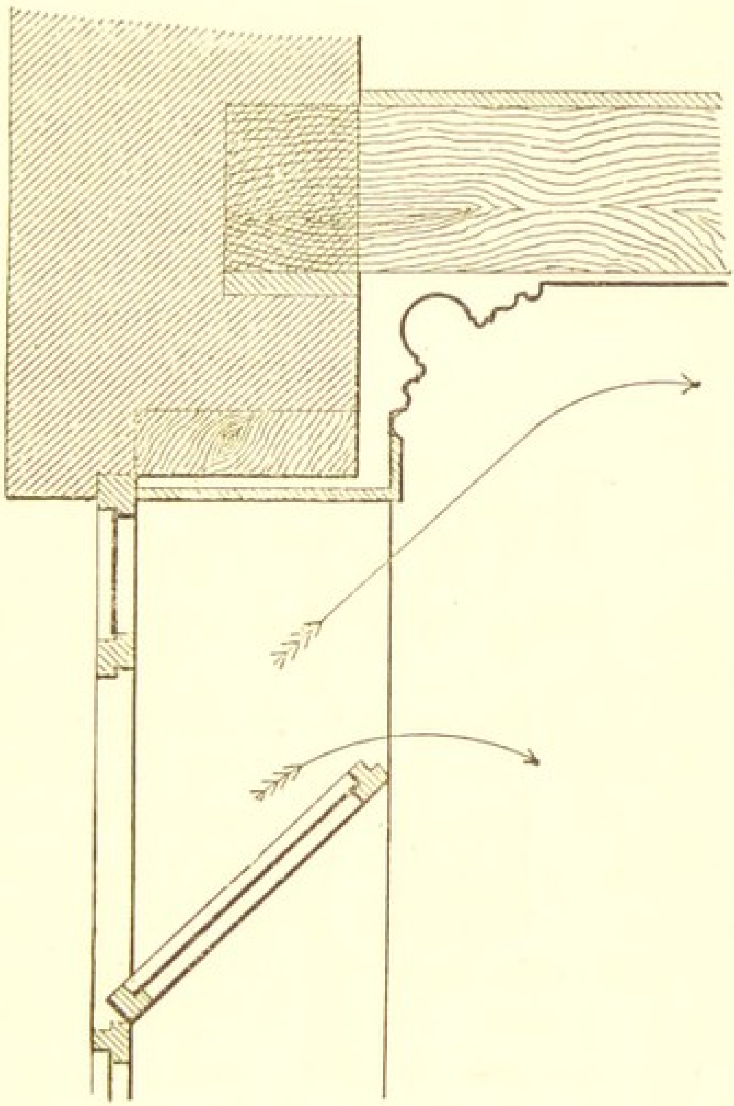


Fig. 15.

being no provision for outlets from the ceiling. The fireplace served as outlet ventilator so far, especially when the fire was on; but as its opening was only about $2\frac{1}{2}$ ft. above the floor level, it was of little use for preventing the pollution of the atmosphere by the warm breaths of the children, and the warm air rising off from their bodies.

In front of the top sash and reaching down about a foot there was placed a screen of gauze or minutely perforated metal A, through which the incoming air percolated or flowed. At same time, however, this pulling down of the top sash so far opened up the seam between the sashes at B, through which sometimes a large wave of cold air could come in as indicated by the arrows in Fig. 16.

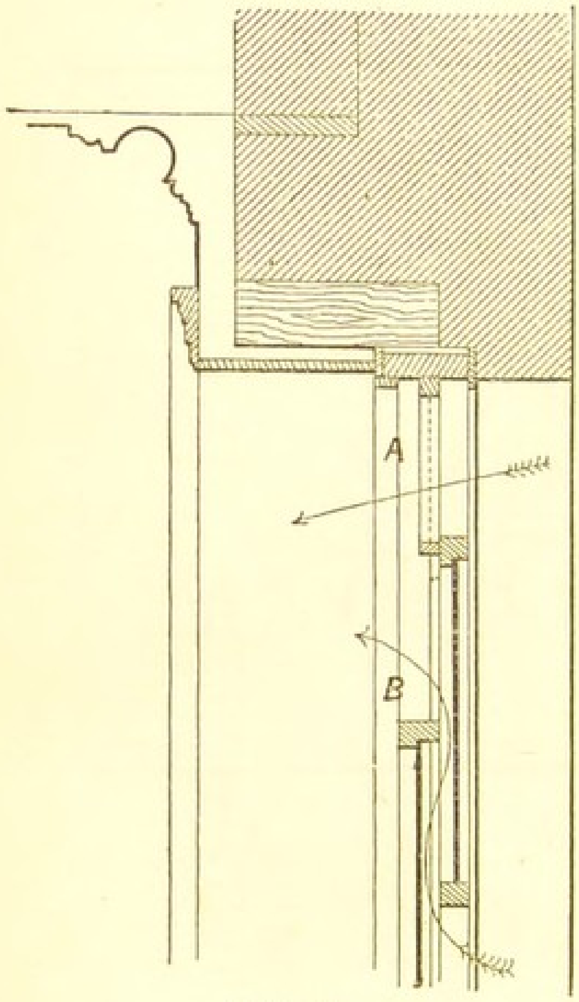


Fig. 16.

The children often complained of cold draughts from this arrangement. As one gentleman expressed it:—"The pupils are between the deil and the deep sea; when the windows are opened they catch cold, when they are shut they are poisoned with bad air."

The author has been recently examining a number of public schools, some of them rather pretentiously spoken of, and was very much surprised at the meagre, bad, and in some cases even shabby means provided for their ventilation. There have, for some time back, repeated allusions been made to the children being overtasked and so breaking down in health, but discovering the inferior ventilation and the *bad atmosphere* of so many of the schools has led the writer to consider that the public has been led off the scent in this matter, and a good deal of the blame lies with those school boards and directors who have been slowly poisoning and killing the children by making them breathe and rebreathe vitiated air, and also forcing them to sit in cold draughts.

Many of the teachers have also complained of suffering for years back from the bad air in their schools, and from the disagreeable and dangerous draughts. All this points to the great prevalence of ignorance and carelessness, or callousness, as to the necessity and requirements for proper ventilation.*

Fig. 17 is a sketch of a room at Dotheboys School

Fig. 17.

where natural ventilation is carried out with a vengeance. This is one of the *legal* means for keeping

* What has been said here, and published elsewhere by the writer, has just been amply supported in a paper read before the Sanitary Association of Scotland, on July 23rd, 1890, by Professor Matthew Hay, Medical Officer of Health, Aberdeen, on "Vital Statistics of School Children." He states that the death rate among children between ten and fifteen had actually increased, while nervous disease was on the increase among children of the school age, the special cause of mortality among school children being from tubercular disease and diseases of the respiratory organs, especially among girls between the ages of ten and fifteen. To remedy this Professor Hay says, "The first and great essential is a sufficiently pure atmosphere within the schoolroom." Professor Hay's paper is published in the *Sanitary Journal*, Nov., 1890, issue, of which Dr. James Christie, A.M., Glasgow, is the editor. Dr. Neil Carmichael, Glasgow, considers that the children's nervous systems are considerably overstrained in the ordinary routine modes of teaching in most of our large schools.

down the population. Who ever heard of a dominie being punished for killing the children with *kindness?* Fresh air is good, *ergo* you can't have too much of it. "It's cold, did you say? Let me hear that remark again and I'll warm you." It would require a Dickens to duly describe the scene. Only it is not the teacher who ought to be hanged, but those at his back.

A bad system of fresh-air inlets, especially for buildings intended to accommodate a considerable number of persons, is the homœopathic one. In this case one or two small 2-in. or 3-in. pipes will be fitted in and covered with wire-gauze or with fine perforated sheet zinc, which gives a merely nominal provision, something equivalent to a thimbleful of milk and half a cubic inch of bread to each for breakfast.

A very common, disagreeable experience is the want of efficient ventilation in ball-rooms. This becomes more marked after the room has been occupied for a couple of hours or so, and all the worse if many gas-lights are burning. In the author's experience the fault generally lay in the want of proper provision for carrying off the heated and vitiated air at the ceiling.

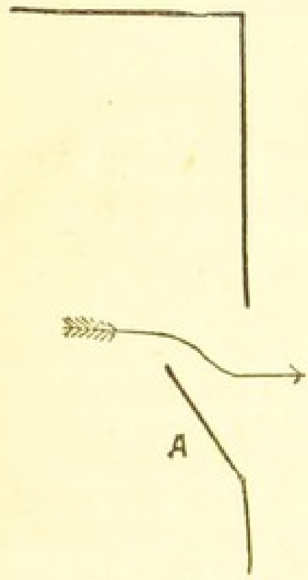


Fig. 18.

At a ball in a recently-erected hall, at which the writer was present, owing to want of ventilation the atmosphere in the ball-room to one entering it felt like that of a midden, even although the lights were electric, and this, too, within about an hour and a half after the ball opened. The thermometer was up to about 70°, or about 12° above what it should have been. An attempt at ventilation was made by having an opening in the window, as per A, Fig. 18, about eight feet down from the ceiling, but the effect was most unsatisfactory.

Most people seem to be unaware that while a *water* cistern has its bottom lowest, as per Fig. 19, a *foul air* cistern has its topmost, as per Fig. 20. To let out the *water* a hole is needed in the bottom, as at A, Fig. 19, but to get vitiated *air* out a hole is needed at the top, as at B, Fig. 20, and even then it has to be coaxed out by some of the appliances herein referred to further on.

In addition to the temporary discomfort, and sometimes or oftener than we note, lasting evil from defective ventilation, we now and again—apart from the disastrous effects of foul air and explosions in mines—read in the newspapers of men going into reservoirs of bad air and being killed. As this is being written a newspaper says:—"A man who descended 120 feet into a well, at Boydon in Wiltshire, for the purpose of cleaning it, was overcome and suffocated by the foul air. A man who went to his rescue shared his fate."

An explosion of gas occurred under the following

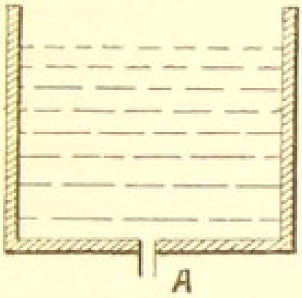


Fig. 19.

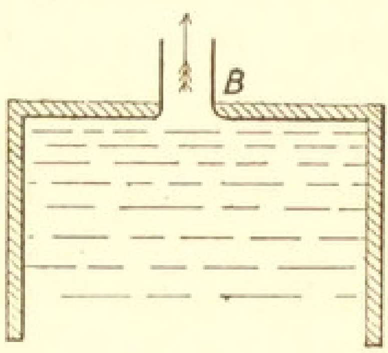


Fig. 20.

circumstances:—The gas was found to be escaping in a room by the servant, who partially opened the window and then went for a gasfitter, after first turning off the meter. When the gasfitter came he lighted a candle, but when it was raised up to near the ceiling the explosion occurred. The top of the window in this case was about two feet below the ceiling, so that there was a considerable space for the gas to lodge. Being lighter than the air it floated on the top for a time, like oil on water. This shows the propriety of having the outlet for the vitiated air as high as possible. Had there been a proper ceiling outlet in this case, all the gas might have gone out at it before the gasfitter had time to arrive.

A match will not burn inside a gasometer, but 10 per cent. of gas in the atmosphere makes an explosive mixture.

CHAPTER VII.

Improved Systems of Ventilation. Inlets, Etc.

Among the modern pioneers of improvements in ventilation the names of Drs. Desaguliers, Franklin, and David Boswell Reid are worthy of special remembrance.

The first of these invented the fanner or blower, in A. D. 1734. It was used for some time to ventilate the House of Commons. The value of Desaguliers' ideas were not properly appreciated when he lived, but now, long after his death, the return to the use of fanners in the ventilation of large buildings is a compliment to his genius, although too late to do him any good personally. We read of him in, what is to be hoped, were rather exaggerated lines:—

"Can Britain . . . .
. . . Still permit the weeping muse to tell
How poor neglected Desaguliers fell!
How he who taught two gracious kings to view,
All Boyle ennobled, and all Bacon knew,
Died in a cell, without a friend to save,
Without a guinea and without a grave!"

In D. Murray Lyon's "History of Freemasonry in Scotland," we read that Desaguliers died at the Bedford Coffee House, Covent Garden, London (A. D. 1749), and was buried in the adjacent churchyard of the Savoy. General Desaguliers and another son survived him.

The Doctor was a Fellow of the Royal Society, London, and a Past Grand Master of the Masonic Grand Lodge of England, as well as one of its founders, and also assisted greatly at the institution of Speculative Freemasonry in England about A. D. 1717.

Dr. Benjamin Franklin, F.R.S., who died in 1790, *inter alia*, invented the plan of ventilating a room by an opening into the chimney below the ceiling with a shutter to open and close the opening as desired.* Dr. Neil Arnott has sometimes been credited with being the inventor from his name being coupled with the balanced valve afterwards introduced, and known as Arnott's chimney valve.

Dr. Reid carried out his system of ventilation for the Houses of Parliament in the fourth decade of this century. He also arranged the heating and ventilation of St. George's Hall, Liverpool, in 1854.

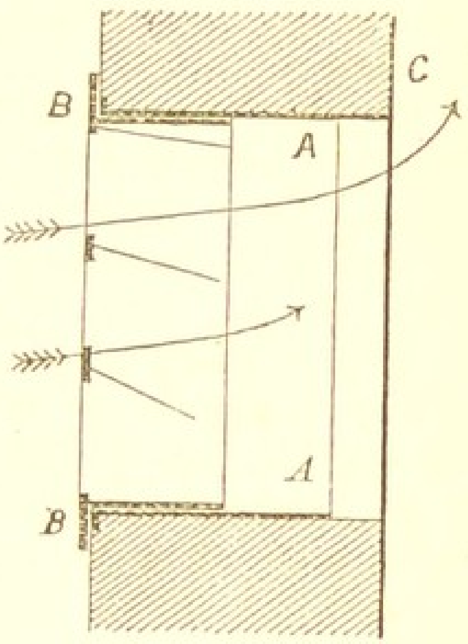


Fig. 21.

By the use of a large chimney, heated up by a furnace at its foot, Dr. Reid drew down the vitiated air from the ceilings of the enclosures to be ventilated, by means of pipes or shafts, and sent it off by the chimney on the principle of the aërial siphon.

Various modifications of or improvements upon the chimney-breast valve are largely in use. Fig. 21 gives a vertical section of one of these; the valves being of silk. They do not make so much noise in shutting as the mica valves do. In fitting these valve boxes into a hole in the wall of a room, immediately under the cornice leading into either the vent or into a special ventilating duct inside of the wall, it is preferable to use and first set in an outer case of galvanized sheet iron about 6 in. or so deep, as at A A, Fig. 21. This outer case is flush with the face of the wall inside of the room, and is made air-tight with lime or cement. Thereafter the

* Franklin is generally credited with being the inventor of the lightning rod. The story of his bringing down lightning from the clouds by means of a kite and its string is both interesting and instructive, as showing from what small beginnings great results flow.

valve box, B B, is slipped inside of the case as shown in sketch. Also see L, Fig. 23.

Where there is a good going vent this valve ventilating outlet is of great service, and works whether fire is off or on. The writer has fitted many of them into offices and other places with good results, the sizes being from about 9 in. by 5 in. to two and three times as large.

These ventilating outlets into vents are of most service where the vent is large in section, say 12 in. or so in diameter, or square. They do well, however, with vents 10 in. diameter, especially when these are made with fireclay pipes or linings, so as to be smooth inside.

It enables more air to be carried off by the chimney-breast valve when the fire is on if the chimney is contracted close above the grate, so as not to let more air in at the grate than is necessary to carry off the smoke properly.

Another way of utilizing the vent to promote ventilation in a room, is to put in a flat pipe 9 in. by $2\frac{1}{2}$ in. or 12 in. by 3 in. or 4 in. in section from near the cornice, at the back of the plaster, down to within about 9 in. from the floor, and then turn it into the back of the register grate in the fireplace. Fig. 22 shows this plan, C being the flat pipe referred to, and D its inlet. B is the register grate, and A the vent. Of course this outlet pipe C works best and extracts most air from the room when there is a good fire on, and when the grate is tightly fitted in, so that air cannot be drawn in from outside of it. Instead of a register grate a stove may be fitted into the fireplace in such a way as to allow the pipe C to work. When either the grate or stove is not burning provision may be made at the back of the grate to have some gas jets lighted when wished to increase the current or draught up the vent. This is one style of the aërial siphonic system of ventilation, the vent A being the long leg of the siphon, and C the short leg. The explanation of its working is that the weight of a vertical column of the atmosphere from D up to a level with the top of the vent is greater than the weight of the warmer air *in* the vent A of same height, so that a pressure is put upon the inlet D, and in the struggle to make a balance, a continuous current of air goes down C and up A, the air in the C column being heavier than that in the inside of the vent or A column.

Although the pipe C has been described as being put in at the back of the plaster, out of sight, it may be set up upon the outside of the plaster, and larger than above mentioned. Or there may be two pipes like C put in, one on each side of the grate.

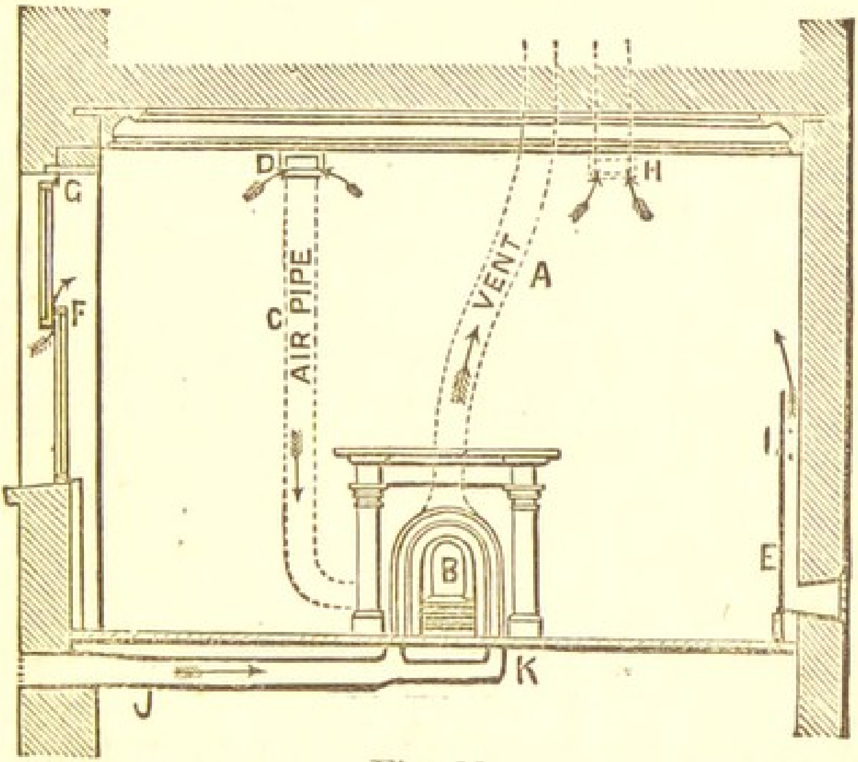


Fig. 22.

H indicates a special outlet ventilating shaft, provided inside of the wall and going up alongside of or between the vents, but quite distinct from them. It may be carried up in the middle of the wall supposing no vents are there. It would be of great service for the ventilation of rooms and offices, &c., and of immense advantage to the general health of the community if provision for carrying off the vitiated air in this way were a *sine qua non* in every house, warehouse, or other occupied building; the law being that this provision *must* be seen to *when the building is being erected.*

F, Fig. 22, shows the fresh air being admitted between the two sashes of the window; the top sash in this case being pulled down about 2 in., and to prevent the air blowing in over the top of the upper sash, a slip of wood about 3 in., or fully that, deep and about half-inch, or fully, thick, is put in all along the top of the window, either inside or outside, as at G.

The author has had this system of ventilation in use in his own house for the last dozen years or so, and can speak highly of it.* The inlet F may be regulated as desired from only one-eighth of an inch open, to about 2 in., according to the weather, &c. Dr. Hinckes Bird, recommended this admission of the fresh air between the sashes many years ago, by raising the bottom sash and putting in a piece of wood below it, but this does not allow the inlet at F being *regulated*, as can be done when the wood is put in at top, as at G.

E, Fig. 22, indicates a Tobin's tube, or panel, or dado inlet, with hot pipes if wished as at I. J is fresh-air inlet led in direct from the outer wall below the floor of the room to the hearth, on each side of the fireplace. This incoming pipe is of galvanized sheet iron. The two inlets at the hearth may be covered with loose tiles if wished, and an iron grating underneath each, with hit and miss valve in grating if wished. If covered with loose tiles, this grating is only seen when the tiles are lifted off to allow of the ventilation. Instead of the fresh air being led in below the floor from the side as in Fig. 22, it may come in from below the back of the grate, as at Fig. 24, if the grate is placed at an outer wall. The author had this in his own library and bedroom for the last seven years, and finds it very beneficial. It is kept continually open summer and winter in bedroom—which as yet has only been used for sleeping in—in conjunction with the outlets D and H. A southerly exposure helps this. In mild weather the top sash may be left down a little all night, and air allowed to enter as at F, Fig. 22. Of course one requires to exercise discretion as to neither

* In *The Builder* for May, 1890, this system is highly commended by the editor.

sitting nor lying in a draught, while during a high wind the window may have to be shut close to keep out the noise; but high winds don't occur every day nor night either. A window on the leeward side might be open a considerable distance, when one on the windward side would have to be either shut or nearly so. Many people virtually elect to suffer ill-health, and shorten their lives, rather than go in for a *little** sensible ventilation in their bedrooms. There could not be a greater mistake. A healthy man who has congenial work to do, and can do it, may be ten times happier than an unhealthy king; but bad health starts the problem :—"Is life worth living?"

Fig. 23 shows the design in Fig. 22, worked out for a two-flatted house, the four ventilating pipes or channels H H H H being seen going up between the vents, and so getting the benefit of their heat when the fires are on. When the fires are off the windows are often more open, when the pressure of the wind is got to help the up-current in the ducts H. L indicates position of an air ventilating outlet into the vent as often put in by myself for offices, especially with the style of valve shown in Fig. 21, where the mode of fitting in the valve is explained.

If in some particular case it is desired to help or increase the speed of the current up the pipe H, this may be done by having this pipe H carried down to Z, where provision is made to light one or more gas jets inside the flue. Of course provision might be made to have the gas jets up near the cornice and inside the flue, which would have the best effect although a little more troublesome to light. It is understood that, especially if gas jets are to burn in any of the H outlet ventilating shafts, these shafts are to be either of fireclay or iron pipes. Provision against fire would also have to be taken.

The air ducts ought to be as smooth as possible inside, so as not to spoil the up-current by too much friction.

* Good air and good food are both good, but a foolish person may take too much of a good thing.

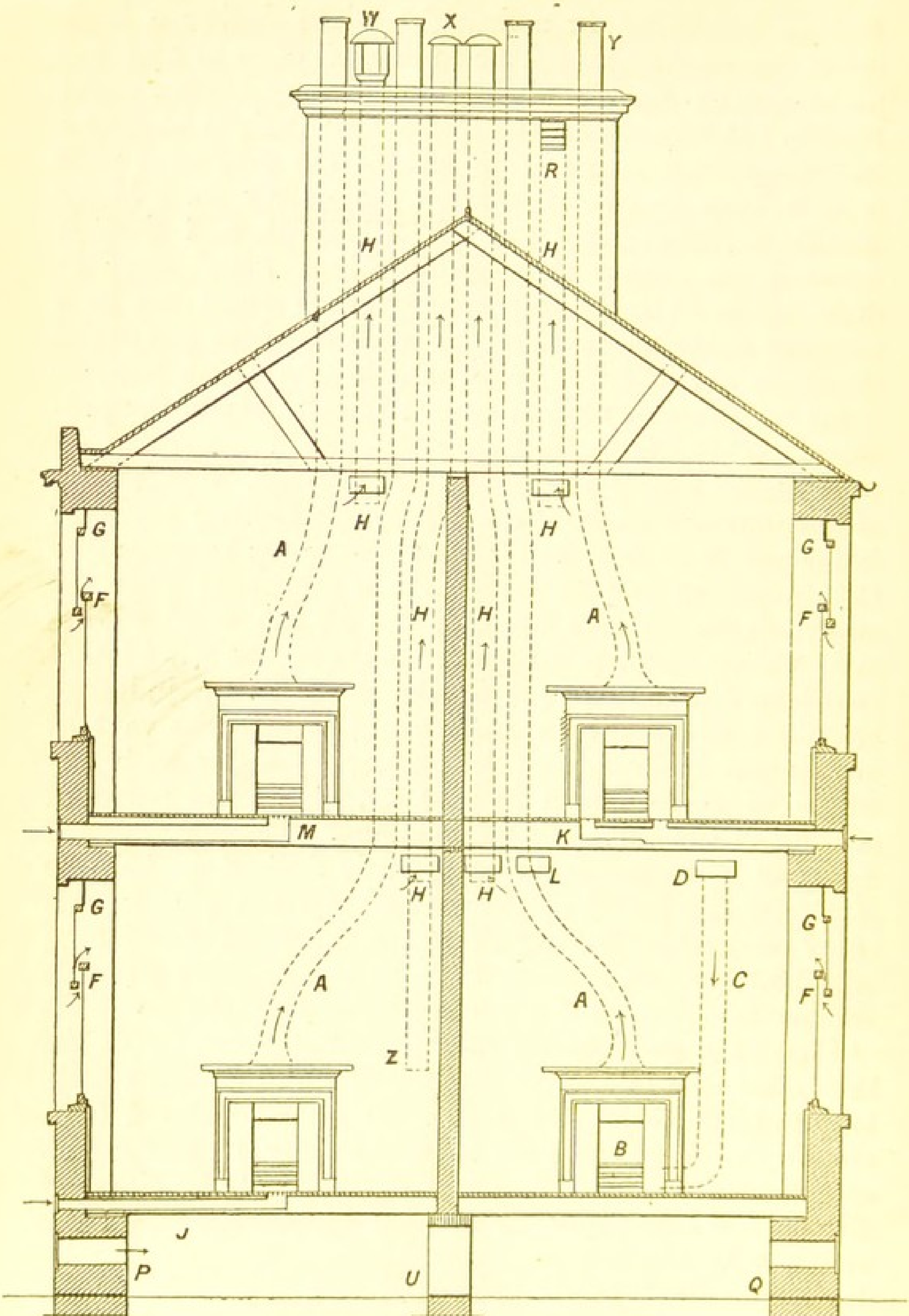


Fig. 23.

For small rooms in small houses 7 in. diameter flues put in as per H, would be a great boon. For larger rooms in large houses 9 in. or larger pipes should be used, and in some cases more than one flue might be used for a large room. (See p. 125).

In some cases where as large a ventilating air flue as possible is wished inside the wall, then the pipe or flue might be made of, say, No. 20 galvanized sheet iron, or heavier if expense not grudged. *E.g.* where only a 9-in. or $9\frac{1}{2}$-in. diameter flue could be put in if of fireclay, an 11 in. diameter flue might be got of galvanized iron.

Fig. 24 is part of the same design in longitudinal vertical section, as Fig. 23, and showing in addition, that for an upper room—say a drawing-room. The vitiated air may be drawn off from the

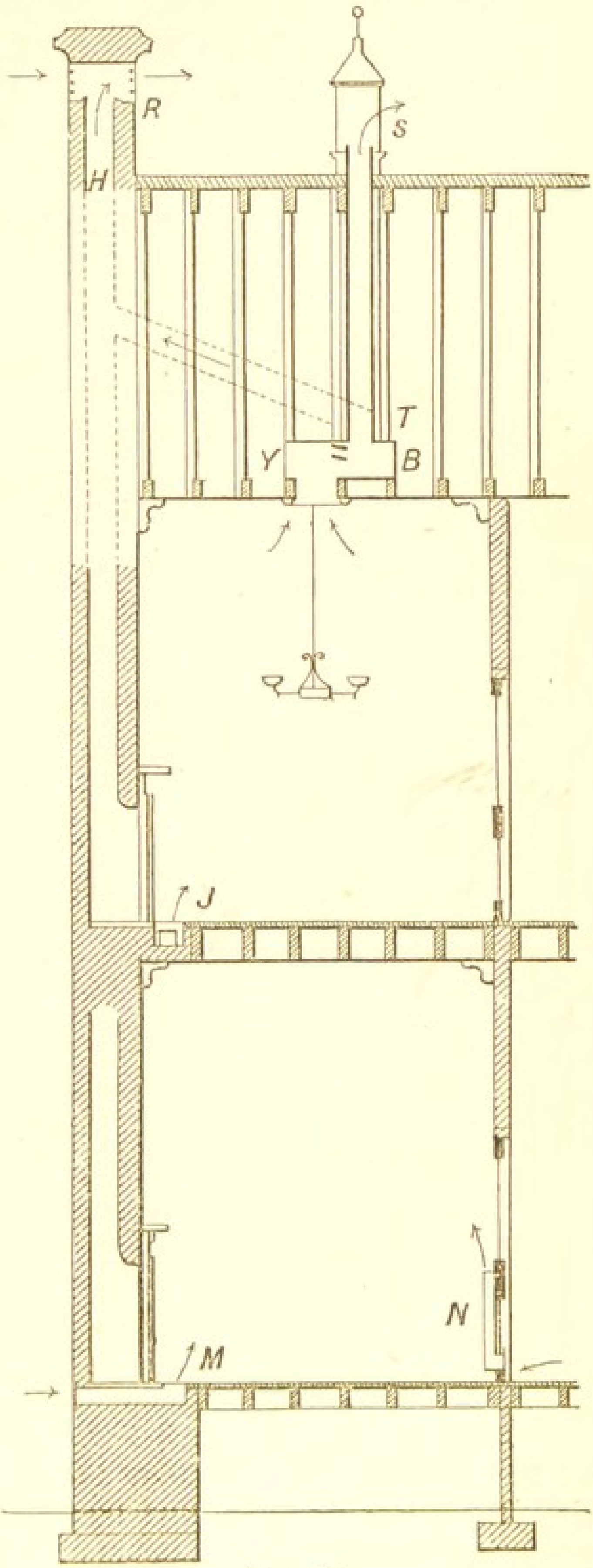


Fig. 24.

centre of the ceiling of the room in two ways, as most suitable, or as wished. In Fig. 24, the fresh air is seen coming in below the hearth stone from the gable, as at M. At N we see a pipe or panel inlet at the back of the room door. In a recent case, where privacy was no object, the panel was recommended to be a fresh air inlet grating. R in Figs. 23 and 24, indicates style of the outlet below the chimney cornice.

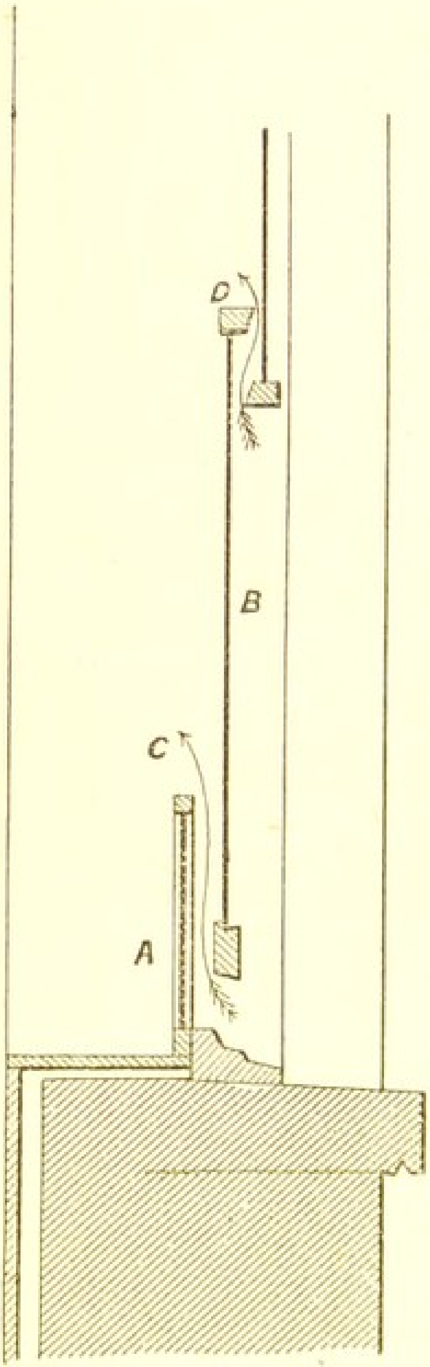


Fig. 25.

When considering as to either purchasing or leasing a house, site aspect and surroundings are all important. A damp clayey site is bad, and especially if low. A dry site is generally good, and especially if on rising ground, and a little elevated. A southerly out-look is generally preferable for the front of the house in this country, or at all events for the living rooms. Of course the state and style of the drainage ought to be particularly seen to.

Another style of the window fresh-air inlet is shown in Fig. 25, in which a board or a piece of plate glass A, obscured or clear, is fixed in front of the lower part of the bottom sash B, so that when said lower sash is lifted the fresh air comes in as shown by the arrow C. The lifting of the lower sash B also allows the fresh air to come in at D between the sashes. If it is not desired to allow the fresh air to get in at D, then a fixed piece of sheet zinc or wood, &c., may be put in on the top of D, fitted close to the glass to prevent the air coming in at the opening at D when the lower sash is lifted. Or this piece of sheet zinc or wood may be so fixed, in either one or two pieces, with a hinge or hinges, so that the fresh air may be allowed to come in at D or not as wished. Some Glasgow schools have Fig. 25 inlet.

It does not do to have too much window area in schools or churches, &c., where people sit, as the air in cold weather may be cooled too much by coming into contact with the cold glass.

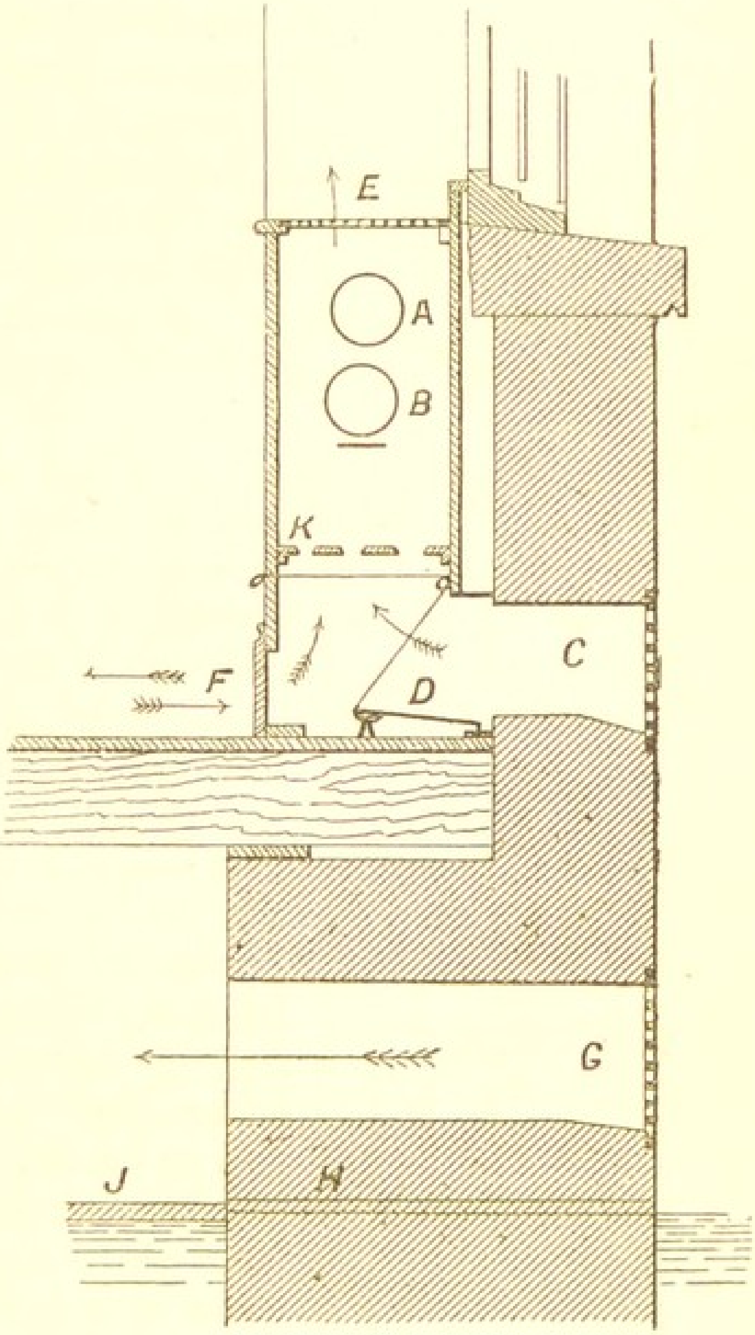


Fig. 26.

In some buildings this cooling of the air by the glass is found so disagreeable that double windows are put in, the air between forming a first-rate non-conductor.

Instead of the double window, it often does well to have hot-water pipes A and B in the window bossing, as shown in Fig. 26, the fresh-air inlet from the outside being at C. The entering air may be shut off either by a hinged valve D, or there may be one or more large hit and miss valves at E.

When the valve D is shut the valve F may be open. In some cases the air may come in from C through F.

As a preventive of freezing the water may have an alkaline solution in it—say chloride of calcium—and under the pipes a narrow slip of wood may be fixed, a little below the pipes, to prevent the cold air from striking the centre of the bottom of the piping.

K indicates that a wood board, about 2 ft. or less or more long, with a number of $\frac{3}{4}$-in. holes in it, may be placed there to act as a side deflector by preventing the air from C all coming up in one place immediately above the inlet C.

G, Fig. 26, also shows fresh-air ventilation below the flooring of the ground flat. It is well to have a number of these gratings, G, in order to thoroughly ventilate the space below the flooring. H indicates damp course in wall, and J a bed of asphalte to prevent damp rising up through the ground.

Where this cellar, L, is dry and clean, and done as indicated in Fig. 26, fresh-air inlet gratings, with hit and miss valves, may with advantage be put in horizontally on the floor, in suitable positions, especially if the gratings can be placed where there would be little walking over them, and where the upcoming air from cellar would not blow in or up upon the persons in the room in a way to be uncomfortable.

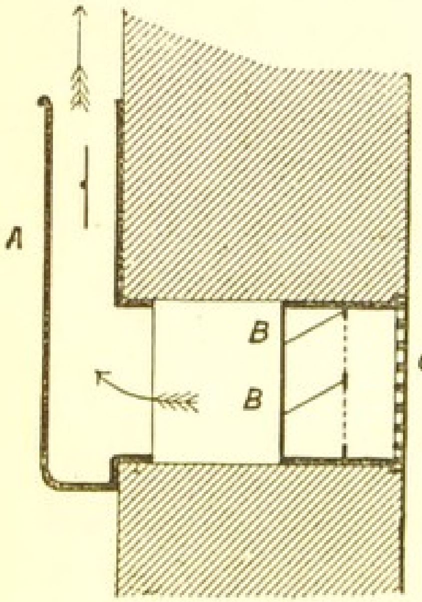


Fig. 27.

Fig. 27 shows a short Tobin's tube A, which may have self-acting valves B B of silk or other material attached to the frame of the metal outside iron grating or fresh-air inlet C, so that while air may get in here none can get out. The insertion of the valves B B is done to stop a cross draught at a low level (especially where the Tobin's tubes are placed on opposite walls of a room, hall, or church), and to cause the pressure of the incoming air if any to be exerted on the proper *high level* outlet or outlets, so as to help in causing the vitiated air to go out at the ceiling and before it falls.*

Although certain objections and precautions have been referred to in relation to the use of the windows as fresh-air inlets while the schools or halls, &c., *were occupied,* yet, especially for schools, the use of the windows for supplying ample provision for quickly *flushing* the rooms in the intervals *when the pupils were out* is to be highly commended. A number of the Glasgow schools are well provided in this respect, although, as it seems to the writer, the *fixed* provision for *outlet ventilation* when the schools are occupied was very deficient.† Some of the schools have the flushing arrangements at the top of the windows, as per Fig. 28, or the top sash may be simply pulled down in the ordinary way.

With Figs. 28 and 29 styles the windows may be sometimes opened for a short time with advantage, even when the pupils are in, as on a hot or close and warm day in summer or autumn, when it is certain there is no wind to cause a draught. An open window on the leeward side of a room might do no harm where one on the windward side would.

In the new edition of the "Encylopædia Britannica," Professor J. A. Ewing, in the article on Ventilation, says:—"With regard to inlets, a first care must be to avoid such currents of cold air as will give the disagreeable and dangerous sensation of draught. This danger is sometimes most insidious—people sometimes catching cold before they are aware of it."

* In the *Building News* for August 29th, 1890, the question is asked:—What causes the air to ascend a vertical or Tobin's tube? The reply to this might be:—The same cause that makes it sometimes descend, viz. *pressure*. Pressure causes motion of the air in the tube towards the point of least resistance. *Ergo* the pressure of the wind on the windward side of a building with Tobin's tubes in it will send the air up these Tobin's tubes on the windward side of the building, and, especially where there is not sufficient or proper provision for outlet ventilation, the air may be forced down and out through the Tobin's tubes on the leeward side of the building.

† Judging from a school now erecting, improvements will be made in the future.

Instead of having the folding-in inlet at the *top* of the window, or in addition to it, the inlet may be at the *bottom*, as in Fig. 29. Each side of the opening pane, or opening sash, in Figs. 28 and 29 should be closed so as to prevent the air coming in at the *sides* of the hinged opening.

In the Society of Arts Hall, London, Mr. E. C. Robins, architect, in 1883 fitted in a "dado" system of long fresh air inlet, across one end of the room, with several openings, A, through the outer wall, for the admission of the fresh air. Each of these horizontal openings, as

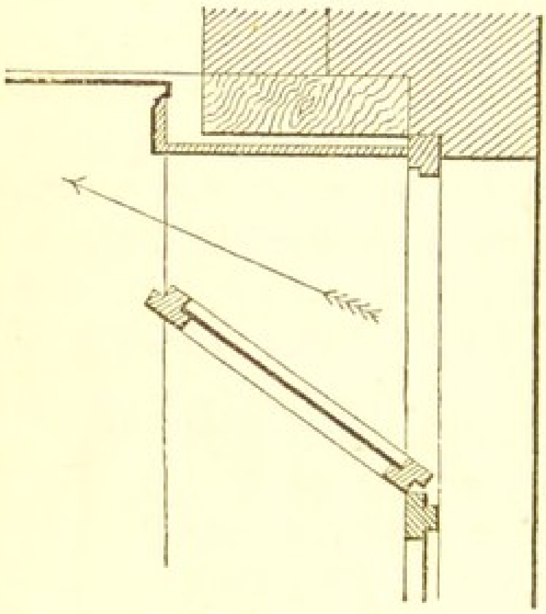


Fig. 28.

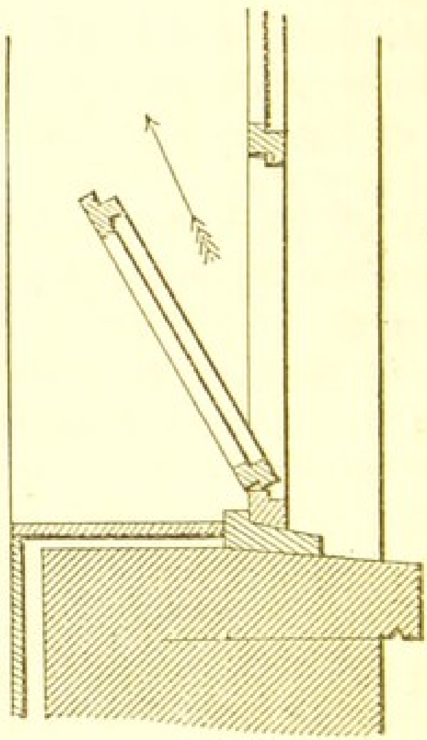


Fig 29

shown at A in longitudinal vertical sketch, Fig. 30, debouches into an expanding upright duct, B, which, by causing the incoming air to spread out greatly curtails its initial velocity. All these coned ducts, B, open up into and below the long inlet grating, C, through which the air enters the room.

Inside each vertical duct there is a hot-water worm pipe for heating the incoming fresh air in cold weather. There are also screens, D, Fig. 31, for filtering the air, so as to keep out dust and smoke flakes. These have to be cleared at intervals or they would become choked up; so unless it is intended to attend to them they would be better omitted. When the work is finished

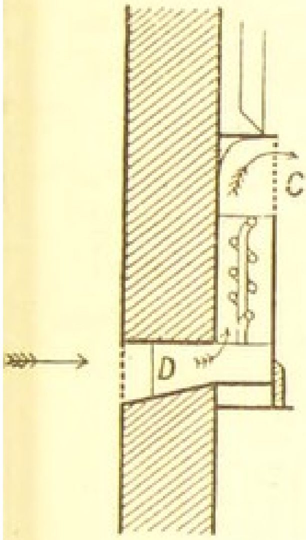


Fig. 31.

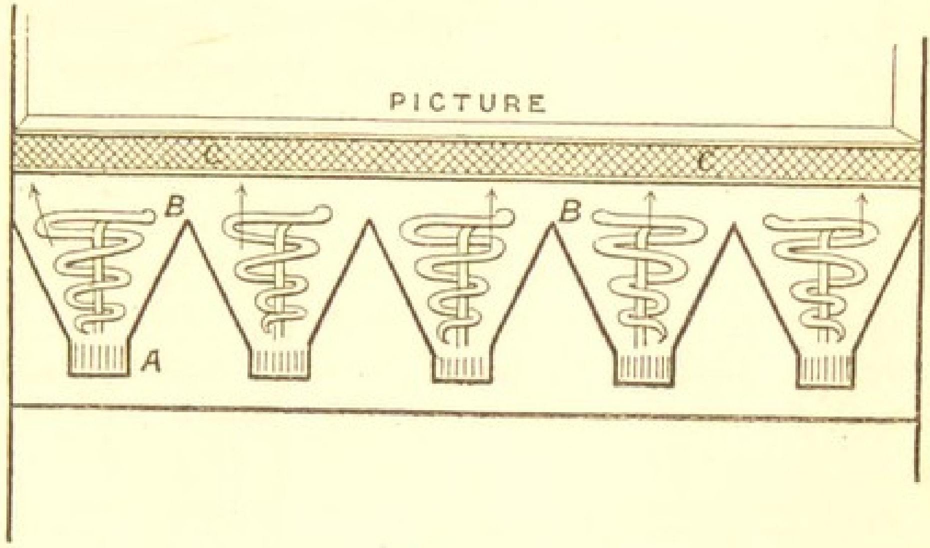


Fig. 30.

the coned ducts and heaters are not openly visible, being boarded up in front on side next room.

Fig. 31 is a cross vertical sketch showing the grating, c, set in vertically, as is necessary in this case owing to

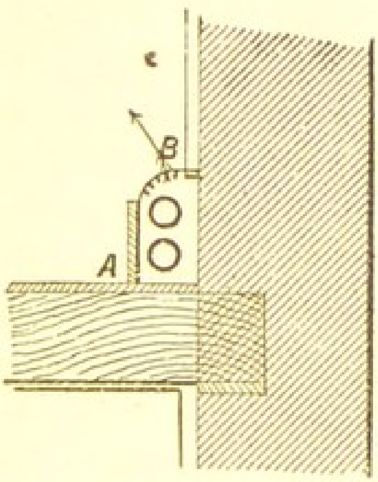


Fig. 32.

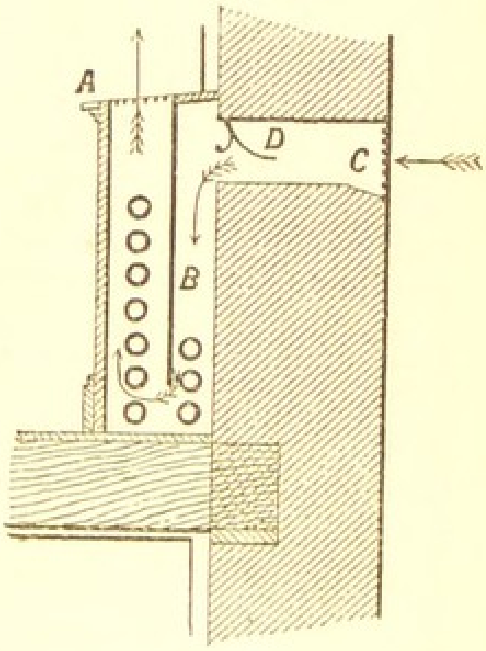


Fig. 33.

the large valuable painting above. In other cases, however, the grating may be put in horizontally, so as to let the incoming fresh air rise vertically.

In the Liberal Club, Glasgow, a long skirting, or low dado, was put in in October, 1887, along one side and

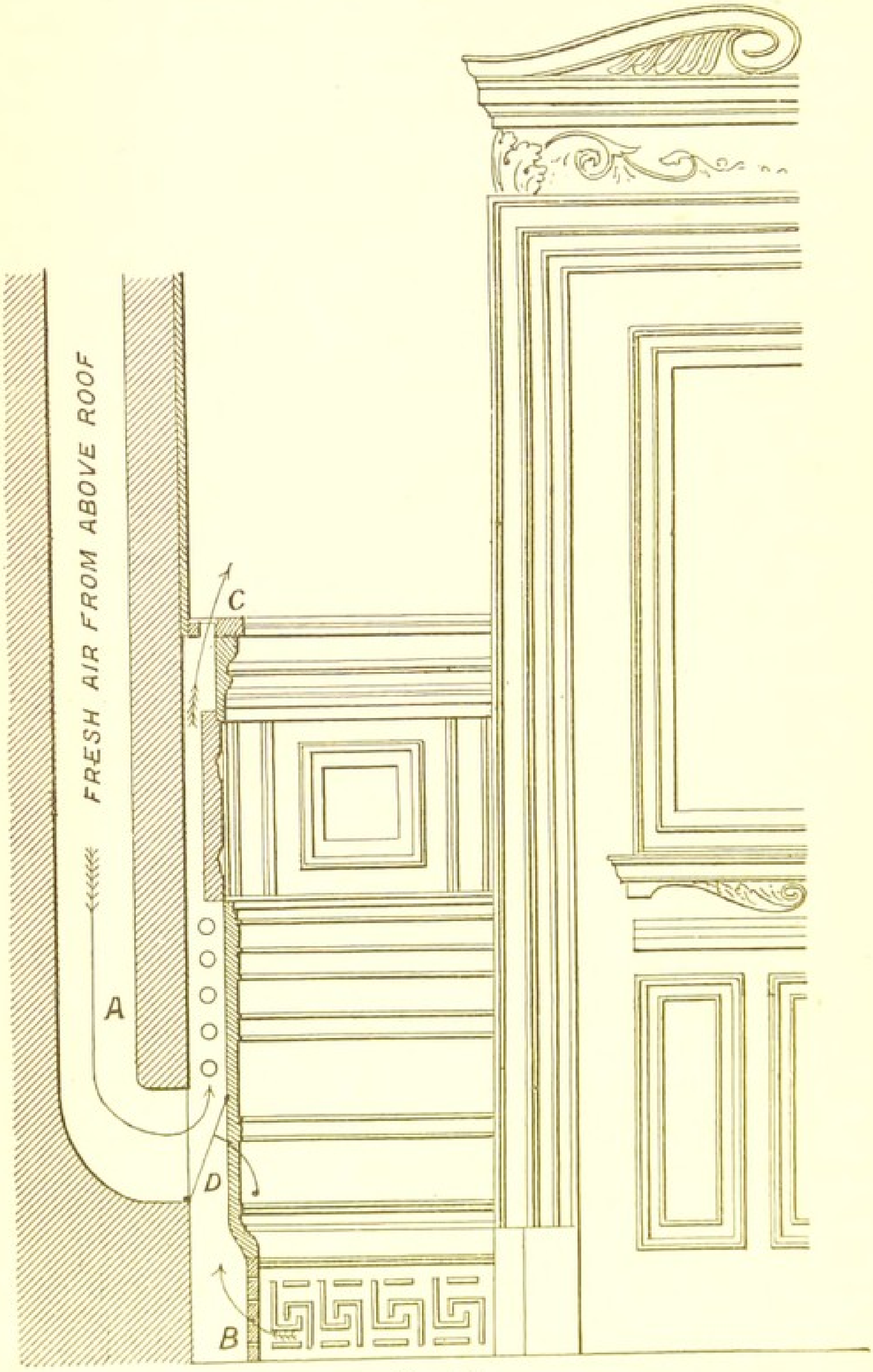


Fig. 34.

end of the room, as shown in Fig. 32, which skirting, A, stands out about six inches from the wall and has an iron grating all along its top, as indicated at B. Inside the skirting are hot-water pipes for heating the air.

In "Technical School and College Building," by Mr. E. C. Robins, F.R.I.B.A., published in 1887, there is a large amount of valuable information in connection with ventilation and warming. The work is lavishly illustrated. The author approves highly of using the spaces in front of windows for bringing in the fresh air. To warm this air, if wished, there may be a stack of hot-water pipes fitted in at the window. Fig. 33 is from an illustration by Mr. Robins, showing the fresh air coming in from the outside, and first deflected down and then made to turn up, and in its course passing through rows of 1 in. diameter hot-water pipes, fixed behind a dado. This plan tends to spread the air before it comes out at A.*

Fig. 34 shows the system of dado fresh air inlet along wall in the saloon of the Town Hall, Greenock, as executed by Messrs. H. & D. Barclay, architects, Glasgow, in A.D. 1883. In cold weather the fresh air is warmed by coming into contact with the hot-water pipes. The bottom arrow, B, indicates that air may be let in at the skirting near the floor level inside, when wished, by shutting the valve or door D.†

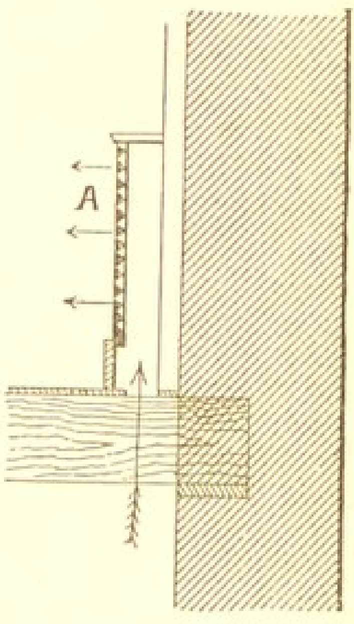


Fig. 35.

Dr. D. B. Reid, in 1845, published a style of dado inlet, as per Fig. 35, the wooden dado being pierced with a large number of holes in its face. To retard the velocity of the air

* Mr. Cormack, heating engineer, Glasgow, objects to the cold incoming air requiring to pass down through the hot pipes in the "B" division next the wall. He says the three pipes there tend to reverse the current at times.

† A patent was taken out in 1888 for a dado system of fresh air inlet, but the dado inlet was in use long before, as referred to above, in Mr. Robins' and Messrs. Barclays' works, and also at schools in Dundee and Aberdeen. All are free to use plans published and in public use prior to the date of a patent.

coming in through the holes, A, these holes might be coned or expanded towards the interior of the room. This might do for a picture gallery, or place where people were *walking* about; but it would be somewhat dangerous for persons to *sit* near such an inlet, as in a school or church.

In schools or other buildings where there are some feet less or more of vertical space below the floor that is unoccupied, this space, or cellar, A, Fig. 36, if kept clean, and also asphalted or cemented on bottom, might

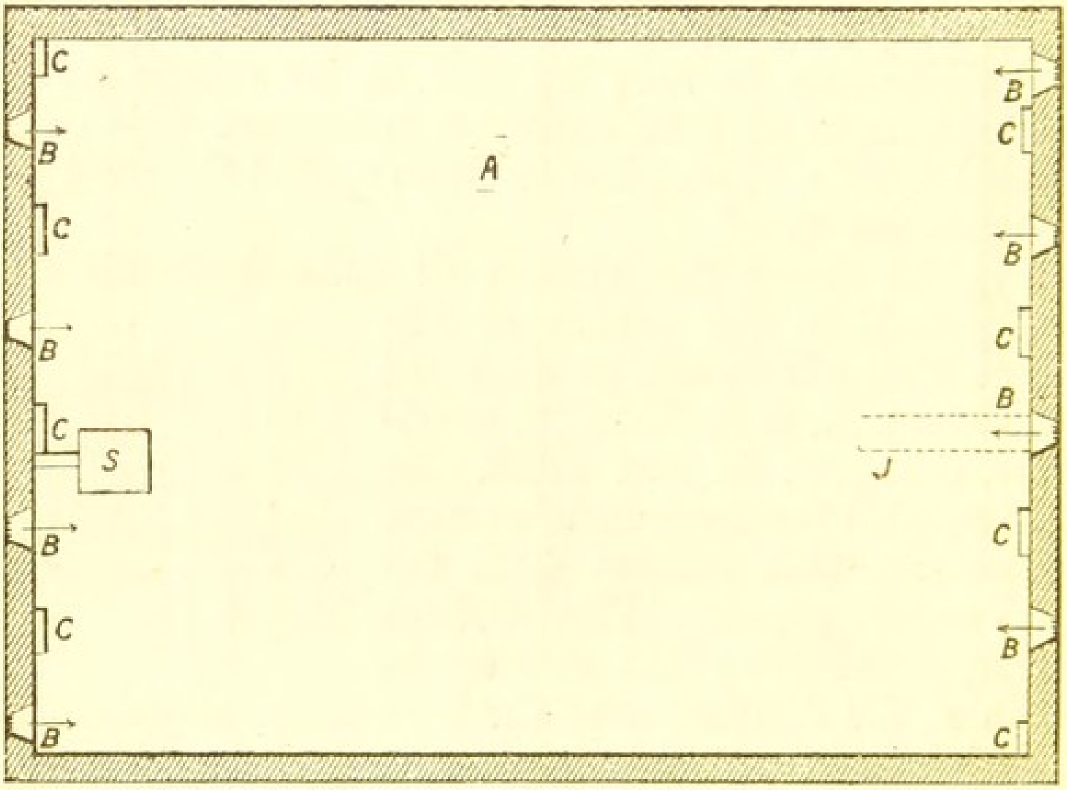


Fig. 36.

do very well as a chamber from which to draw the incoming fresh air. This chamber might help to heat the air a little in winter and cool it in summer. In the latter case, the cooling might be occasionally assisted by the use of the water-hose or spray, to wet or wash the whole surface of the asphalte with clean water.

There may be hot-water or steam pipes in this cellar, or space A below the floor, in Figs. 36 and 37. B indicates fresh air ventilating openings through the outer walls, C position of air inlets up through floor to rooms or hall above, which are to one side of the inlets, B, in same wall. Openings may be made in the floor, with hit and miss gratings in other places, or in place of the C openings, as most suitable. Fig. 36 shows a ground plan, and Fig. 37 shows vertical section of one end or side, A being the cellar in each case, and C one style of fresh air inlet into the room or hall, D : G indicating a different style, rising up through the floor with a hit and miss valve; E is damp course. The outlet for the vitiated air is off top, F, of the room, as

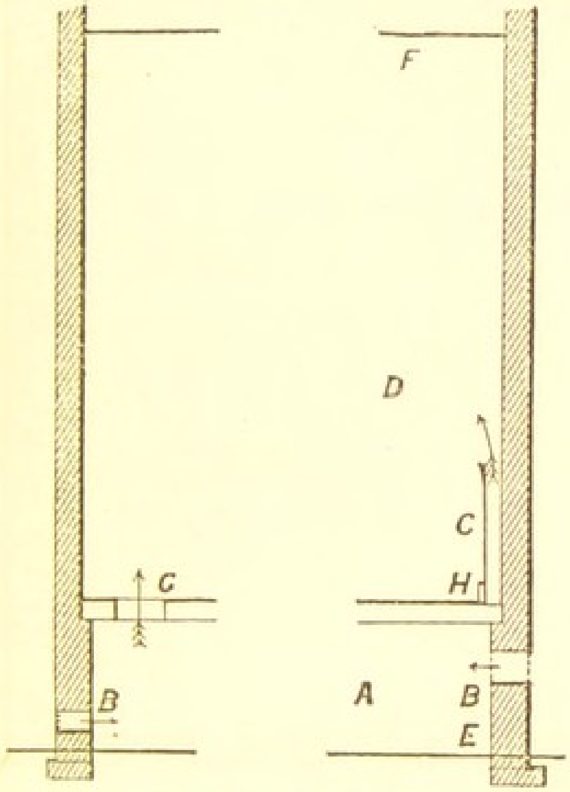


Fig. 37.

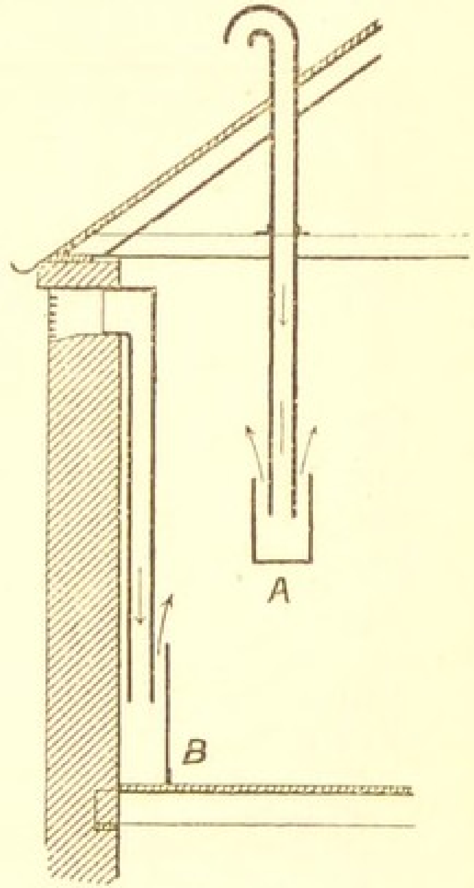


Fig. 38.

per Fig. 48. S, Fig. 36, might be position of a Sylvester gill-stove, or there might be one or more coils of hot-water pipes; J, Fig. 36, indicates that the fresh air inlet, B, at outer walls in place of being left flush with the wall inside may be carried forward some feet, if wished. In doing this it must be seen that there are no "dead" or unventilated portions left in the cellar. The inlets C C, Fig. 36, instead of having Tobin tubes, may be the window bossings boarded in, and with hot-water coils inside.

Fig. 38 indicates styles of bringing in the fresh air from a higher level—making it come down and then turn up.* Ice, scent, or disinfectants may be placed in the lower part, in vessel or dado A or B.

It is to be understood that various modifications of these various styles of inlets may be used as most suitable in the circumstances. *E.g.*, the Tobin's tubes may either be put in all the same width vertically, as per

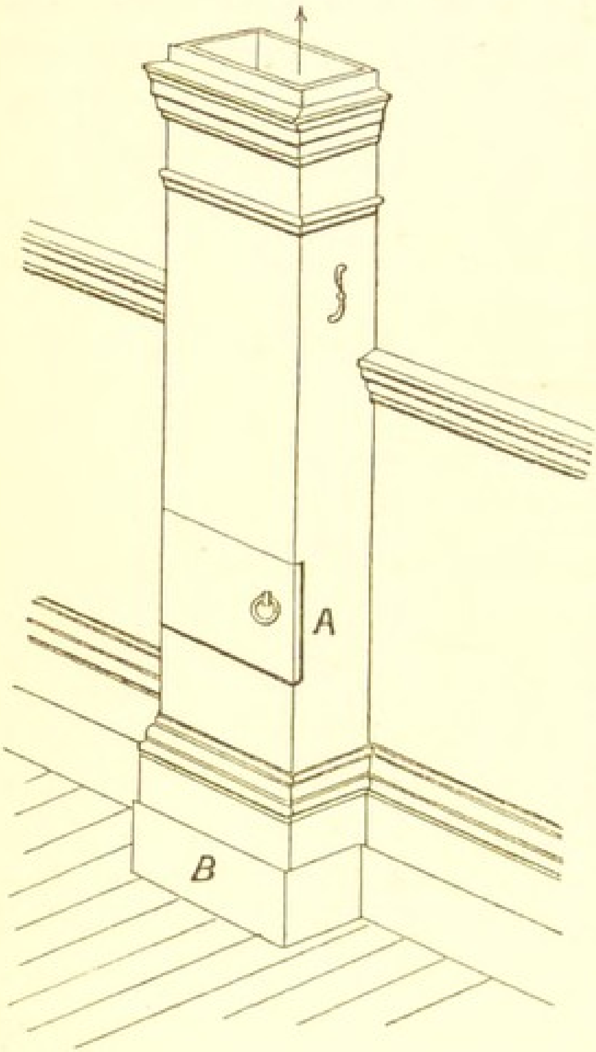


Fig. 39.

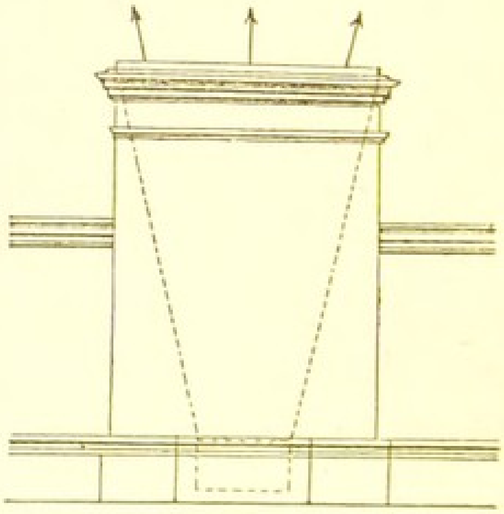


Fig. 40.

Fig. 39, or expanding outwards towards the top, as per Fig. 40; the intention of Fig. 40 style being to make the air come in more slowly, where that is desired, so that it may not be felt so much as a draught.

In some cases the Tobin's tubes might have a hinged or sliding door, as at A, Fig. 39, so as to let the air in

* In some cases the inlet pipe C may be allowed to flow down open or towards the floor, the part A being omitted. Or the dado B may either be omitted or have an opening or openings at its base.

at this door, when wished, in a horizontal direction. When so let in the air should be directed away from persons in the room. When Tobin's tubes, or dado inlets, are fitted into schools especially, it is advisable to make provision to get into the bottom of them readily, to take things out that may be put down by some of the tricky scholars. These Tobin's tubes require to be of a size and number to suit the place to be ventilated. In cross sections they may be 9 in. by 3 in., 12 in. by 3 in., 12 in. by 4 in., 15 in. by 3 in, 15 in. by 4 in., 18 in. by 3 in., 18 in. by 4 in., 36 in. by 4 in., and so on.

Fig. 41 shows a Sheringham fresh air inlet ventilator.

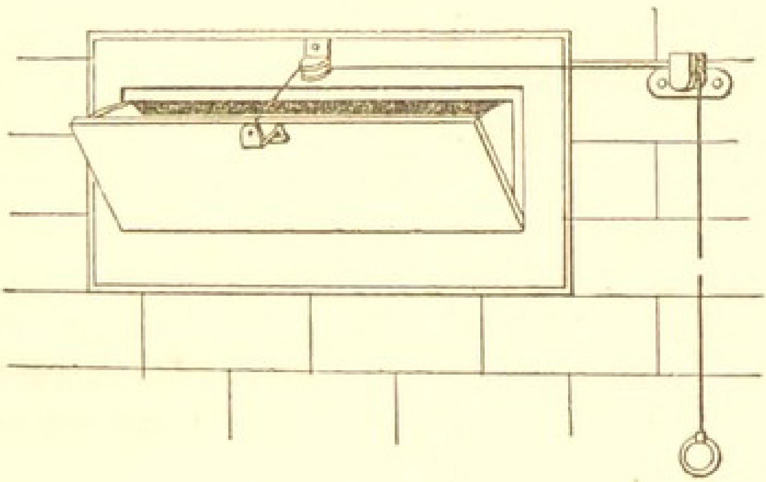


Fig. 41.

In the sketch the valve is shown open. In some cases this appliance may be used as an outlet, although I prefer to use Fig. 21 style for outlets.

The aim of good inlet ventilation may be summed up in a sentence, viz., a large or requisite amount of fresh air, to be admitted slowly, and of a temperature and in a manner so as to be both comfortable and safe, and therefore hygienic.

The styles of ventilation we have been describing belong to the atmospheric, wind-acting, or automatic systems. It so happens that Professor Carnelley, F.C.S., Professor of Chemistry in the University of Aberdeen, has been lately engaged examining the air of a large number of schools in England and Scotland, and as the result of his examinations has asserted that the air in all the automatically-ventilated ones was bad, and therefore all schools ought to be ventilated by mechanical means. Now if the automatically-ventilated schools examined and referred to had their ventilation carried out in some of the foolish, inadequate and bad styles hereinbefore described and condemned in Chaps. V. and VI., it is no wonder Professor Carnelley should have found the air in them to be very bad, and most unwholesome both for the teachers and the pupils.

It does *not* necessarily follow, however, that because the great majority of the schools hitherto "ventilated," or pretended to be so, upon the automatic system are badly and insufficiently ventilated, that therefore there are no schools that are well ventilated upon the automatic system, *or that the automatic system could not give good and satisfactory results if it were properly carried out.*

I have already demurred to this, and asserted that there were a number of schools ventilated with my appliances, none of which Professor Carnelley had tested when he wrote or published what is stated above, but which schools, if tested, would be found to have the atmosphere in them very much better than those other bad ones he had tested and rightly condemned.*

Where the style of and provision for ventilation are bad and too small the effect will not be satisfactory whether the means be automatic or mechanical.

I have just visited a mechanically-ventilated school where the air felt very bad, and, as I considered, because the outlet or exhaust ventilating-pipes were too small—*e.g.*, for one large room serving for 130 pupils there were only two 9-in. diameter outlet ventilating-pipes. This size of pipe was much too small, especially as these branch pipes were a long distance from the exhaust fan and the main pipe.

Where the mechanical system was good both inlets

* Professor Carnelley wrote to me requesting a list of schools ventilated with my appliances, which he intended to test, but I fear he has been unable to manage this, and now he has suddenly died, on 27th August, 1890, at the early age of 37, prematurely closing a bright and highly promising career. The rising generation have lost a friend.

and outlets were large. It surely follows therefore that where an automatic system is adopted for ventilation the provision should also be ample—in fact, *greater*, short allowance giving unsatisfactory results.

Ventilation of schools by mechanical means is more expensive than the automatic system, and especially for small schools. It is more appropriate for some of the extra large schools in cities, especially where these are set down in a position that is confined, or not airy.

Some of the large city schools are two or more storeys in height, and serve for from 1,000 to 1,500, or more, scholars; while many of the country schools are only for about seven hundred or less.

To force small country schools of only one storey to adopt a mechanical system of ventilation would be a hardship owing to the first and *continuous* expense, and is not necessary, more especially if there be any truth in what the architect, the head-teachers, and the School Board agree in stating about the public school at Blairgowrie, in Perthshire (which was examined by me in December, 1885, and thereupon improved). The architect, Mr. Lake Falconer, wrote in 1886: "The ventilation of the public schools is now excellent. The self-acting valves are doing splendidly. The teachers are delighted with the pure atmosphere in the rooms; it is so different from what it was formerly."* He also remarked:—"In regard to ventilating a school by means of a fan driven by a gas or other engine, had we adopted it here we would have been put to a ridiculous expense, and could not have got better ventilation."

The Blairgowrie school serves for about 600 pupils. It stands on high ground and well exposed to the wind and fresh air. The ceilings are about 19 ft. high. The ventilation was improved in June, 1886, on the plan for outlets shown in Fig. 47, and with Tobin's tubes for inlets. Were the work to be done now I would recommend the provision for outlet ventilation; that is, the size of the outlet pipes and ventilators to be larger

* It was only nominally and badly ventilated before this in the Fig. 9 style already condemned herein.

than was supplied in 1886.* Possibly an improvement in this direction may yet be effected if considered necessary by changing the position of some of the present ventilators and pipes and putting up a couple or so of new larger-sized ventilators with pipes to suit. As the school is, however, it is an immense improvement upon what it was in previous to May, 1886. I think mechanical ventilation would be quite superfluous here. The schoolrooms are heated by low pressure hot-water pipes. Heating by large hot-water pipes (low pressure) is the most generally used method, and the best.

A new secondary school has just been erected at Cambuslang, near Glasgow, Mr. A. Lindsay Miller, Glasgow, being the architect, where the ventilators illustrated in Fig. 64 † have been set up above the ridges—viz., six 30-in. diameter ventilators with octagonal base for 18-in. diameter piping, and one 27-in. diameter ventilator for 16-in. pipe. This makes provision for carrying off the vitiated air at the rate of about 3 square in. of outlet area for each of the 568 pupils.

Fig. 42 shows the ground plan of the school.‡ The fresh air inlets are indicated by the dotted lines A. These inlets are below the floor, as shown at A, Fig. 43; they are long wooden ducts, about 15 ft. long by 14½ in. wide, and 12 in. deep. There is one below each window of the schoolrooms. These wooden ducts allow the fresh air to enter into the dark area, or space below the floors, from the iron gratings B,§ set in the

* My ventilation-calculating formula—explained farther on—was not in existence then, not being brought out by me till the autumn of 1887.

† These look exceedingly well in this case, being in thorough harmony with the style of the architecture of the building. See Fig. 65, page 95.

‡ A surface area of 10 square ft. is allowed for each scholar. With the height of the room, 14 ft. at least, this gives 140 cubic ft. for each pupil. Professor Hay, of Aberdeen, asks for 200 cubic ft. for each. The height of the ceiling at Cambuslang new school is however, 16 ft., giving 160 cubic ft. See footnote, page 144.

§ There are twenty-seven of these gratings, each 16 in. by 13 in. In addition to these there are nine other gratings, each about half that size. The latter have no wooden ducts.

face of the wall, as shown in Fig. 43. The depth of this space ranges from about 30 in. to about 5 ft.

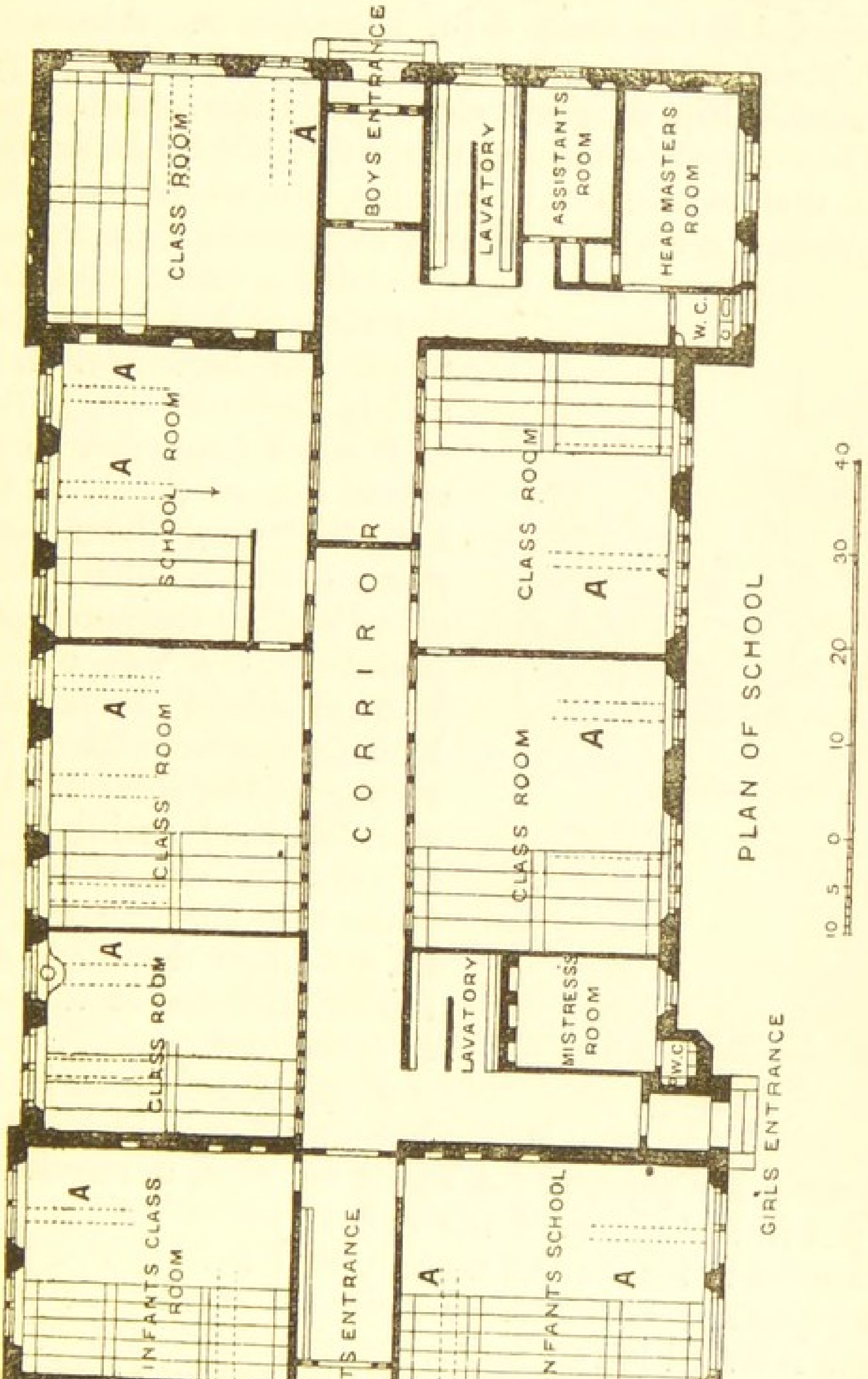


Fig. 42.

After the air has blown into the space below the floor it comes up at each window, as indicated at D, Fig.

43, there being provision in each window bossing to heat the air in winter or in cold weather, by means of a coil of ten 3-in. low-pressure hot-water pipes, branched off the main 3-in. hot pipe, F. Above the hot pipes there is a metal grating, E, with valve to open and shut. Fig. 65 gives elevation of the school.

When schoolrooms are supplied with fresh air from below the floors in this manner, the whole surface of the ground underneath should be asphalted, in order to keep down damp, to prevent the rise of bad ground air when the barometer falls, and to keep out rats.

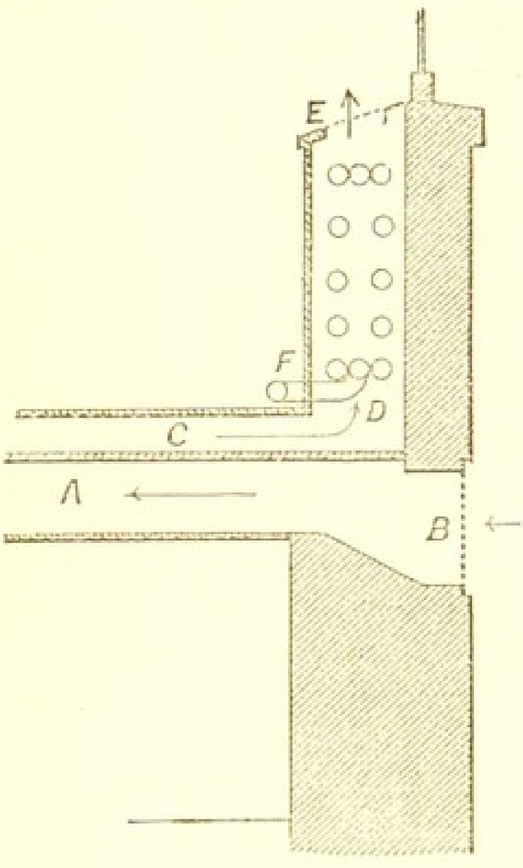


Fig. 43.

When I happened to examine one of these ducts a few days ago, the air was going out by it—not coming in. Possibly the one I happened to try was on the leeward side of the building. This shows that, without self-acting valves, some of these ducts will act as inlets and others as outlets. When this is the case less pressure will be put upon the inlets into the schoolrooms at the window bossings.

Fig. 44 indicates how a hot-water coil is joined to the main hot pipe, F. A small air pipe, G, requires to be put in at the top of the coil to let the air out. If this were not done the water would neither rise up in the pipes nor circulate. A indicates position of the air ducts referred to in connection with Figs. 42 and 43.

For the new Landward School at Galashiels, Mr. John Farquharson, architect, Haddington, is also putting in exhaust ventilators in Fig. 64 style, with self-acting anti-down-draught valve-boxes. For the largest room, for 110 scholars, he is fitting up a 36 in. No. 2 octagonal base ventilator, with 22 in. main up-cast pipe; the large 22 in. valve-box, as per Fig. 90, having three inlets from the three ceiling openings, and one outlet. For the other three rooms there are two 27-in. and one 24-in. ventilators, with 16-in. and 14-in. diameter piping, and anti-down-draught valve-boxes to suit. The provision for outlet ventilation here will be at the rate of $3\frac{1}{2}$ square in. for each pupil, which is the largest I yet know of for any automatically, or naturally, ventilated school in the kingdom; the piping, &c. in the generality of cases being far too small.

This provision of 3 in. and $3\frac{1}{2}$ in. for these country

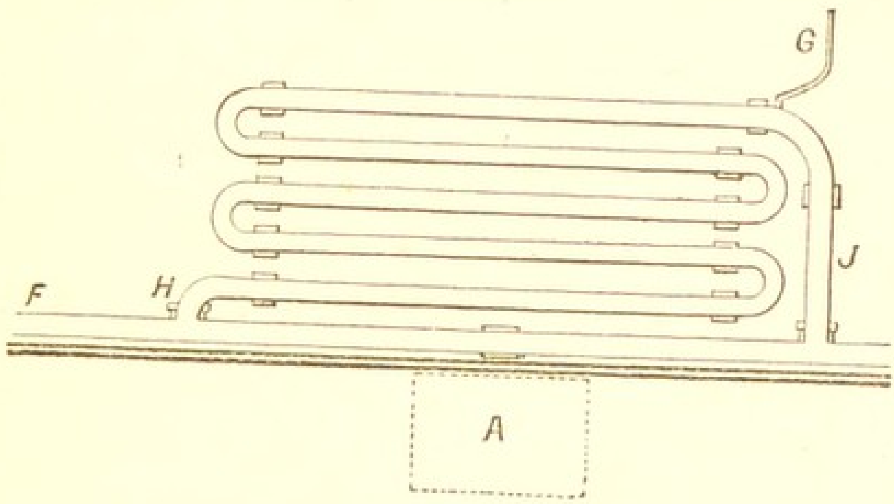


Fig. 44.

schools points a powerful lesson in the right direction, not only to other country schools but also to our schools in large cities, most of which have far less provision than this for carrying off the vitiated air from the school-rooms; in those I have examined only about $1\frac{1}{4}$ square in., or less, for each pupil, when the real allowance should have been as much as 5 in., *or more.** Perhaps when those who are responsible for this state of matters hear or read of this, they will "tak' a thocht and mend," not merely for their own credit but also for the reputation of the communities they repre-

* Since writing the foregoing I have seen a new Glasgow school now building with more than the $1\frac{1}{4}$ in. I should like to see it as much as 7 in. where the ventilation is automatic.

sent and serve, as well as for the comfort and health of both the teachers and the taught. Many of the teachers complain strongly of the bad air in their schools.

Were bad air visible like smoke, better provision would probably have been made long ere this for carrying it off, but the *mind* at this time of day ought to have eyes, in this relation, as well as the face.

CHAPTER VIII.

IMPROVED OUTLETS.

SOME have said that if they could get their mind of the outlets, they would let the inlets take care of themselves; but while this points strongly to the great importance of attending well to the outlets,* it does not follow that the inlets should really be left to take care of themselves. The fact is that for good results, attention to both inlets and outlets is necessary, but as we have just been treating principally upon the inlets, we shall now deal here specially with the outlets.†

As the vitiated air is exhaled from the lungs at a temperature of about 97° it naturally rises towards the ceiling, and as the air vitiated by the combustion of gas, candles, or lamps, which is much hotter, does the same, the natural conclusion is that, generally speaking, the proper place in a room or hall from which to carry off the vitiated air is at or as near to the ceiling as possible. Ample and good provision for satisfactorily carrying off the vitiated air, and preventing its accumulation at

* Air in many cases comes in by a thousand chinks and crevices we know not of. It even percolates through seemingly solid walls, as amply proved by Pettenkoffer's experiments, in which *inter alia* air was easily blown through a dry brick.

† It will be useful to understand that at 32° Fahr., air expands $\frac{1}{491}$ of its bulk for every degree Fahrenheit it is heated, so that, as Dr. J. S. Billings says :—" If the air in a chimney be heated 50° Fahr. above the surrounding air, it will be increased in bulk as 1 is to $1 + \frac{60}{491}$, or $\frac{1}{10}$ nearly. With a chimney 50 feet high, and the air in it 60° warmer than the outer air, Dr. Billings gives the theoretical speed of the current at 20 feet per second; but this may be brought down to 20 or 50 per cent. less by friction caused by roughness, bends, &c.

and below the ceilings of our rooms, schools,* churches, and halls, &c., ought to be the rule, but as yet such is really the exception, ventilating engineers and their masters having been strong homœopathists, to the no small detriment of the health and comfort of the community.

This is not as it should be, and must be rectified. When outlets have been provided for carrying off the vitiated air at the ceiling, painful experience has shown that unless proper practical precautions are taken these outlets, as has been already stated, are apt to often transform themselves into disagreeable inlets. We shall therefore here show how to prevent this.

Firstly, however, in order to point out the difference between the action of a plain pipe and one surmounted by a good exhaust ventilator, see Figs. 45 and 46. In the former by blowing as per the arrows A and B on the end G a small ball of cotton (F) will be carried up the G limb, but if the wind or air is blowing in the direction of the arrows C or D a down-current or down-draught will take place in the limb G, blowing the cotton out at the end E. By putting a small fixed exhaust ventilator on the top of the limb G, as per Fig. 46, we find that no matter how the air is blown upon the ventilator G, the cotton ball F rises up towards the ventilator, as indicated by the arrow. This shows that there is some virtue in the ventilator G.

Another use of the exhaust ventilator G is *to increase* the speed of the current up the pipe. This it often does considerably. Of course it is well known that the wind as a motive power is very variable,† yet before

* In schools the air ought to be fresh when the pupils come in at first in the morning, and by the aid of the means for ventilation provided, the proportion of carbonic acid gas should not, previous to leaving, be more, if possible, than 7 parts in the 10,000, or 3 above the nominal amount. As each pupil exhales about 100 times as much carbonic acid gas as he or she inhales, it is difficult to secure this purity, especially with a large attendance, but it should be aimed at. Ample flushing at the intervals with fresh air is of great service.

† In experimenting in his own house, the author has found the ventilator, that would only be exhausting at the rate of 300 lineal feet a minute one day, indicated in a few days after, 2,000 feet a minute,

the steam engine was invented sailing vessels managed to make good voyages, and many do so still. So with good wind-acting exhaust ventilators, where large enough and properly fitted; these are doing good service in a considerable number of places.

Although Fig. 46 shows how a *small* ventilator prevents blow down, yet in practice it is found that a *suck*

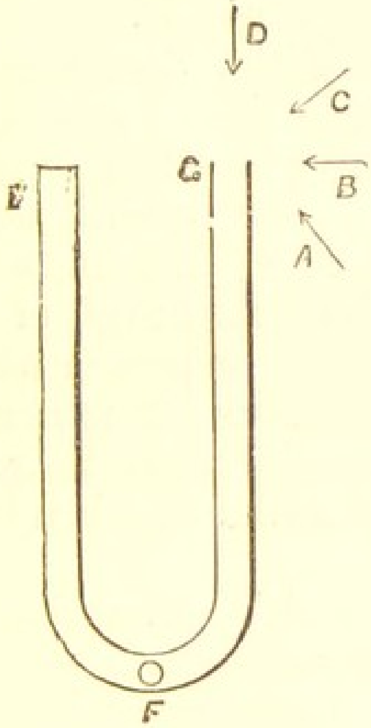


Fig. 45.

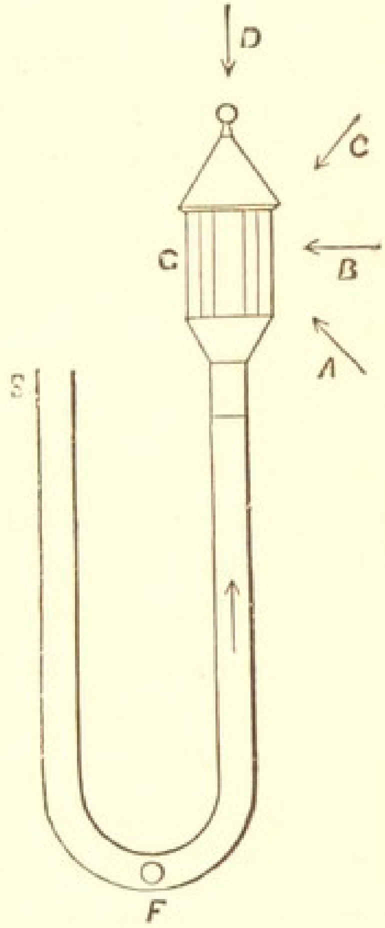


Fig. 46.

down often occurs, especially in a building with fires on, as also that in certain states of the weather, and especially with large pipes* and ventilators, it will

but this was rare and during a high gale. A common indication is 250 to 700 lineal feet a minute. After visiting a large mechanically-ventilated establishment, where the air was going out at the rate of 500 lineal ft. a minute, the author upon coming home tested the outlet speed through his automatic or wind-acting ventilator, and found it to be 800 lineal ft. a minute! The Fates were favourable upon this occasion.

* Unless large enough pipes are used the ventilation will be a sham, or merely nominal, whether for school, church, hall, &c.

happen that occasional down-draughts occur upon people sitting below the outlet ventilating pipe if it is fitted up without any self-acting provision for preventing such down-draughts.

It is therefore advisable in all such places as churches, halls, schools, &c., where people sit below the ventilating outlets—and especially if said outlets are large—that these should be *really outlets only*.

Fig. 47 shows sketch of a No. 2 Buchan's patent exhaust induced-current fixed ventilator B, seated upon a square wooden frame K, the top of K being about six inches above the top of the ridge. This wooden frame K has sheet lead or zinc flashings round it.

Supposing the ventilator B is 20 in. diameter in the body, B, the width of its base, which, for economy's sake is generally square—but may be either octagonal or round—will be $20\frac{1}{2}$ in., so that the breadth across of the wooden frame need only be about $19\frac{3}{4}$ in., so as to allow for the thickness of the lead flashings, or 20 in. across if the flashings be zinc. For a person who has never fitted up one of these ventilators it is generally better not to interfere with the roof or make the wooden frame or seat until he gets the ventilator, when he will understand better what to do.

A is a Buchan's patent "Style A" self-acting anti-down-draught and inspection valve-box, with two automatic silk valves C, which open freely to let the vitiated air up and out, but *close at once against any attempt at down-draught.** When the valves C shut, the outgoing column of warm vitiated air is imprisoned in the pipe F L until the valves open and let it up and out, so that owing to these valves C, whatever ascending energy there may be in the warm column of air in the outlet pipe is conserved.

With such fitted in people have confidence to sit

* By the adoption of these self-acting anti-down-draught valve-boxes, the outgoing current is not "apt to be reversed," as Dr. T. G. Nasmyth, in his "Manual of Public Health and Sanitary Science," states is common with the ordinary outlets. When the valves are at rest they are partly open, so as to let out the air more readily.

below the ventilating outlets, and keep them open without fear of down draughts. This, as experience has pointed out, is a very important matter in connection

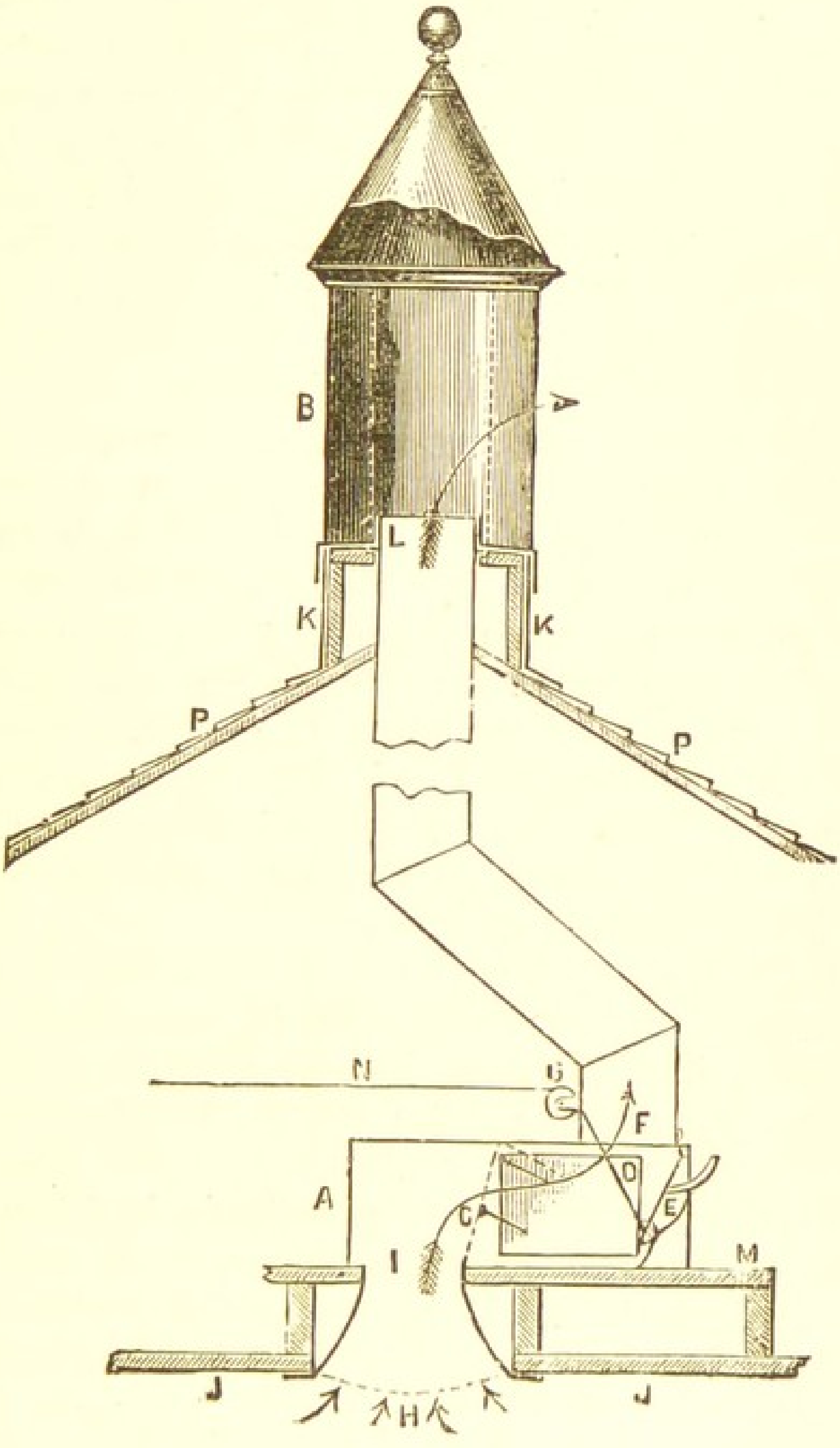


Fig. 47.

with the ventilation of schools, churches, halls, &c., &c. The inspection glass windows, D, enable the working of the valves, inside of the valve-box, to be easily seen. E is the metal valve, loaded, so as naturally to remain open. It can be closed when wished by pulling the cord or wire N, should the ventilator be drawing up too much, as when heating up the interior, or during a high wind when the building may be thinly occupied, although in this case the effect of closing the inlets should be tried first, before closing the outlet or outlets, or have only a partial closing of both. (See page 118).

It was said above that the ventilator B, Fig. 47, was supposed to be 20 in. diameter on the body. In that case the pipe F L leading up to it—which may be made either of galvanised sheet iron or of sheet zinc—may be 12 in. diameter inside.

Some manufacturers of fixed exhaust ventilators have been in the habit of making the diameter of their ventilators from about two and a quarter to three times the diameter of their pipes, but this has been considered by the author to be a mistake, and a pure waste of money, *e.g.*, to set up a three feet diameter ventilator upon the top of a 12 in. pipe, is an absurdity, and not getting value for its cost.* The author makes his 3 ft. induced-current fixed exhaust ventilators so that they serve for either 21 in. or 22 in. diameter outlet pipes; so that while the area of a 12 in. diameter pipe is only $12 \times 12 = 144 \times \cdot 7854 = 113$ square in., the area of a 22 in. diameter pipe is $22 \times 22 = 484 \times \cdot 7854 = 380$ square in., or *more than three times as much.* This is a point of great importance in connection with the proper provision for ventilation necessary for either a school or church, &c.

The benefit of having the pipe large is felt most in calm and warm weather when the passing out of the vitiated air is slowest. With a small pipe the friction is greater, and the air cannot get out quick enough and in sufficient volume, but with the larger pipe it may get out though slow in sufficient volume and quick enough to be satisfactory.

* It has been asserted that the great virtue of a wind-acting exhaust roof ventilator lies in the *bigness* of the head, but that is all nonsense, for the author's 9 in. head beat another party's much lauded 12 in. head by 11,000 feet of greater exhaust in two hours.

A gentleman who had got some of these big-headed ventilators with small pipes fitted up, took it into his head to experiment with them, when he found the small pipes at the ventilators simply obstructed the out-

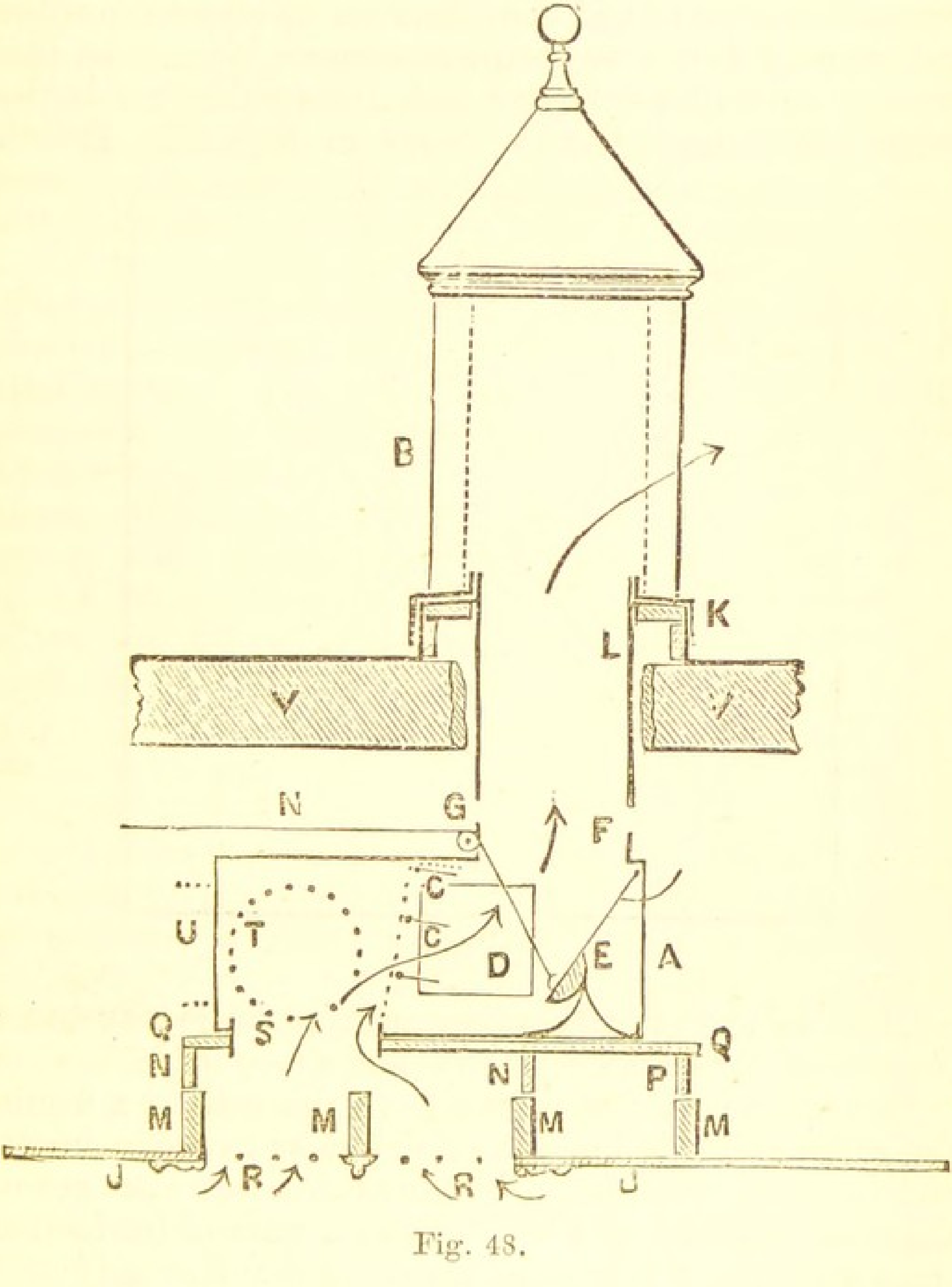


Fig. 48.

current. He therefore took off the whole of them and put on others with larger pipes.

In Fig. 47 the valve box is shown seated across the ceiling joists, and so as that the pipe F L requires to be bent to get up into the ventilator, but by turning the valve-box quarter round the pipe may be carried up vertically if the ventilator is set up a little further along the ridge to suit.

Fig. 48 shows a 30-inch diameter No. 2 "I.-C." (or induced-current) fixed ventilator set up above the ridge and with a 17-in. or 18-in. diameter pipe L. In this case the valve-box is bigger, and the opening R R in the ceiling also larger than is shown in Fig. 47. It is a

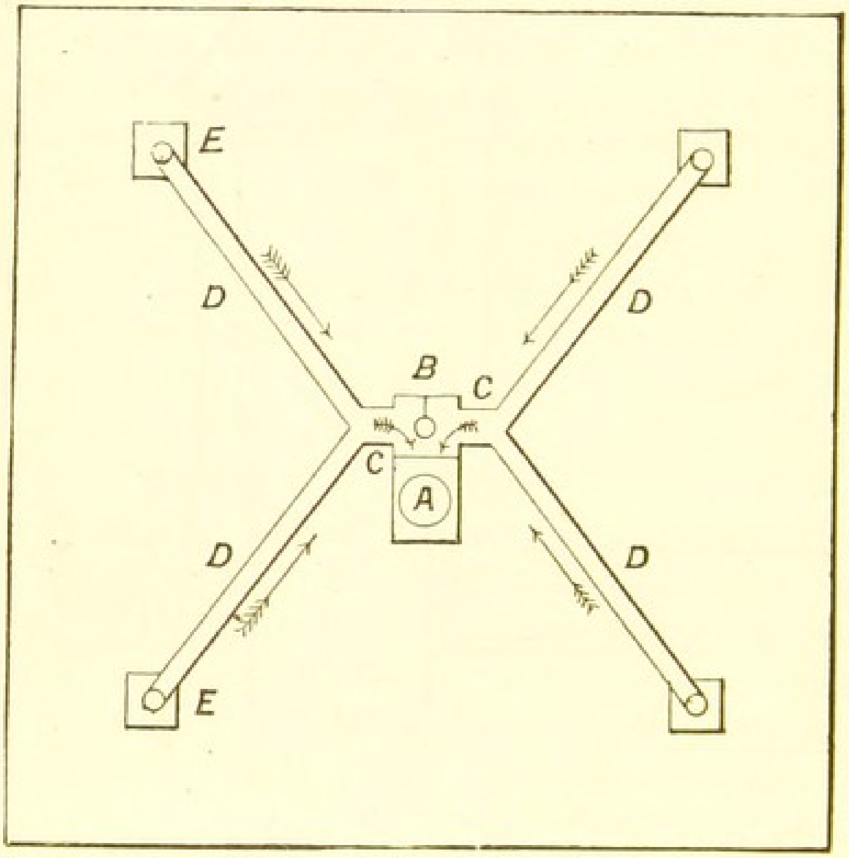


Fig. 49.

good thing to have the ceiling opening large, say twice the diameter,* or more, of the pipe above it.

In addition to the inlet S from the ceiling R R into the valve-box there may be also one or two side inlets, and also one end inlet U, but in such a case the area of the inlet S should only be a half or a quarter (or less) of the area of the main outlet pipe L, so that the said outlet pipe L may draw its supply of air from the side inlet pipes T, and also from end pipe U, if so arranged.

Supposing the outlet pipe L, Fig. 48, is 18 in. dia-

* Twice the diameter gives four times the area.

meter it is sometimes more suitable to make the opening s into the valve-box rectangular so as to allow the box to be made shorter or to fit some particular space or purpose, always making the area suitable to the outlet. When a valve-box has several inlets and one outlet the sum of the areas of the inlets may with advantage be a quarter or more greater than the area of the main outlet. This allows for friction.

D, Fig. 48 indicates position of glass inspection panes, one on each side of the valve-box, which allow the working of the valves inside to be seen. Access to the interior of the box may also be had at them.

Fig. 49 shows horizontal plan of valve-box fitted in to suit five openings in the ceiling. This was for a small public hall, Mr. John Farquharson, of Haddington, being the architect. A 36-in. No. 2 I.-C. ventilator was placed upon the ridge, with a 21-in. diameter main outlet pipe A leading up from off the top of the style A valve-box to it. At the bottom of the other end of the valve-box there was a 16-in. diameter inlet from the centre of the opening in the ceiling, while the two 13-in. diameter pipes C C branched into the sides of the box as shown. The 9-in. diameter pipes D D D D branched into the pipes C C from the ceiling openings E E E E.

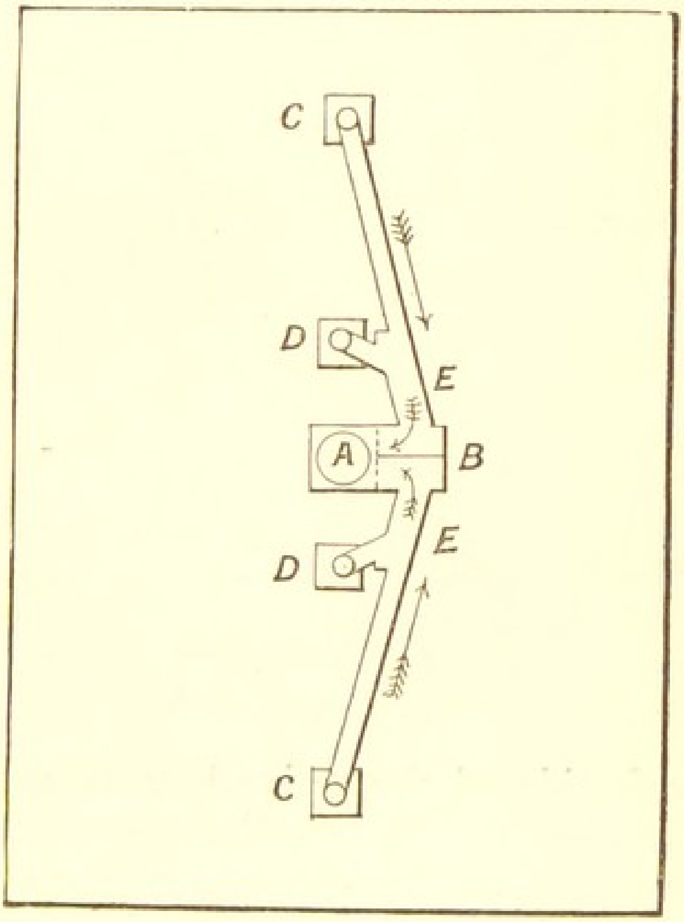


Fig. 50.

Fig. 50 shows the plan of pipes over a ceiling with four openings leading into one large 24-in. "Style A" patent valve-box with 24-in. vertical outlet pipe A leading up to a large 39-in. No. 12 induced current fixed ornamental ventilator set up above the ridge (as shown in Fig. 51). The piping from the two openings C C is 14-in diameter, leading into the ends of the two 18-in. diameter pipes E E. The two short 14-in. pipes from the two openings D D branch into the sides of the pipe E E, while the two 18-in. diameter pipes E E join into

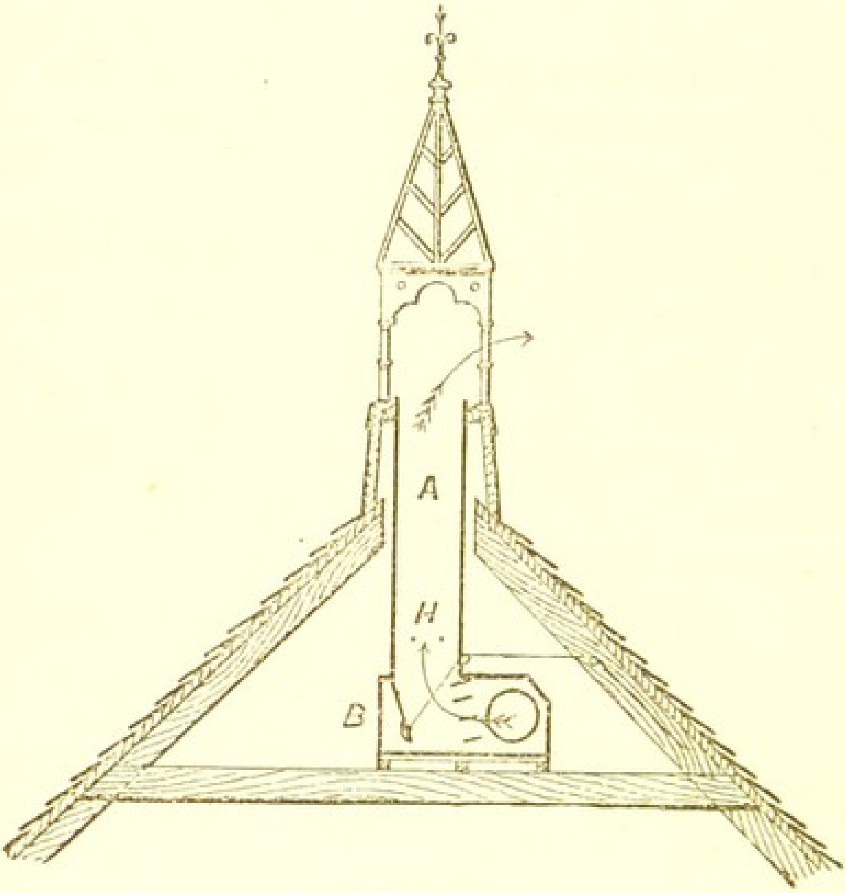


Fig 51.

each side of the valve-box B, as shown. The vitiated air from the hall passing through the pipes E E enters the valve-box and passes through it and up the 24-in. pipe A to the ventilator and then out to the outer air.

Inside the main outlet pipe A, and, as indicated at H, Fig. 51, a few gas jets may be placed which could be lighted when wished in extra calm close weather to help or quicken the out current of air. When gas jets are put in the outlet pipe, A might be wrapped round with asbestos felt. See last paragraph, page 89.

Fig. 52 is a rough vertical section of the same piping and valve-box as are shown in Fig. 50. In this sketch the two 18-in. diameter pipes, E E, are shown entering into the two sides of the valve-box. In Fig. 51 a longitudinal section of the valve-box, B, is seen with one 18-in. diameter pipe entering into one side of the box, and the 24-in. diameter main outlet pipe, A, led up to the No. 12 ventilator. Fig. 51 gives a cross vertical section of the upper part of the roof portion of the building with the No. 12 ventilator set up above the ridge.

Figs. 50, 51, and 52 give an idea of how the piping and ventilator were fitted up for a public hall in Cheshire. Some differences in detail were adopted in fitting up

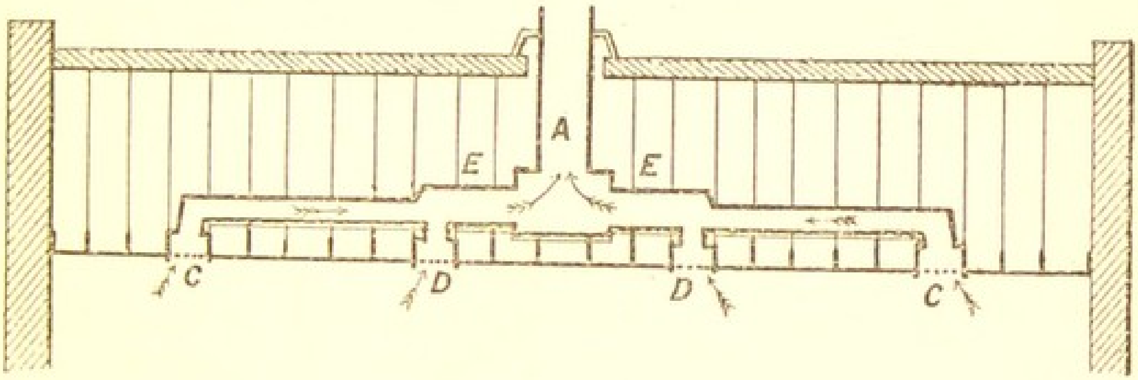


Fig. 52.

the same style of ornamental ventilator upon the roof of the parish church at Newbattle.

At the new Cranston Hill United Presbyterian Church, Glasgow, Messrs. Steel and Barbour, architects, a large 42 in. No. 6 ornamental ventilator (as shown in Fig. 69) was set up in 1887 above the ridge, with 22-in. diameter* main outlet pipe, and two 16 in. diameter branch pipes led into the 22 in. main pipe. There were three openings in the ceiling, as shown at A, B, and C, Fig. 53, and two 16-in. style A patent valve-boxes had to do duty for the three openings. The boxes were therefore put in over the ceiling openings A and C, each valve-box having an inlet at its bottom, and also one at its side as shown, a 16 in. diameter pipe, D D, being led off the top of the outlet end of each valve-box

* For this size of ventilator a pipe may now be used any size up to 26 in. diameter.

and joined into the sides of the 22 in. diameter main outlet pipe E, as indicated in vertical section in Fig. 53 *

In some cases where the ventilator is limited to a certain size, and it is desired to get as much work as possible out of it, the pipe may be enlarged as per B, Fig. 54, *e g.*, supposing the size of the ventilator is 36 in.

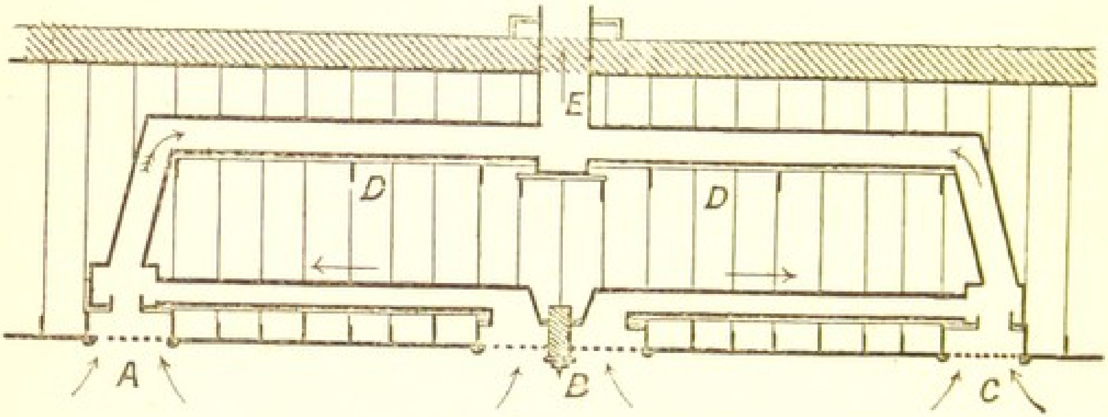


Fig. 53.

diameter in the body, then, as per Fig. 54, about 6 in. of 22 in. diameter pipe is used at the ventilator to allow for slip up through the top of the wooden frame, and $2\frac{1}{2}$ in. into the socket of the ventilator, while the pipe B, receiving say two 18-in. diameter pipes, C and D, is 24 in. or more in diameter. Circles are to one another as the squares of their diameters, but to allow for friction, &c., it is better to have the sum of the area of the two branch pipes, C and D, considerably larger than the area of the pipe B. Thus B at 24 in. diameter gives $24 \times 24 = 576$, while C and D give $18 \times 18 \times 2 = 648$.† In position a flange is

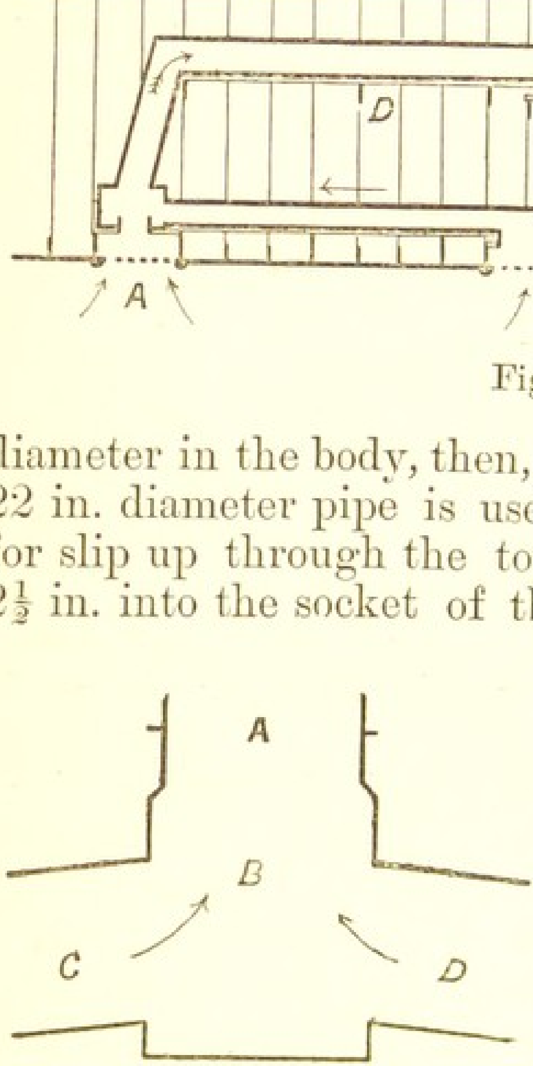


Fig. 54.

* With the outlet pipe E 22 in. diameter, the two pipes D D might be 17 in. diameter.

† The pipes B, C, and D, being circular, 576 and 648 require to be multiplied by ·7854 to get the real area in square inches. Or to multiply by three and divide by four gives the area approximately, but a little too small.

soldered on at E round the pipe A, $2\frac{1}{2}$ in. or so down from the top, to support, or help to support, the pipe A B and keep it in position. In some cases the flange may be soldered on close to the top of the pipe, and especially if the pipe is a square one, or larger than the opening in the bottom of the ventilator. In this case the contraction at A is dispensed with.

Fig. 55 shows, say, a 4 ft. diameter exhaust ventilator, A, upon the ridge, with a 30 in. or 31 in. self-acting valve-box, B, below it. The pipe C being either 30 in. or 31 in. diameter. In this case, supposing there are three openings in the ceiling, then if the pipe C is 30 in. in diameter

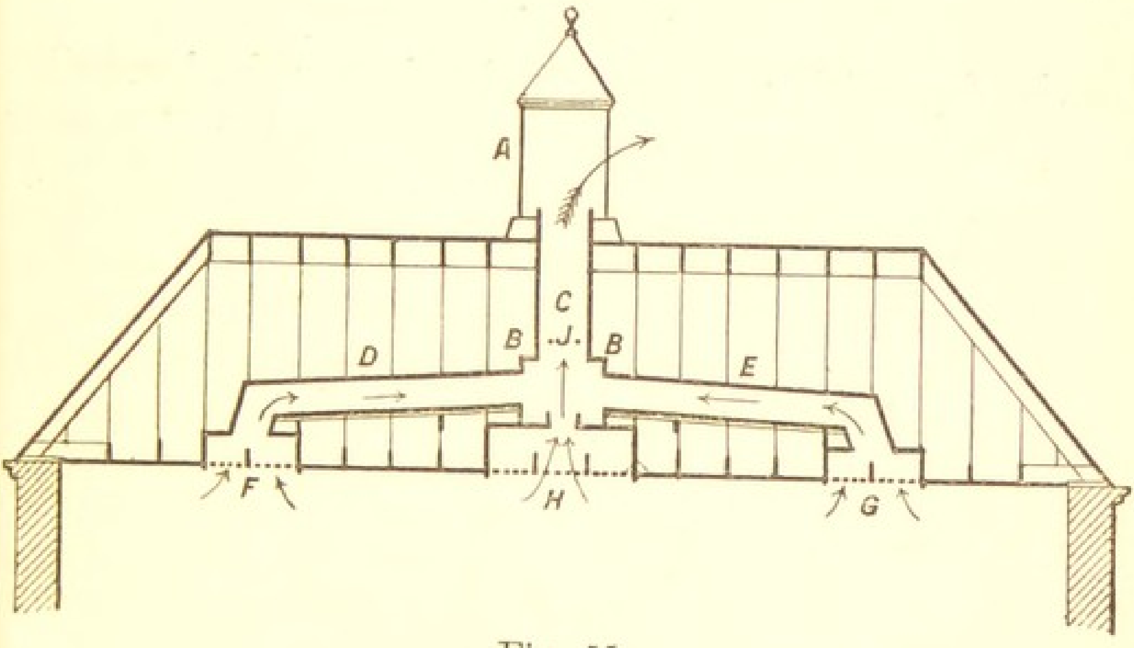


Fig. 55.

the pipes D and E may be each 20 in. diameter, and the opening into the bottom of the valve-box from ceiling outlet, H, 15 in. diameter. If there were no centre opening H in the ceiling, but only the two openings F and G, then with the main pipe C 30 in. diameter, the two pipes D and E might be each 23 in. diameter.

If desired a ring of gas jets may be fitted in at J, at the bottom of the galvanised iron pipe C, to be lighted occasionally if necessary in very calm and warm weather to improve the up-current. In this case the flat top of the seat for the ventilator may be of strong sheet iron, a little raised in centre, in place of wood.

Fig. 56 shows two openings in ceiling of a hall or

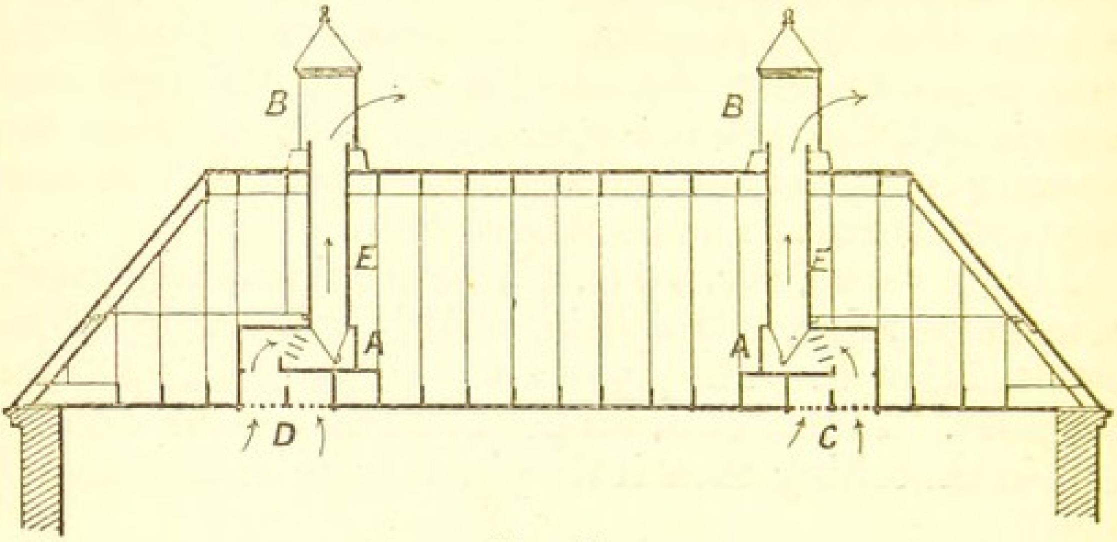


Fig. 56.

church, &c., with a separate valve-box, A, and ventilator, B, for each opening. It is understood that the air

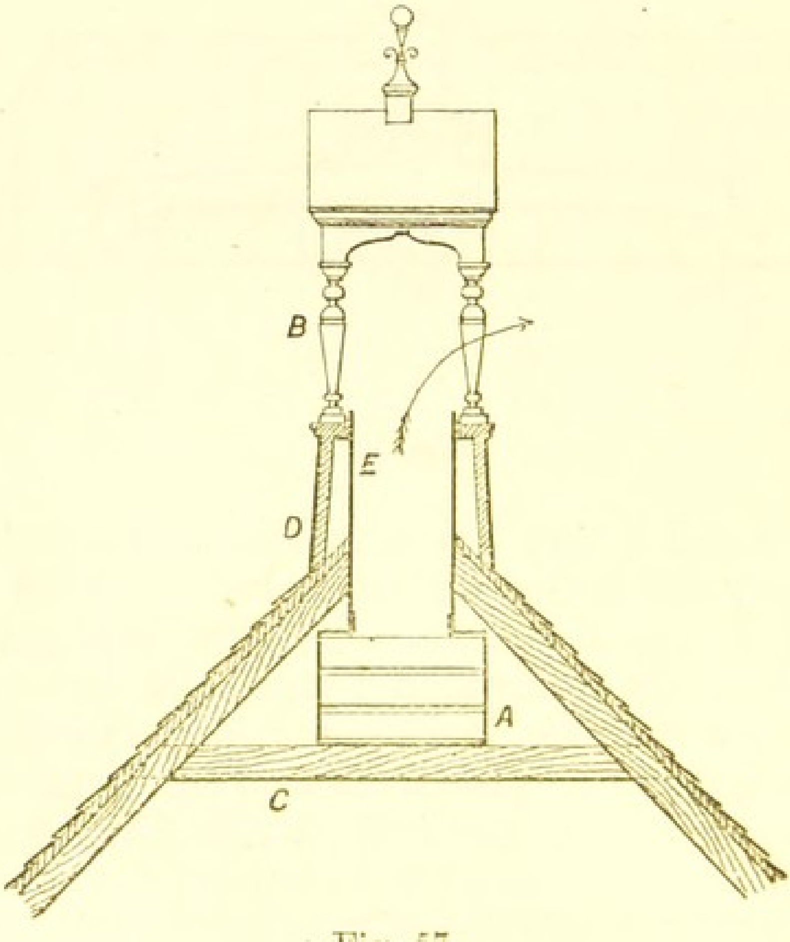


Fig. 57.

from the interior passing up through the ceiling openings C and D cannot get out anywhere, except up through the valve-boxes A and pipes E. The ventilators and valve-boxes shown in the last nine sketches illustrate those fitted up in buildings with a garret or an attic, or empty space above the ceiling. In *open-roof* buildings the outlet ventilating appliances have to be fitted up in a different manner.

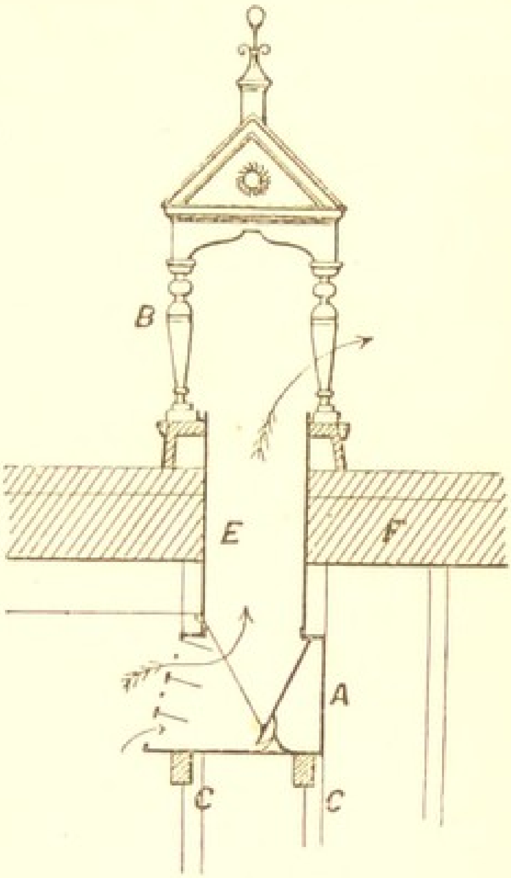


Fig. 58.

Figs. 57 and 58 show a self-acting valve-box, A, fitted up inside an open roof a little below the ridge. The valve-box in this case is shown as supported by two small wooden joists, C, each about 3½ in. or 4 in. deep by 2 in. thick. In other cases the valve-box may be suspended by a couple of strong straps made of strong hoop-iron, just as may be most suitable in the circumstances.

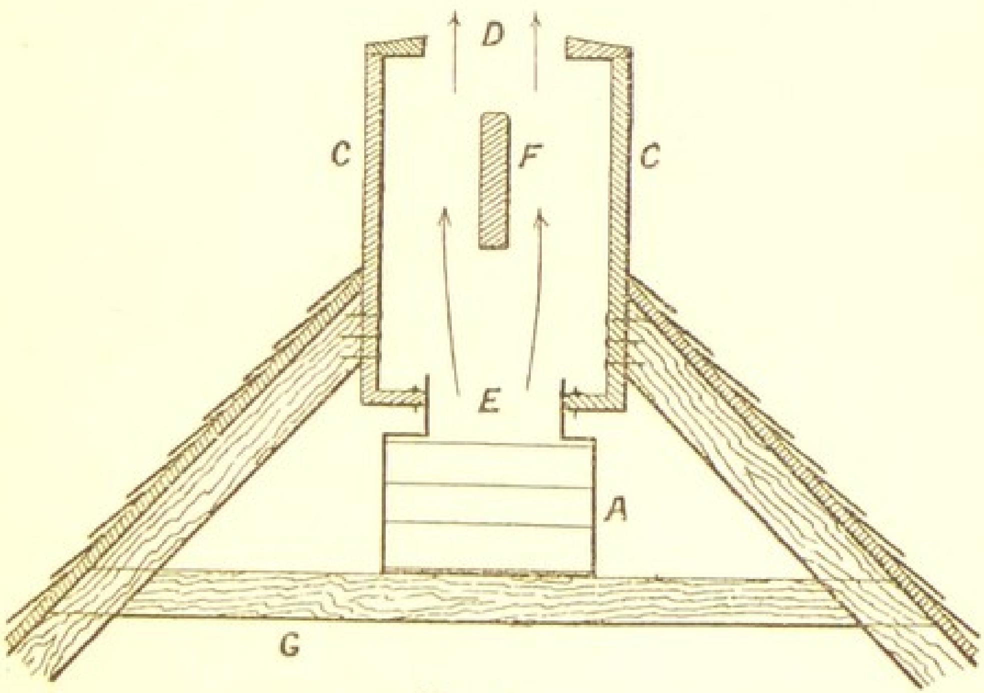


Fig. 59.

Fig. 57 shows sectional view of the roof with a No. 7

ventilator, B, seated on wooden frame, D, above the ridge. Fig. 58 illustrates a longitudinal view of the same ventilator and valve-box, and shows the outlet pipe, E, passing up through the roof E. Figs. 57 and 58 show the ridge cut to allow the pipe E to pass up to the ventilator. In some cases, however, it is desired not to cut the ridge F.

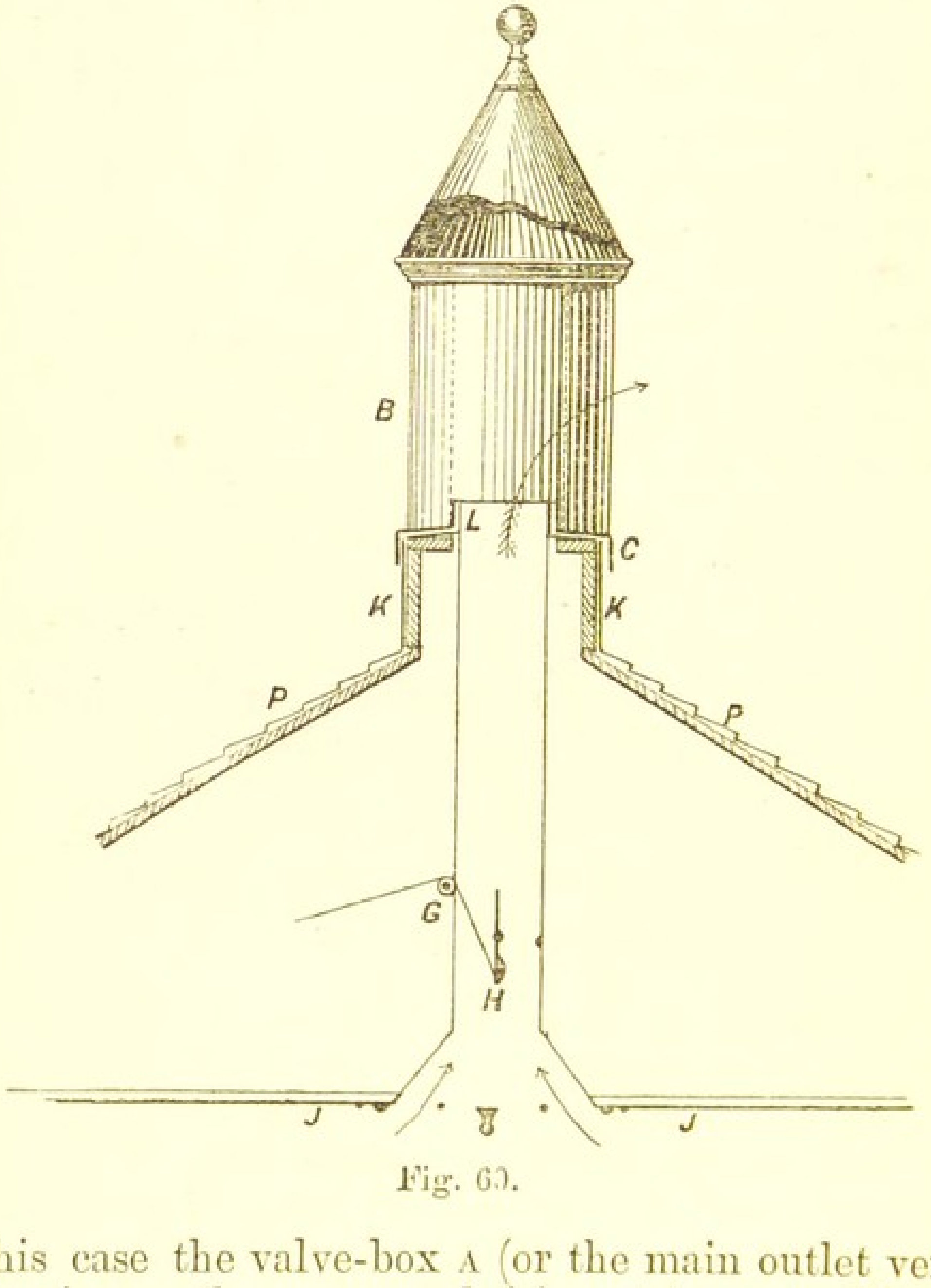


Fig. 60.

In this case the valve-box A (or the main outlet ventilating pipe, as the case may be) is put in as per Fig. 59, the wooden frame, C, being let down inside the roof, and the pipe, E, attached to its bottom. G is one of the small wooden joists supporting the valve-box A. The outgoing air goes up through the valve-box and the pipe E, and passing each side of the ridge, F, goes up through the hole or opening, D, into and then out through the ventilator to be seated upon the square (or octagonal, &c., as the case may be) wooden frame C.

Figs. 47 to 59 refer to the exhaust ventilators fitted up with anti-down-draught valve-boxes. In many cases

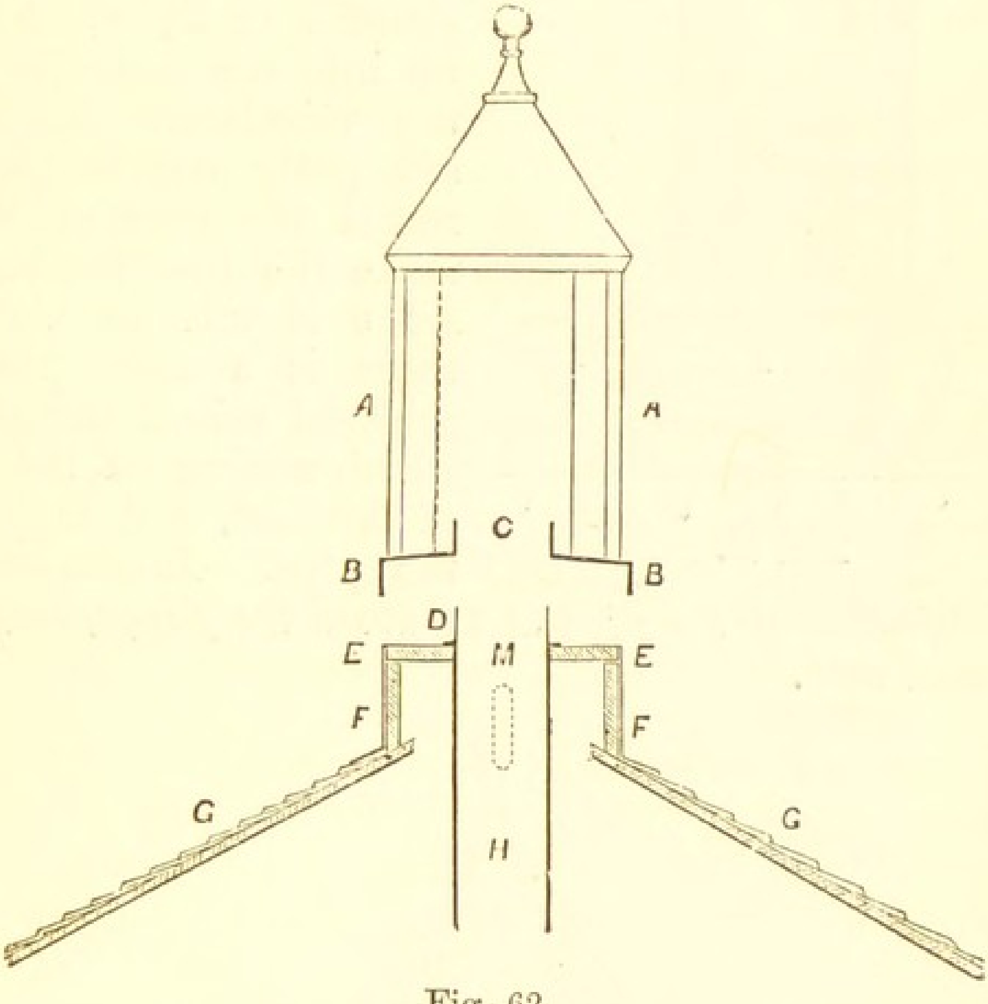


Fig. 62.

the ventilators are fitted up, as per Fig. 60, without a valve-box. In Fig. 60, B is a No. 2 I.C. fixed ventilator seated upon a square or octagonal wooden base, with lead or zinc flashings, K K, around it. L is the outlet pipe, and at G there is a cord or wire working over a pulley to close the metal valve, H, when wished.* J J is the ceiling.

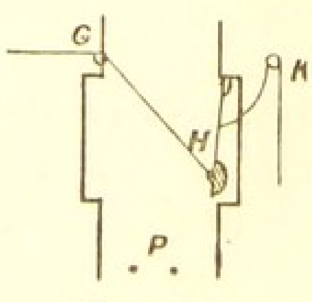


Fig. 61.

* Instead of the metal valve being in the centre of the round pipe as at H, Fig. 52, the pipe here may be square in order to let the valve hang at one side, as per H, Fig. 61. This is best where gas jets may be inserted below, as at P, see note to Fig. 76, page 103.

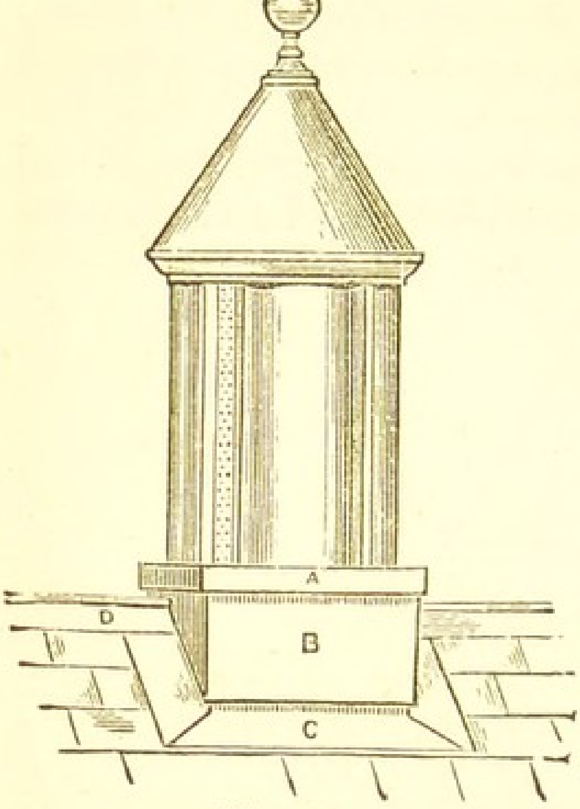


Fig. 63.

Fig. 62 shows a No. 2 ventilator, A, in the act of being lowered down upon the frame or seat, E E, prepared for it. The projecting pipe, D, stands up about 2 or $2\frac{1}{2}$ in. to slip up into the socket, C, of the ventilator. A little soft putty may be placed round the pipe at D to make the junction tight. At D it will be noticed there is a metal flange soldered round the pipe, which resting on the top of the seat, E E, supports the pipe. *In some cases the projection of the pipe at* D, *above the flange, may be dispensed with.*

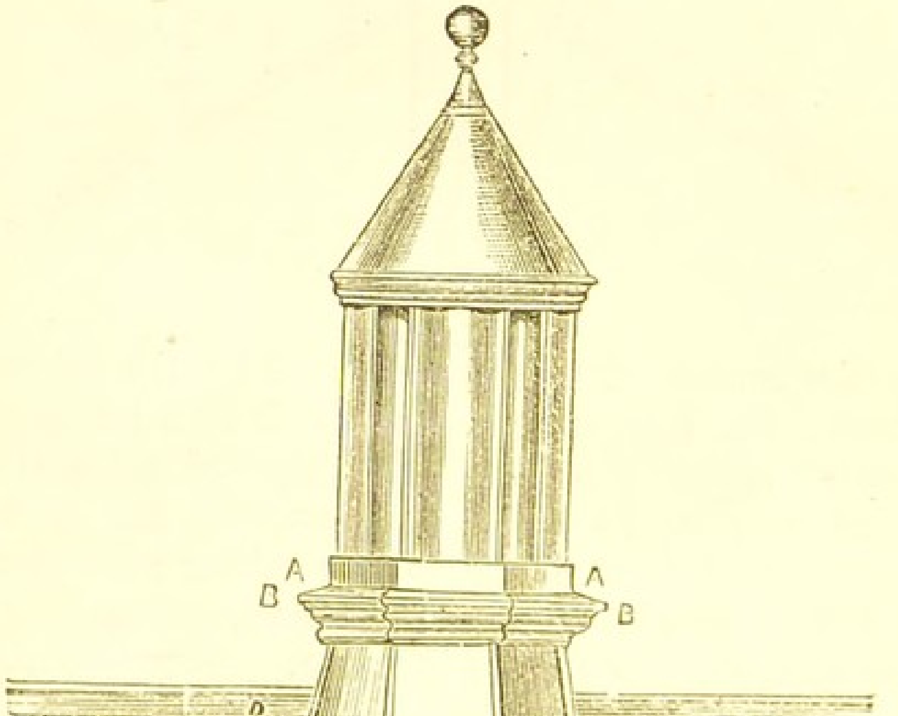


Fig. 64.

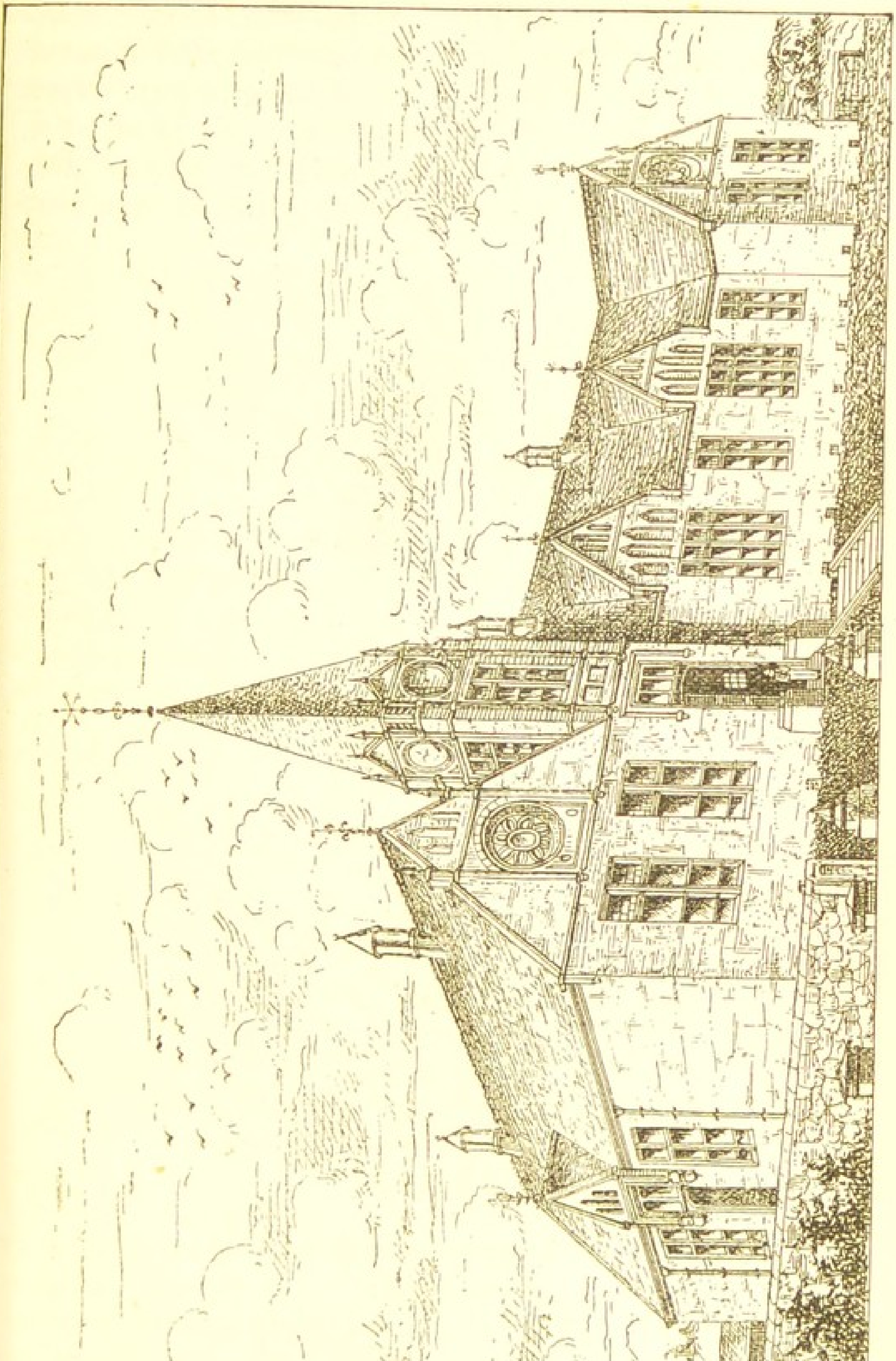


Fig. 65.

Figs. 63, and up to Fig. 73 inclusive show various styles of the author's Induced-Current Fixed Exhaust Ventilators set up above the ridge of the building (except Fig. 72, which is to one side of the ridge). While Fig. 63 shows a No. 2 ventilator with a square base A,* Fig. 64 shows the same ventilator, but with the base, A, octa-

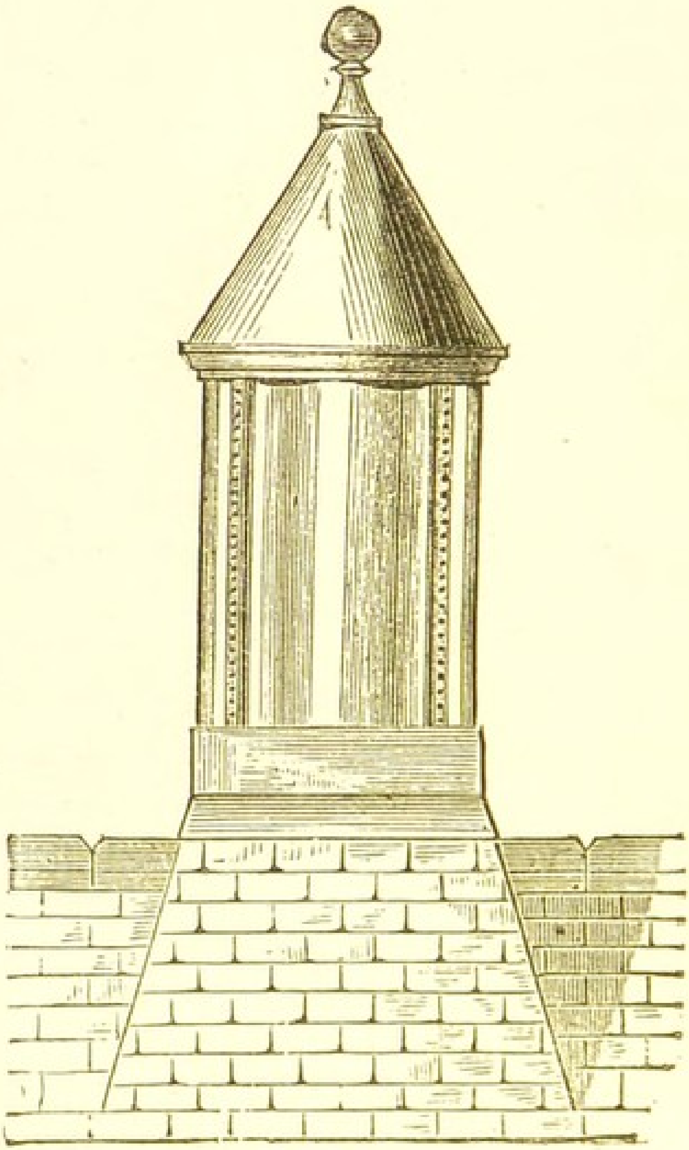


Fig. 66.

gonal. In this latter case the architect has provided an octagonal seat for the ventilator to sit on, and has kept this octagonal seat a good bit higher above the ridge than is the case in Fig. 63. This and the addition of the wooden moulding B, also provided by the architect,

* The top of the base A, Fig. 63, may be from 5 to 9 in. according to size of ventilator above the ridge.

makes the ventilator in Fig. 64 look much more artistic or ornamental than the one in Fig. 63. Both ventilators, *per se*, are the same price, but of course the style of fitting up shown in Fig. 64 costs more than that shown in Fig. 63. Mr. James M. Monro, architect, Glasgow, selected Fig. 64 for one of his churches, upon

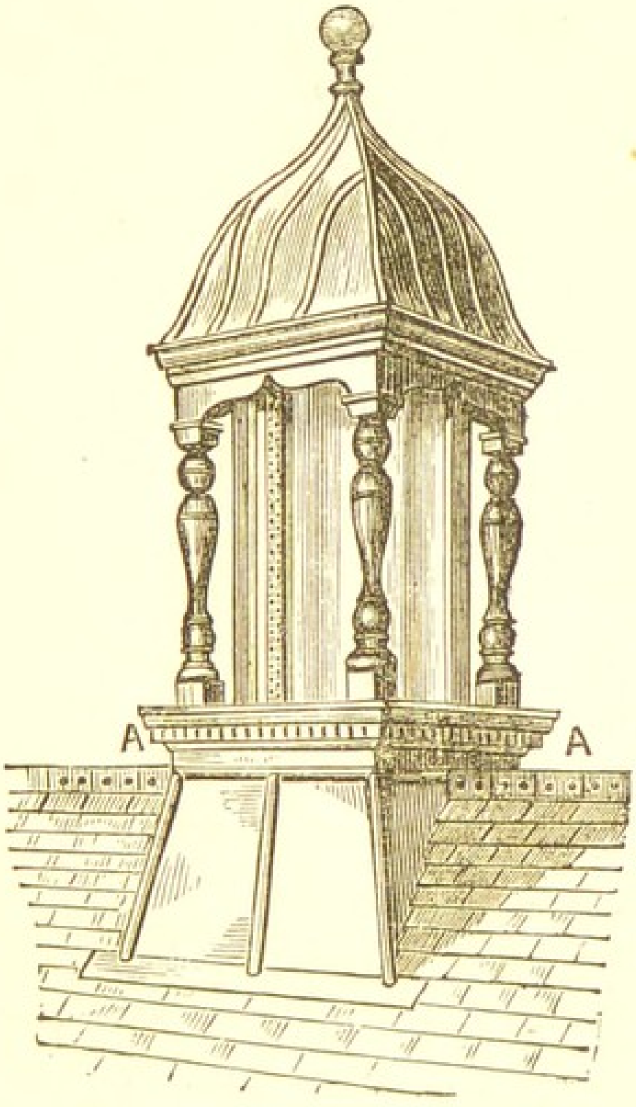


Fig. 67.

which he set up two of the octagonal base ventilators, and he says, "I consider they improve the appearance of the roof by breaking the long outline of the ridge."* These No. 2 Ventilators, with octagonal base, have also been supplied for a number of schools, and for Government barracks, &c.

* This tells well against the foolish notion that ventilators should be hid, just as if a ventilator were not as useful and had not as good a right to be seen as a chimney.

Fig. 65 shows the ventilators in Fig. 64 style upon the new Board schools at Cambuslang, the ground plan of which is given on page 73. With 10 square ft. of surface area for each pupil, and the height of the ceiling being 16 ft., this gives 160 cubic ft. of air for each pupil. This is not up to the 200 cubic ft. of space

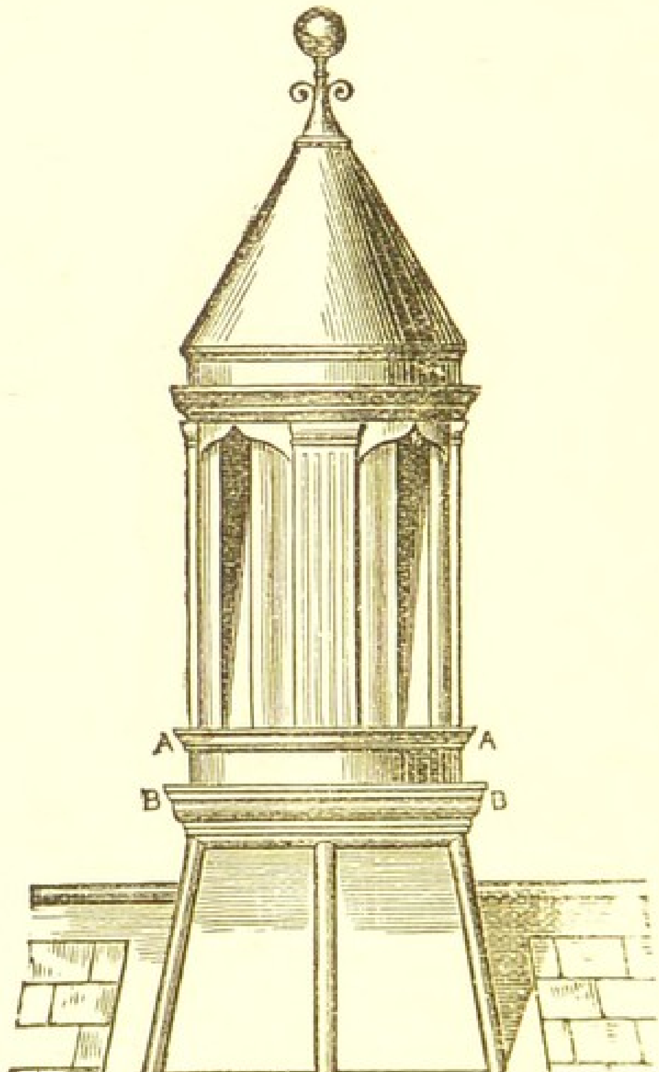


Fig. 68.

asked for as the minimum by Professor Hay, of Aberdeen, but it is better than what many schools have.

Fig. 66 shows a different style of seat from Fig. 63, but of the three I rather prefer Fig. 64.

Fig. 67 shows a No. 3 ornamental ventilator, set up above the ridge of roof. The wooden moulding A is added on to the square base of the ventilator in position.

This ventilator looks well upon the roof of a building, as, *e.g.*, upon St. George's Hall, George Square, Greenock, which has two of them set up above the ridge.

Fig. 68* shows a No. 5 ornamental ventilator with cornice and bevelled top, supported by four fluted

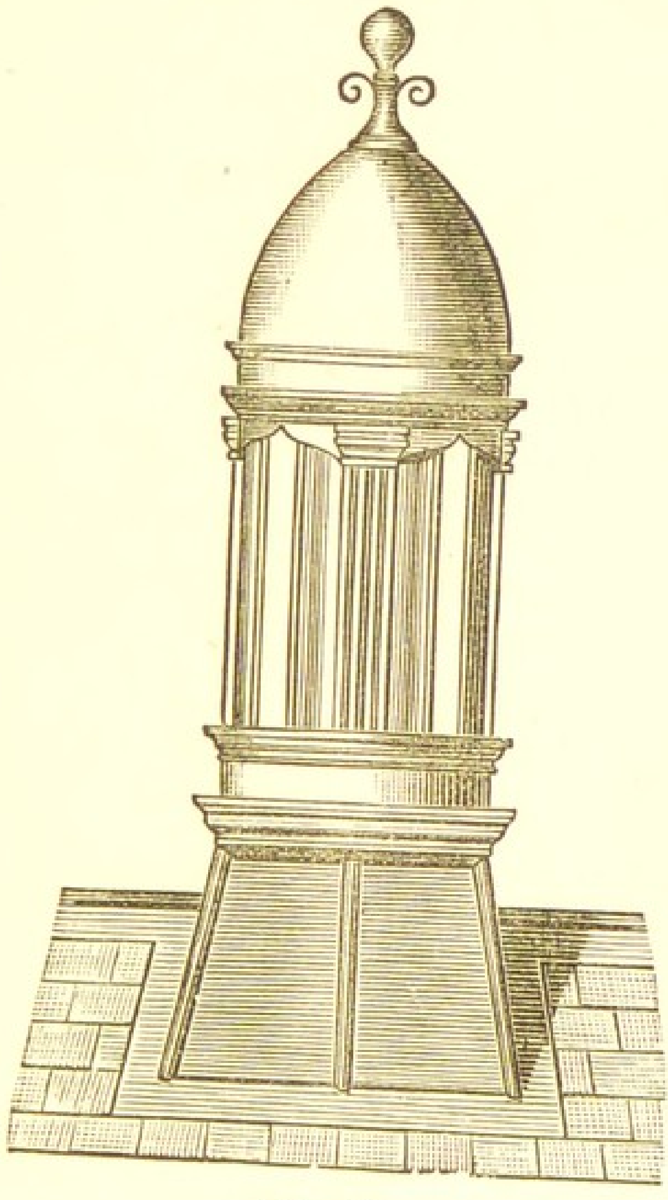


Fig. 69.

pilasters. The circular moulding at A, is in this case included with the ventilator, but the moulding at B is not, but is part of the seat. The base of the ventilator at A is round, but the seat or frame is square. Amongst

* For Figs. 68 and 69 a round wooden seat stands up from five to nine inches high (according to size of ventilator), above the top of moulding B B, for the ventilator to sit on.

other places, this ventilator has been used by Mr. James Thomson, F.R.I.B.A., Glasgow, in carrying out the ventilation at Gartshore House.

Fig. 69 shows a modification of Fig. 68. It is known as "No. 6" and has a dome top.*

Fig. 70 is a favourite pattern of ornamental ventilator (in Queen Anne style), termed "No. 7." The mould-

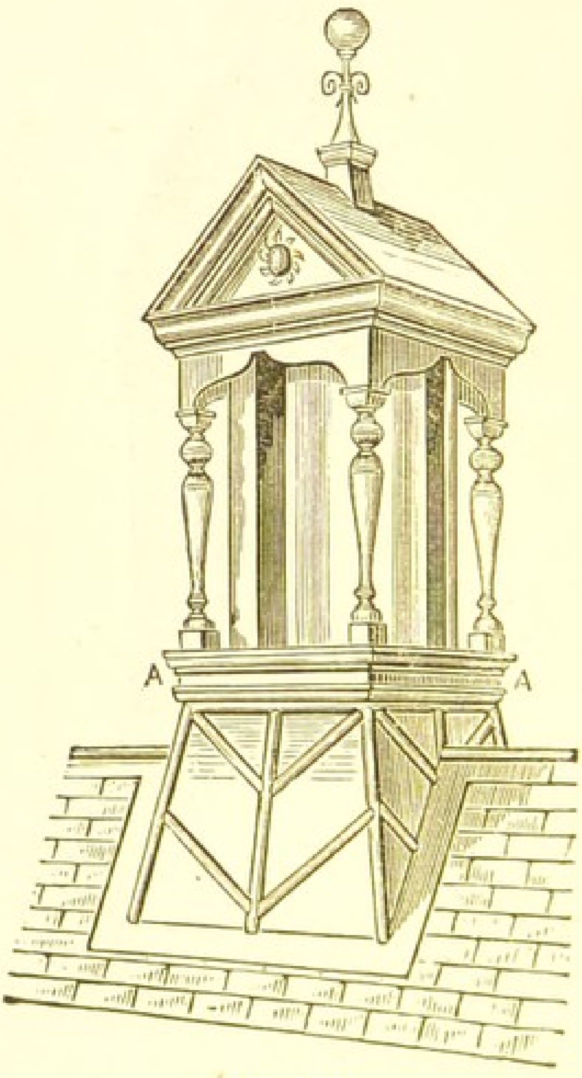


Fig. 70.

ing at the base A A, is not part of the ventilator as sold, but is added on after the ventilator is set up in position. Messrs. John Melvin and Son, architects, Alloa, wrote of these:—"They are the best design of roof ven-

* Nos. 3, 5, and 6 ventilators are suitable for buildings erected in the free Classic or Italian style. These and Nos. 1, 2, 7, &c., were designed by Mr. W. G Rowan, architect, Glasgow.

tilators we have yet seen, and we understand they have worked well."

Fig. 71 is termed "No. 9." It is also shown seated above the ridge. This pattern was used by Messrs. Wm. Henderson and Son, architects, Aberdeen, for the Morningfield Hospital for Incurables there, to suit the style of the architecture.

Fig. 72 shows a No. 2B ventilator with dome top, set up upon a wooden frame *to one side*, or at the back of

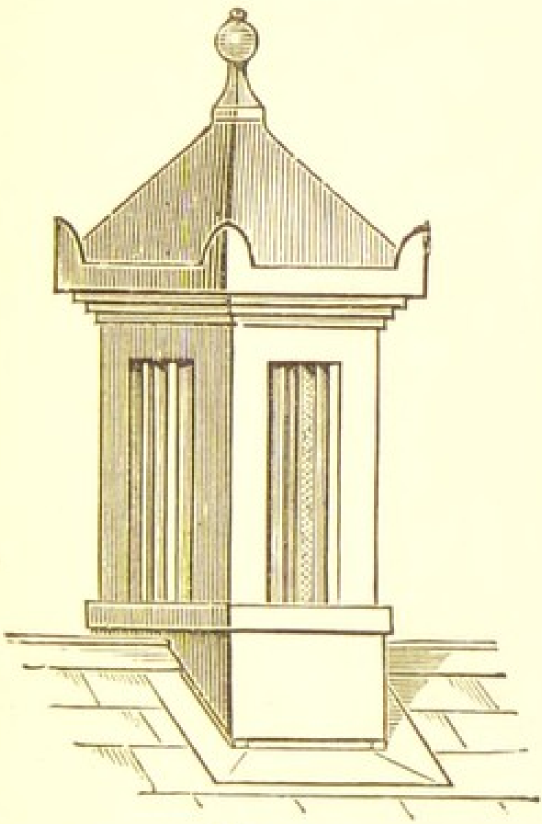


Fig. 71.

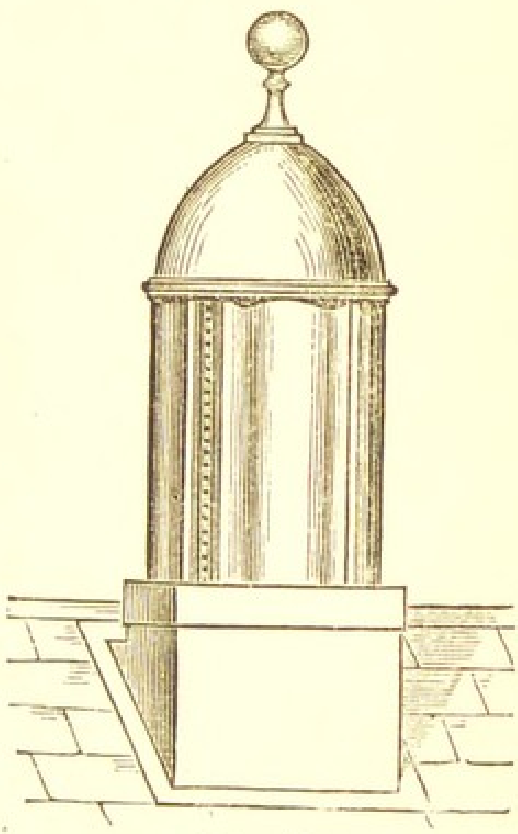


Fig. 72.

the ridge. The bottom of the base of the ventilator should be as high as the top of the ridge, or, to otherwise express it, the top of the frame or seat should be from 4 to 6 in. above the top of the ridge.

Fig. 73 shows a No. 12 ornamental ventilator in Gothic style, seated upon a wooden frame prepared for it, and erected so as that the top of the frame is from 9 in. to 15 in. or so above the ridge, according to the size of the ventilator.

This Fig. 73 ventilator is all of metal—generally galvanized sheet iron, or steel may be used—except the four pillars, which are wood. The pillars in Figs. 67 and 70 are also of wood, turned.

Instead of using the style of ornamental ventilators illustrated in Figs. 67 to 73, the architect will sometimes use a plain No. 2 ventilator, as per Fig. 63, but with a flat top as per D D, Fig. 74, or the top may be

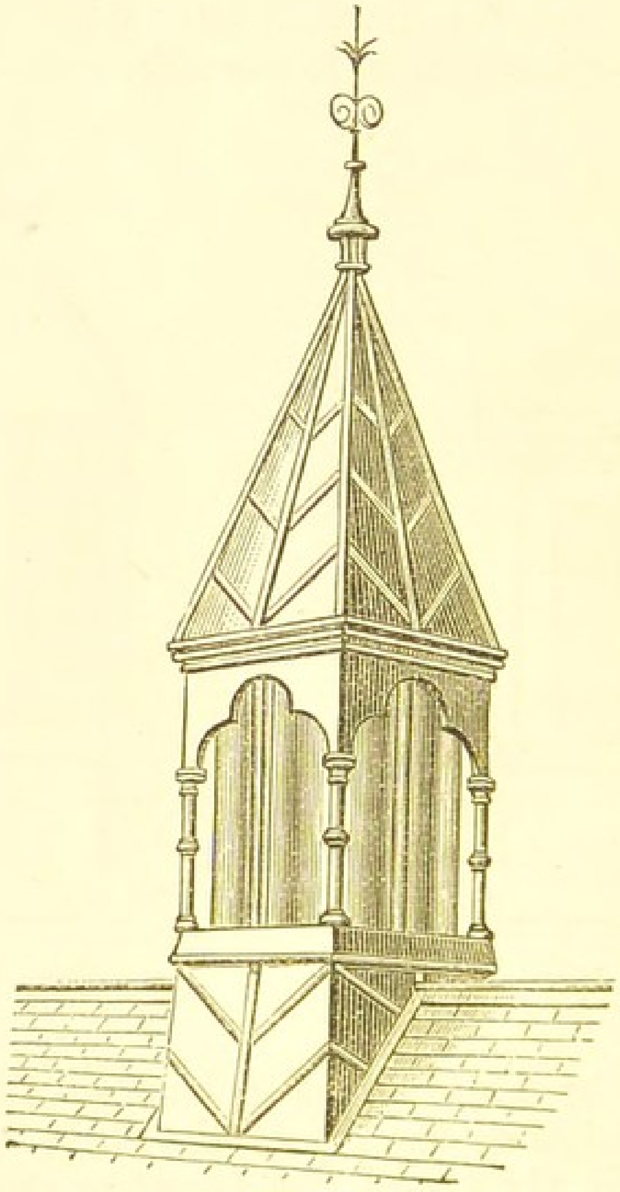


Fig. 73.

rounded as per dotted line E, Fig. 74. The architect places this Fig. 74 ventilator above the ridge, and sets up an ornamental framework of wood of his own design, as per Fig. 75, around and above it, but in such a way as not to impede the action of the ventilator. This form of ventilator, shown in rough elevation in Fig. 74, and in horizontal section in Fig. 89, adapts itself much more readily and artistically to the architect's outer cases, than some others which looked more like a huge cabbage in a large bird's cage, than an appropriate architectural appendage to the building. Of course, however, tastes differ.

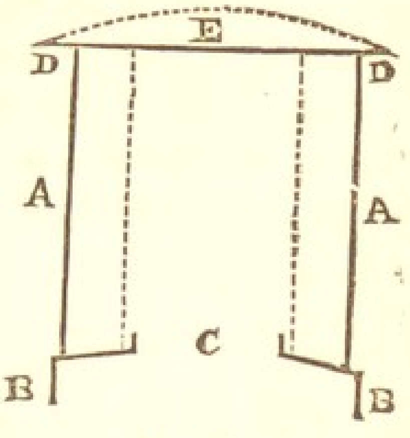


Fig. 74.

Fig. 75 shows the outer case, designed by Mr. James Gillespie, architect, for the St. Leonard's School Hall, St. Andrews.

In setting up exhaust ventilators above the ridge of a building, it is a question whether or not to cut the ridge to allow the ventilating pipe to join the ventilator. Fig. 76 shows the ridge A cut away so as to allow the pipe P to pass right up to above the top of the frame, as at D, where the pipe is shown with flange about 2 in. from the top to suspend the pipe.*

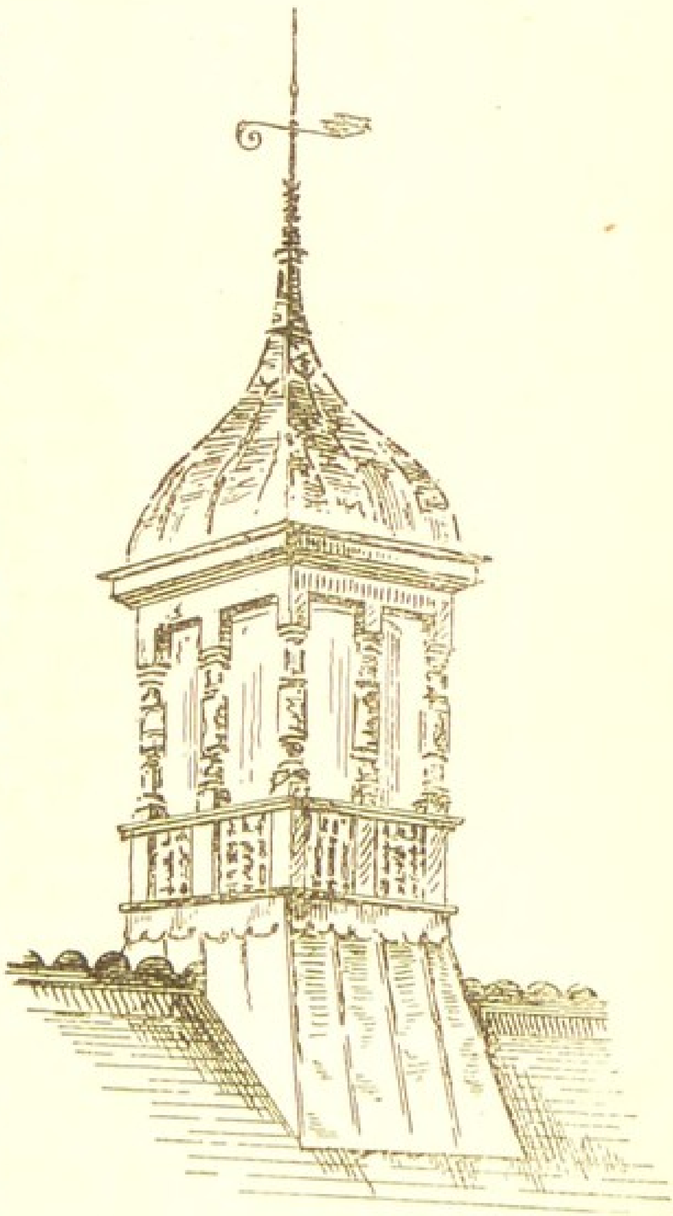


Fig. 75.

Fig. 77 shows how to make and fix the wooden frame C, so as to leave the ridge A intact. In this case the pipe P is attached by means of a flange to the bottom of the

* When gas jets are to be burned in the inside of the pipe P in calm

wooden frame as shown in Fig. 77, the flange being screwed to the bottom of the wooden frame.

Fig. 78 is cross sectional illustration of the wooden frame required for Figs. 68 and 69. In Fig. 78 the ridge A is shown as cut to allow the pipe to pass up to

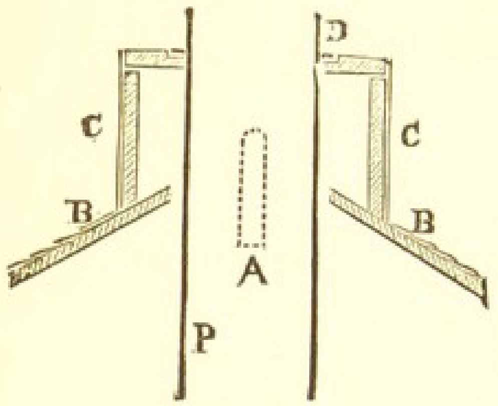


Fig. 76.

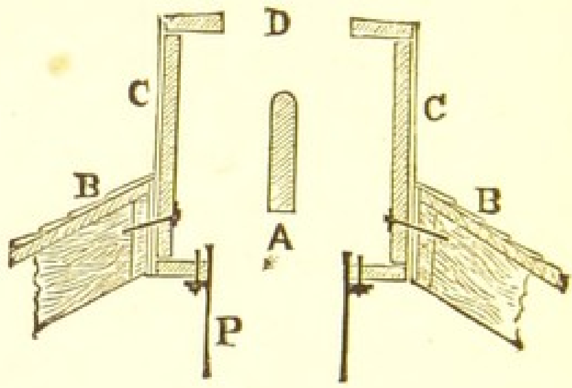


Fig. 77.

the ventilator, when it is required to pass the pipe up. In some cases when the pipe is large, say 2 ft. or more in diameter, the pipe is sometimes passed up without cutting the ridge, by cutting a slit out of each side of the pipe, and then soldering in a piece at the part cut, or else putting in the pipe there in two pieces, and making all tight; the upper piece of pipe being slipped into the lower an inch or so, and soldered all round.

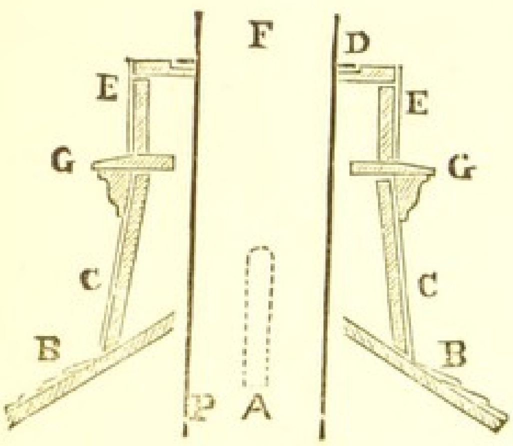


Fig. 78.

If preferred, however, the wooden frame in Fig. 78, may be made longer so as to go down inside the roof a bit and be fixed as shown in Fig. 77.

Fig. 79 is sketch showing both inlet and outlet venti-

weather to increase the up current the top of the seat at D, instead of being of wood, may be $\frac{1}{8}$in. or $\frac{1}{4}$in. thick sheet iron in Figs. 76, 77, and 78, so that the heated air off the gas flames may not come into contact with wood. It would not do to burn gas near to or below the wooden ridge if left in. See note to Fig. 60, page 93.

lation. W is fresh air inlet at window, and with hot water or steam piping to heat the incoming air.

N is a Tobin's tube fresh air inlet, with hole in wall below floor. R is either for supplying fresh air from outside through inlet P, or it may be an iron radiator.

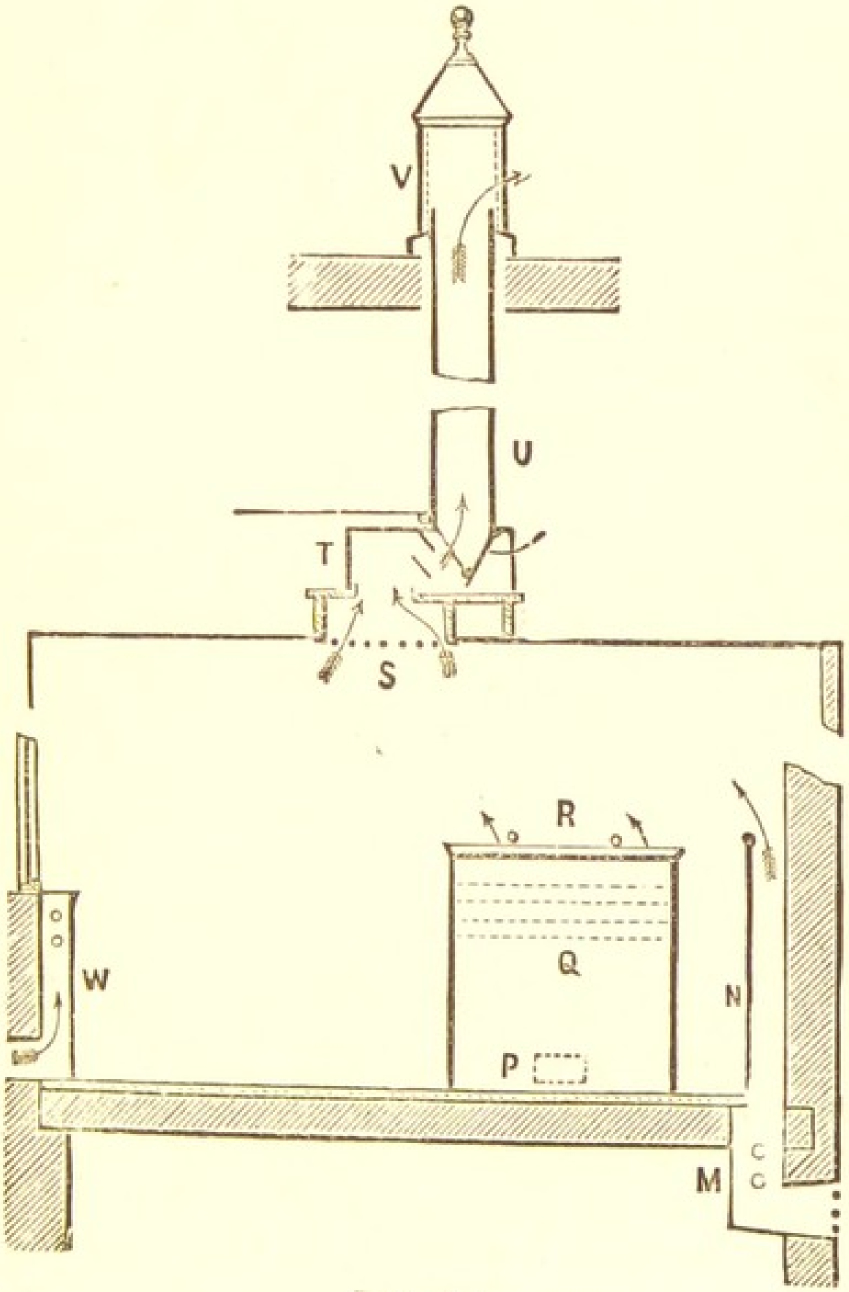


Fig. 79.

T is a self-acting valve-box, style A, set up above the ceiling. The outlet S in ceiling should always be larger than the full area of the pipe so as not to impede the outgoing air. The author has just seen some ceiling outlets whose area was considerably *less* than that of the outlet pipe; which is a great mistake.

In some cases provision may be made so as to light one or more gas jets inside the outlet ventilating pipe, above the valve box, as at U, at an odd time when it may be especially desired, in order to increase the speed of the outgoing air.

Fig. 80 indicates two separate rooms or halls ventilated into one main outlet ventilating pipe B.

In this case there are two style A valve-boxes fitted in, one at C and one at D, with branch pipes E and F joining into the main pipe B. G is seat for the ven-

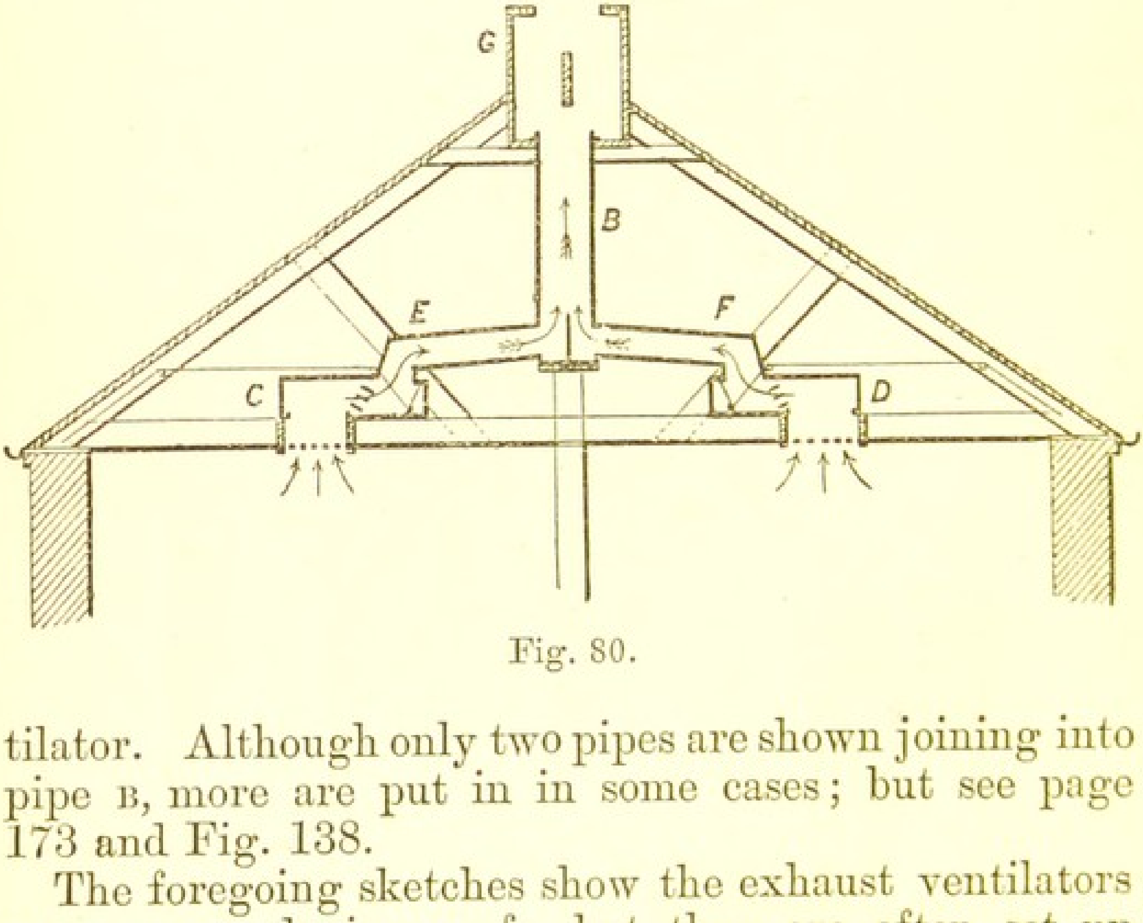


Fig. 80.

tilator. Although only two pipes are shown joining into pipe B, more are put in in some cases; but see page 173 and Fig. 138.

The foregoing sketches show the exhaust ventilators set up upon sloping roofs, but they are often set up upon flat roofs, and especially in the case of billiard rooms on the top flat of a building. There will only be about 1 ft. between the ceiling inside and the top of the sheet lead covering the platform. The author, in such a case, has put the self-acting valve-boxes in between the ceiling joists, as per Figs. 81 and 82.

In Fig. 81 we have a cross vertical section through the valve-box, A A, and the ceiling joists, B B B. C C is the ceiling, D D the lead on top of flat.

In Fig. 82 we have longitudinal vertical section of the valve-box, A, set in between two of the ceiling joists. E is a No. 1 Buchan's induced current fixed ventilator, set up upon the outlet pipe of the valve box. F indi-

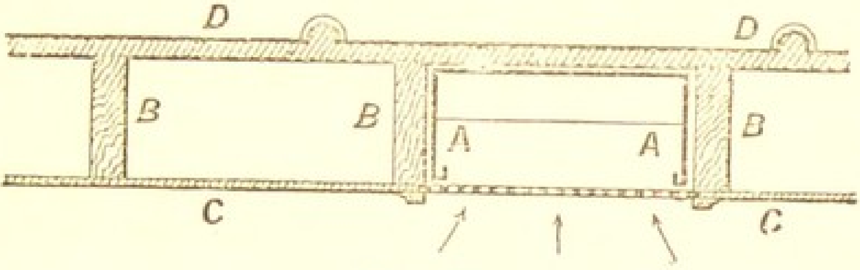


Fig. 81.

cates that four strong wires may be used for staying the ventilator; G indicates how the metal valve may be closed when desired by pulling the cord or wire H; J J show the self-acting silk valves open.

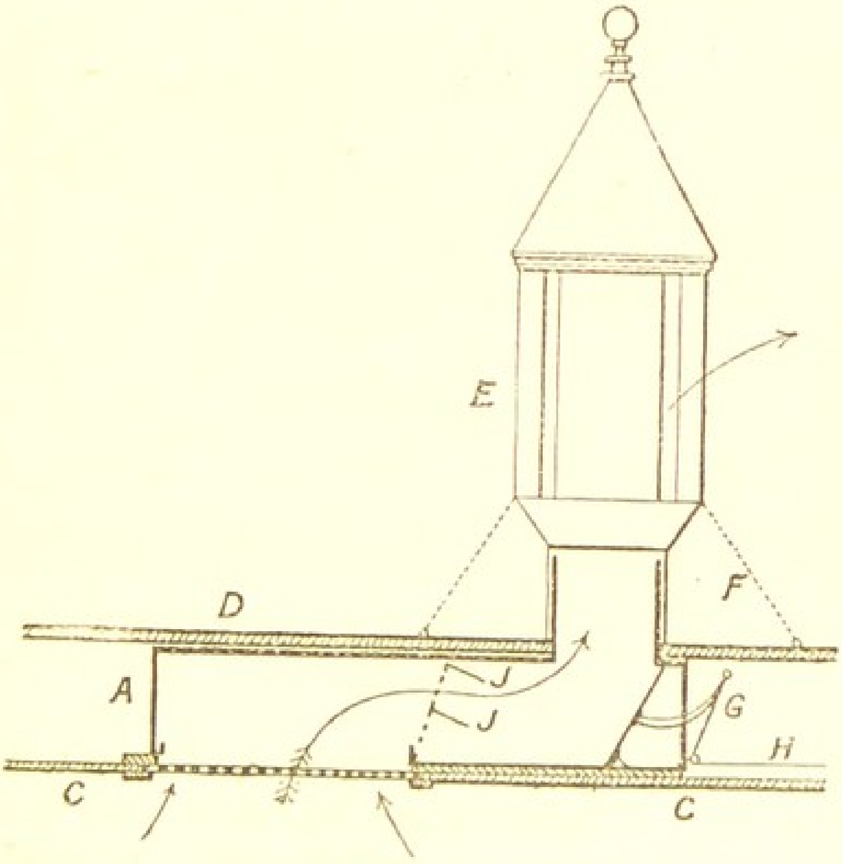


Fig. 82.

Fig. 83 shows how the 30-in. No. 2 ventilators, E, with flat covered top, were placed upon the flat roof, D D, of a large billiard room. C C is the ceiling inside, and A A is one of the 18 in. "style A," self-acting valve boxes. Three of these were placed above the roof of the room, which has four tables in it. The room is 15 ft. high inside. The three ventilating outlets in ceiling are each about 30 in. square.

As the valve boxes are higher than the space between the ceiling C inside and the lead on the top of the flat or platform D, there is a wooden casing or box, G G,

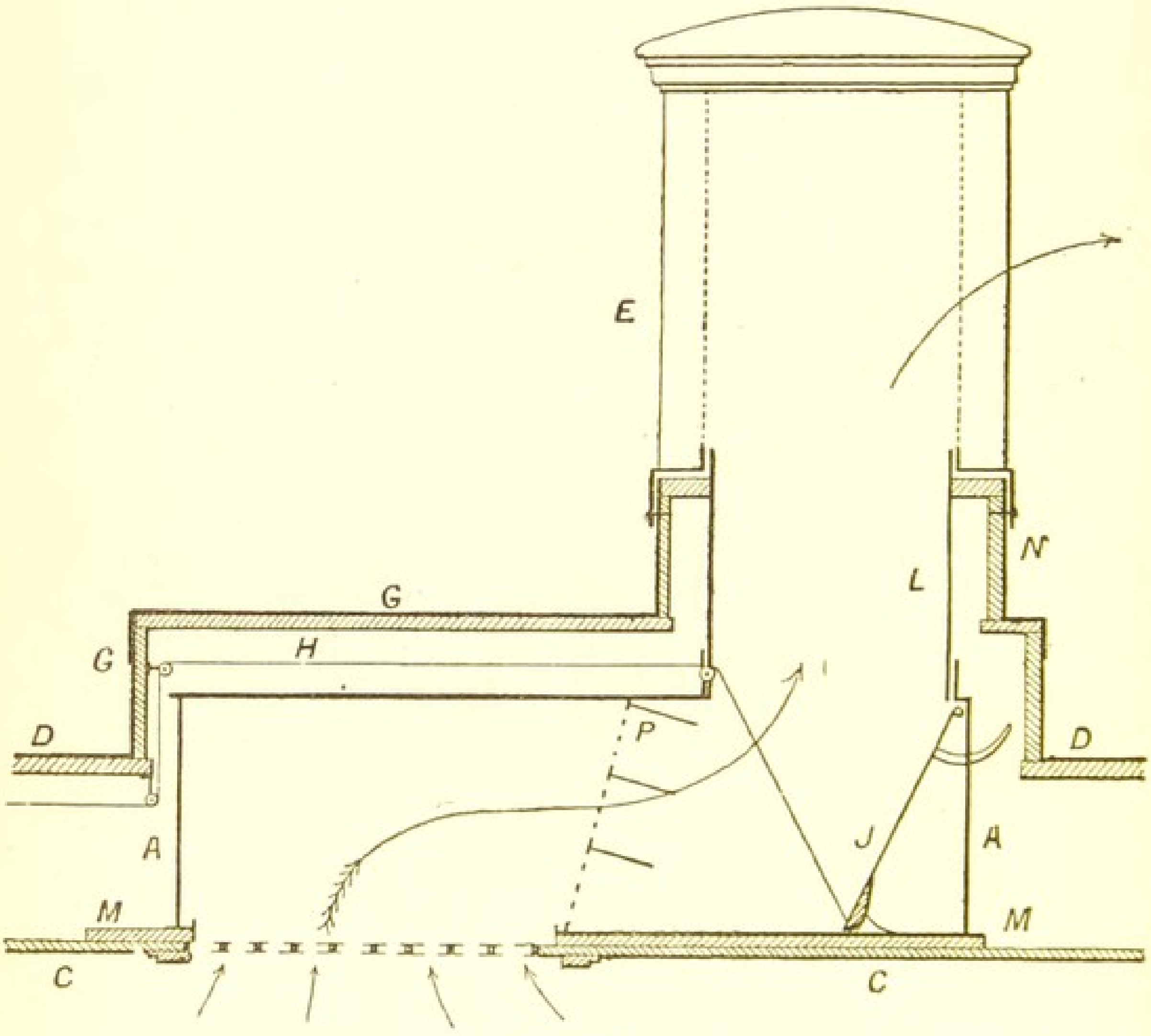


Fig. 83.

covered with sheet lead, set up high enough to let the valve box in. Where it is wished to have a cord put in, as at H, to work the metal valve, J, then a little extra height has to be allowed in the box G for this. The three self-acting silk valves are shown at P. L is a short piece of 18 in. diameter piping, put in between the top of the valve-box and the bottom of the ventilator. N is the square wooden base upon which the ventilator sits. This base rests upon the wooden frame, G G. Both the wooden frame, G G, and the wooden base, N, have lead flashings to keep out the rain.

The valve box may rest upon a long wooden board, or on several shorter pieces placed crosswise for strength, as indicated at M M. Or it may be hung up by kneed

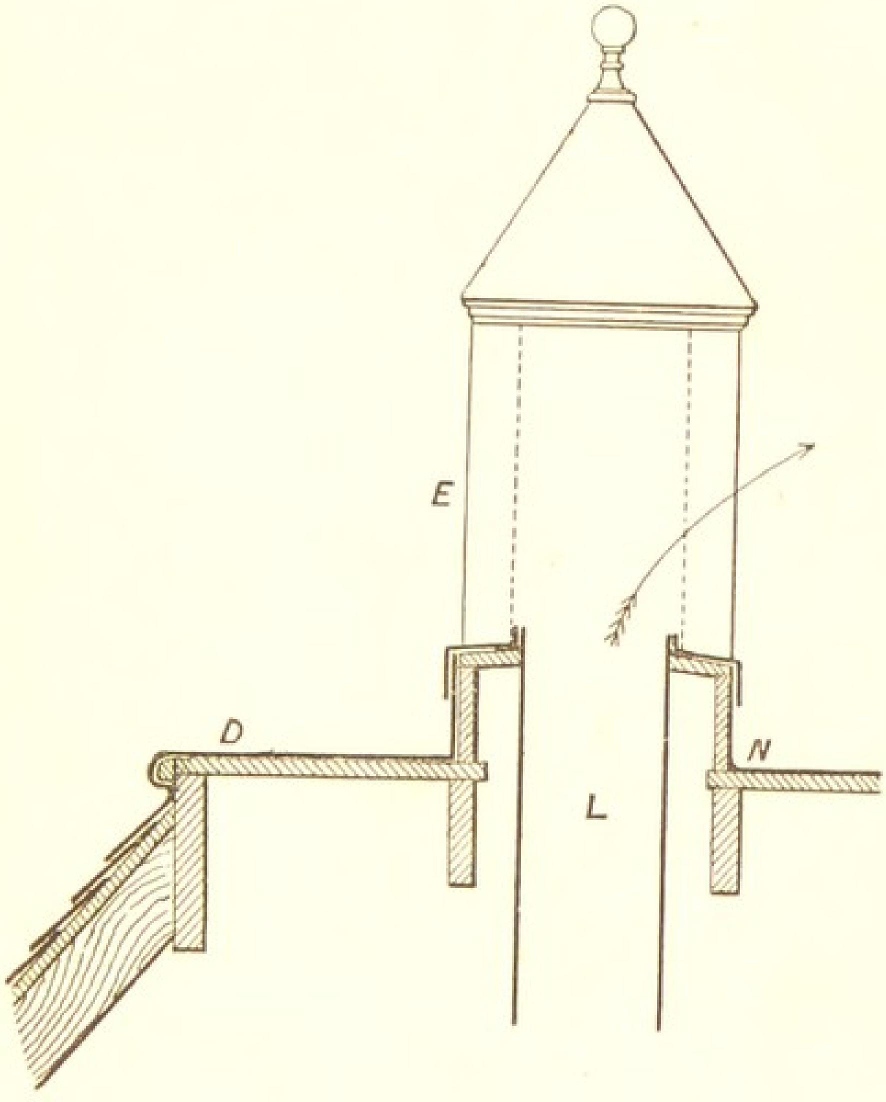


Fig. 84.

pieces of strong hoop iron. These are fixed to the sides of the ceiling joists.

This style, without the metal valve J, was adopted for the new billiard rooms of the new Athenæum at Glasgow; Messrs. Burnet, Son, and Campbell, architects.

Fig. 84 shows another style of setting up a No. 2 ventilator upon a flat roof, or rather upon the flat or platform on the top part of the roof. In this case it is supposed that there is an empty garret space between the flat and the ceiling of the hall or room below.

L is the outlet pipe, E the ventilator, D the top of the flat, and N a square, or octagonal, or round wooden frame or seat upon which the ventilator E rests.

Figs. 85, 86, and 87 show different styles of induced-current fixed exhaust ventilators, styled respectively No 1, No. 1A, and No. 1C. These are not generally used with wooden frames or seats, like Figs. 63 or 64, 83 or 84; but are made to slip on to the ventilating

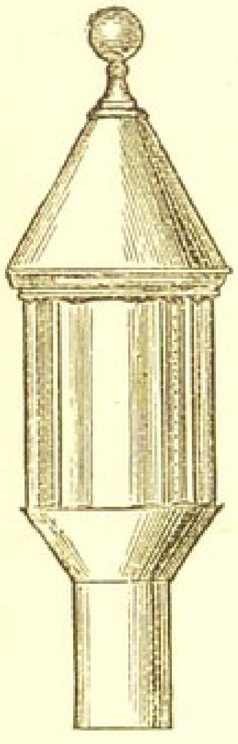


Fig. 85.

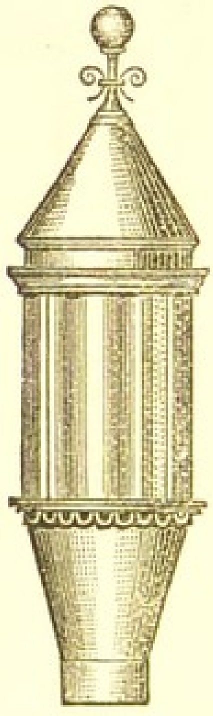


Fig. 86.

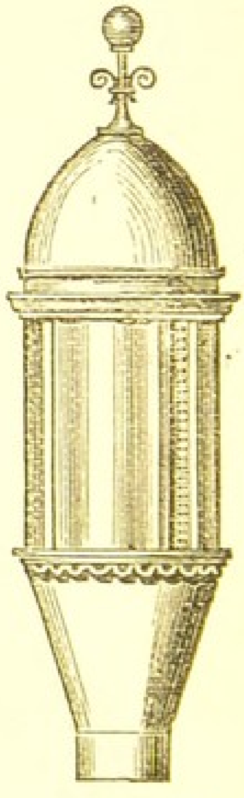


Fig. 87.

pipes they are for, which pipes may be either projecting up through the roof, as shown in Fig. 88, or the pipe may be set up against the wall of the building outside, as for the ventilation of soil-pipes, drains, sewers, workshops, water-closets, &c.

Fig. 87 ventilator, being ornamental in style, is nearly twice as expensive as the plain Fig. 85 ventilator, just as the ventilator in Figs. 67 or 70 is twice as dear as that shown in Fig. 63. The extra expense for ornamentation does not help the *working* any, although it may please the eye. In Fig. 88 the arrow D shows the direction of the wind, while the arrow E shows how the wind after it has come up the slope of the roof is deflected forward after it gets above the ridge a little.

It was one of the author's Fig. 85 style of fixed ventilators that beat all the other wind-acting exhaust ventilators—fixed and movable—of the principal makers in the kingdom by about 94,000 lineal ft. in 21 hours' testing as explained in Mr. S. S. Hellyer's work, "The

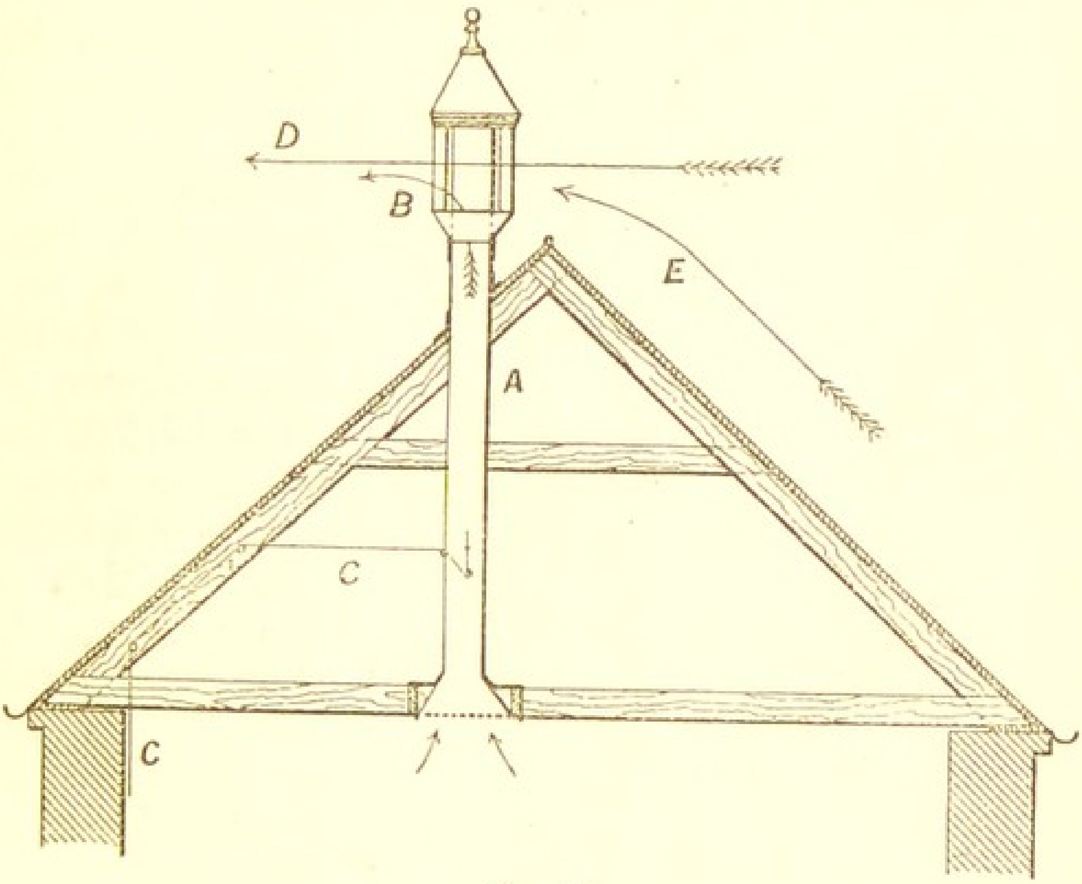


Fig. 88.

Plumber and Sanitary Houses."* The result of this testing demonstrated that the use of old-wife cowls and other movable ventilators was a mistake so long as equally good or better *fixed* ones could be got. The movable cowl is apt to go wrong, or stick fast, and does not last so long as a good fixed ventilator.

Fig. 89 is horizontal cross section of the author's induced-current fixed ventilator (as per patent No. 3062 of A.D. 1885). The interior circle C shows the diameter of the up-cast ventilating-pipe. The diameter of the

* Fig. 104 shows the ventilators Mr. Hellyer experimented with.

up-cast pipe in this case is more than half the diameter of the body of the ventilator, which body is confined within the large circle D.

The square A A A A shows how the square base is placed relative to the body of the ventilator, the four outlets being at the four *corners* in the No. 2 ventilators, as indicated in Fig. 63. The outlets are also at the corners in Figs. 68, 69, and 72.

The square B B B B, Fig. 89, with the small circle at each corner, indicates how the base is put on relative to the body of the ventilator in the ornamental ventilators shown in Figs. 67, 70, and 73, the small circles indicating the position of the pillars. In this case, as will be seen in the drawing, the four vertical outlet openings are at the *sides*, or *between the pillars*. When Fig. 74 ventilator is used for the interior of the architect's own design of case, it is generally set up with the openings *between the pillars*, as indicated by B B square, Fig. 89.

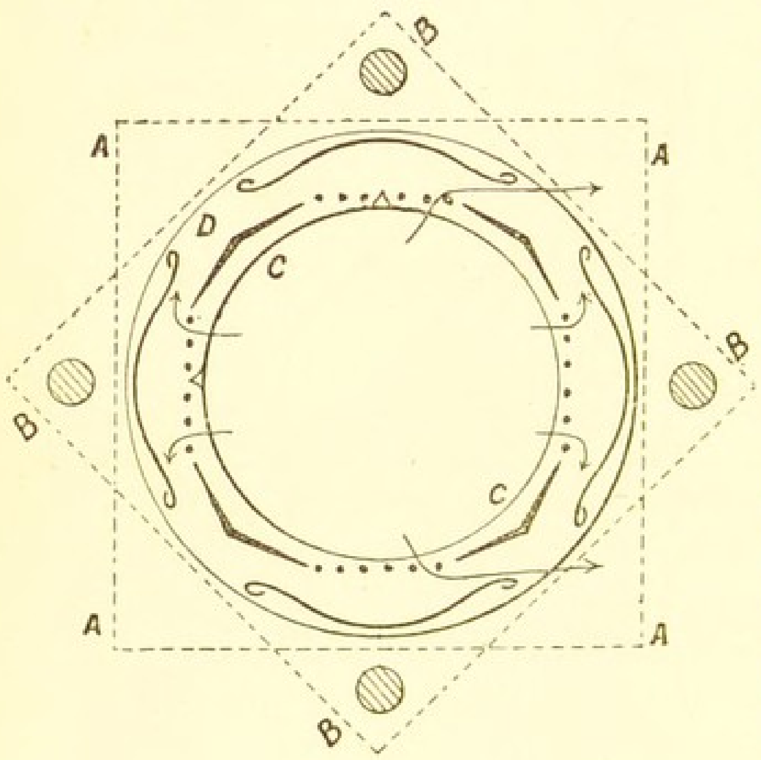


Fig. 89.

The four outer vertical louvres are wave-shaped, as seen in the drawing Fig. 89.

Fig. 90 shows longitudinal vertical section of a Buchan's Patent Style A valve-box, with say 22 in. diameter outlet pipe F, for a 36 in. ventilator. The inlet S in this case is shown the same width as the outlet, but if the outlet be circular and the inlet square, and of the same width, the area of the inlet will be considerably the larger.

This valve-box is illustrated in the article on "Ventilation" in the new edition of the "Encyclopædia Britannica."

In some cases, as shown in Figs. 49, 51, 52, 53, and 55, and as indicated by the dotted circle T and dotted lines

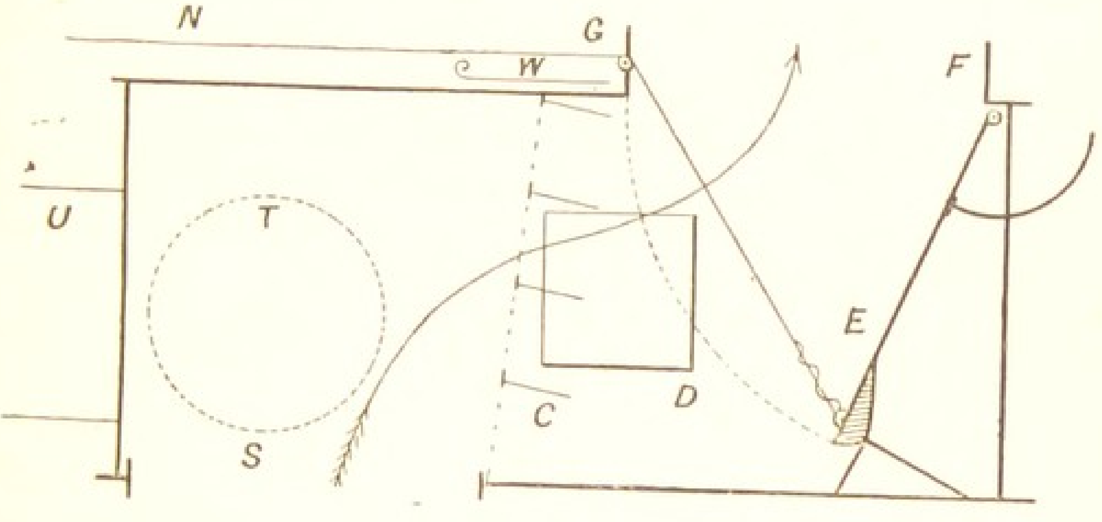


Fig. 90.

U, Fig. 90, the valve-box may have more *inlets* than one, in which case the bottom inlet S is reduced in size. The small square at D indicates that there may be a glass spy pane put in on each side of the valve-box, to look into its inside and see the self-acting silk valves C C working. These panes can be removed to get access into the interior of the valve-box. A sliding lid is sometimes put in at W, on top. E is the metal valve, which can be shut by pulling the cord or wire N, G is the strong brass pulley over which the cord works.

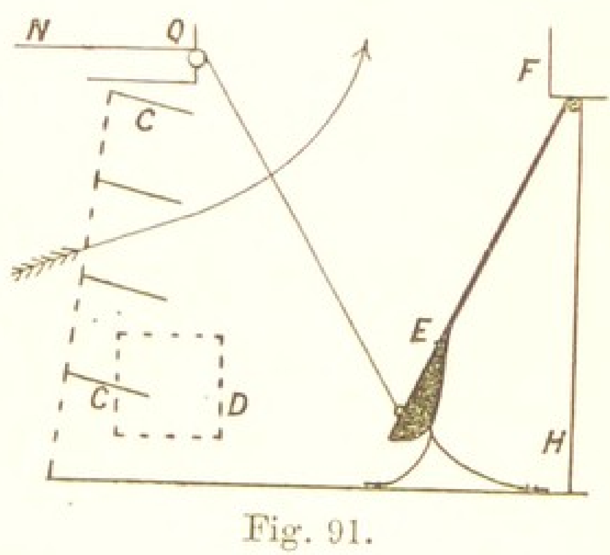


Fig. 91.

Fig. 91 is the anti-down-draught valve-box as made for an open roof * for the same size of outlet pipe F as in Fig. 90.

* If wished, an additional self-closing valve may be put in at H.

CHAPTER IX.

HIDDEN OR UNDER-RIDGE OUTLET VENTILATORS.

WE have been treating of exposed ventilators set up above the roof, where the wind can get freely blowing upon and past them in all directions, and upon valve-boxes in connection with such. Figs. 92 to 98 refer to

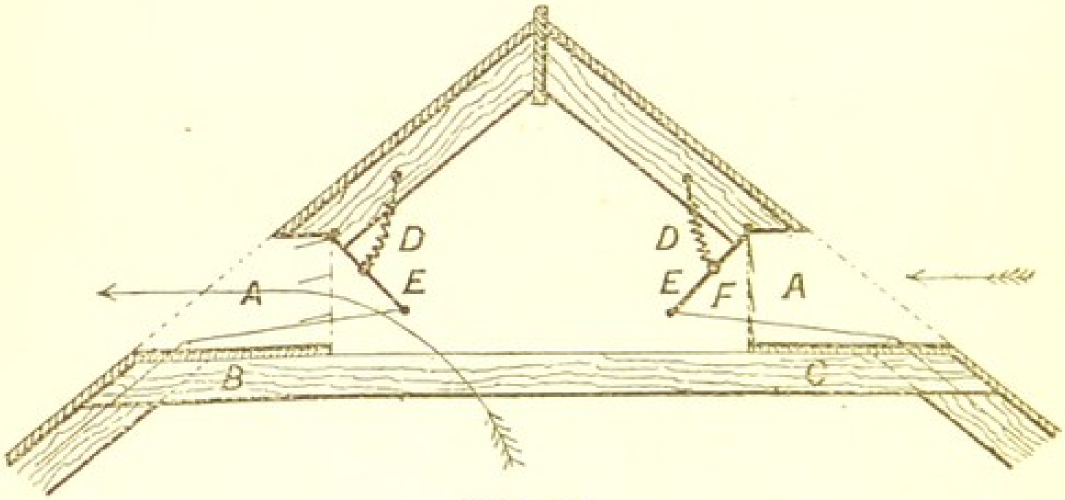


Fig. 92.

valve-boxes and ventilating outlets provided on the sides of the roof.*

In these the valves on the windward side are supposed to shut, those on the leeward side to open—*e.g.*, in Fig. 92 the silk or cloth valves A on C side are shut, while those on the B or leeward side are open. D D are springs or cord, weight and pulley to keep the valves E E open. The cord F is for shutting the valve. Fig. 92 is supposed to show an open roof. In Figs. 93 and 94 there is

* The working of these ventilators depends greatly on the air being pressed out through them from below.

shown a mode of applying the valve-box shown in Fig. 90 to the open channel system of outlet below the ridge. In this case the outlet ventilator C is placed in the centre of the open channel, and communicates with the valve-box A by the pipe B, while the vitiated air which

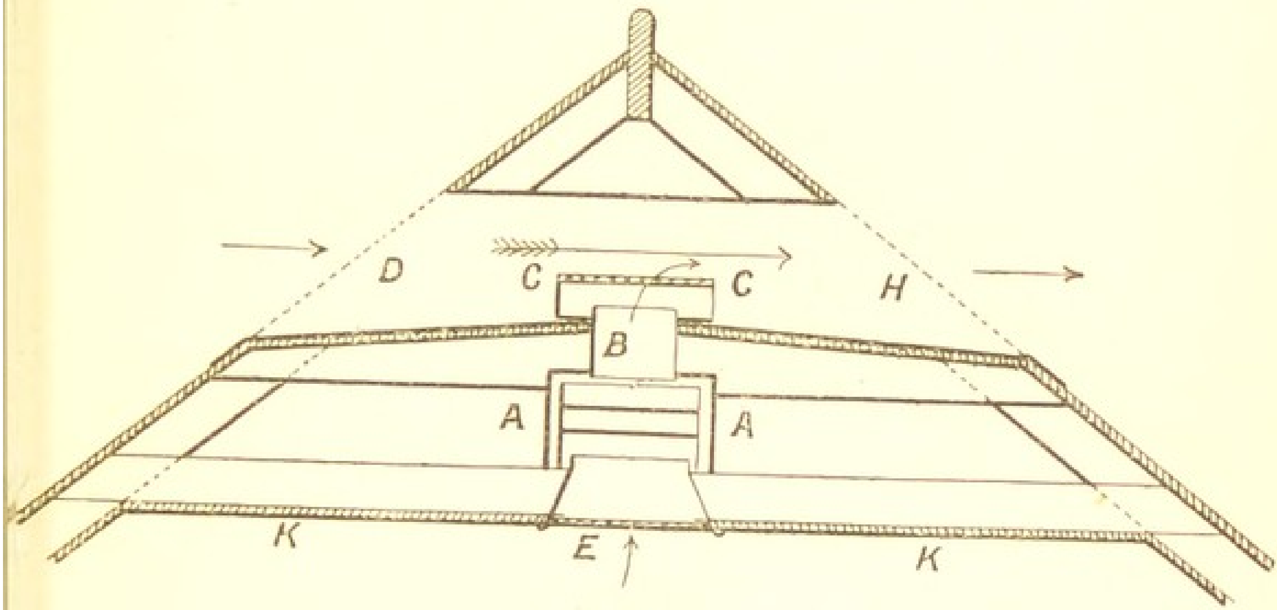


Fig. 93.

comes up through the ceiling-opening E passes off on the leeward side of the roof as at H.

Fig. 95 dispenses with the valve-box shown in Fig. 94, and with the ventilator C in Fig. 93, and instead shows a Buchan's self-acting open-channel valve-box B C, set in the middle of the open channel A D. The wind is shown blowing upon the side opening A in roof, which closes the valves on the windward side B of the ventilator and allows them to open upon the opposite or leeward side C, and thus allows the outgoing air to come up the ceiling opening E and out through C and D. D may be either a grating or louvres.

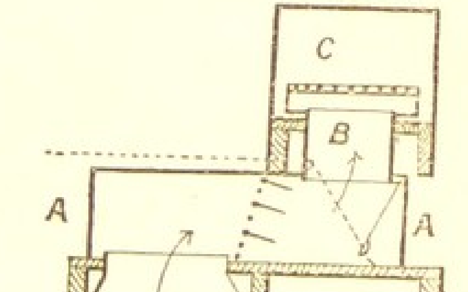


Fig. 94.

Fig. 96 shows the valve-box exposed in the interior of the building below the ceiling. It is merely shown as a modification from the foregoing, which may be used if desired. Fig. 97 shows the system of open-channel ventilation below the ridge, invented by Mr. John Honeyman, F.R.I.B.A. The upper sketch shows cross section of the ventilator with the valves partly

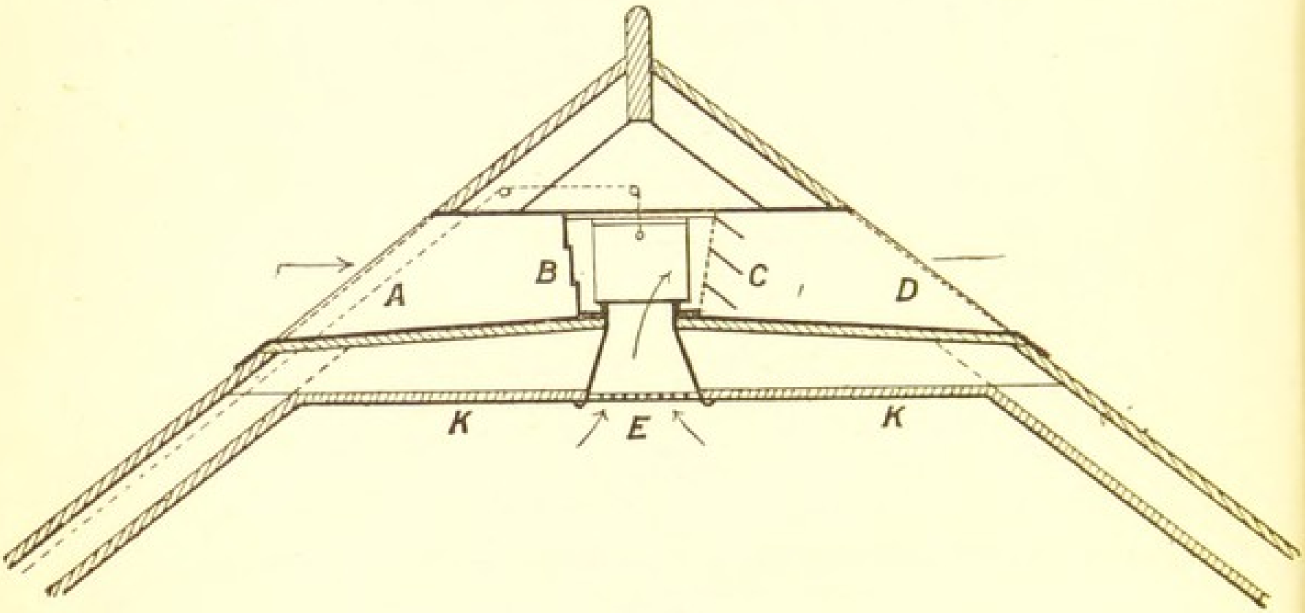


Fig. 95.

open. The lower sketch is a longitudinal section showing the centre barrier C C, through the centre of which the short pipe D is fixed with the intention of helping to

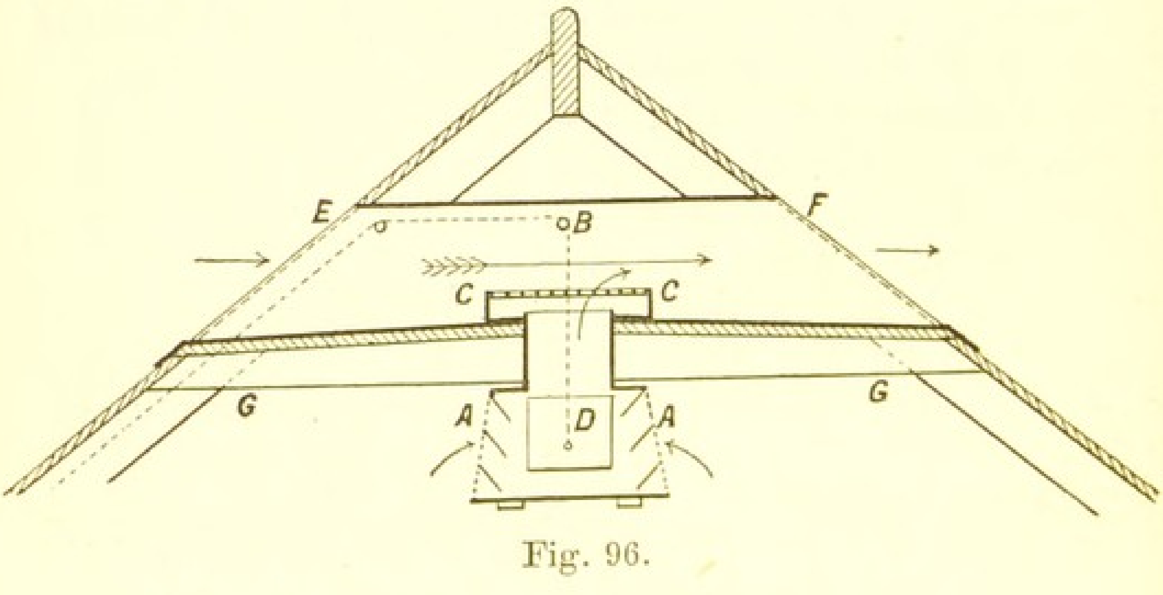


Fig. 96.

open the valves B B on the leeward side of the barrier, and inducing an upward or outward current.

Fig. 98 is sketch of Cormack's plan of inducing a current by means of the small tube below C, which in this case is movable, being suspended by a couple of copper wires so as to hang in the centre of the pipe E.

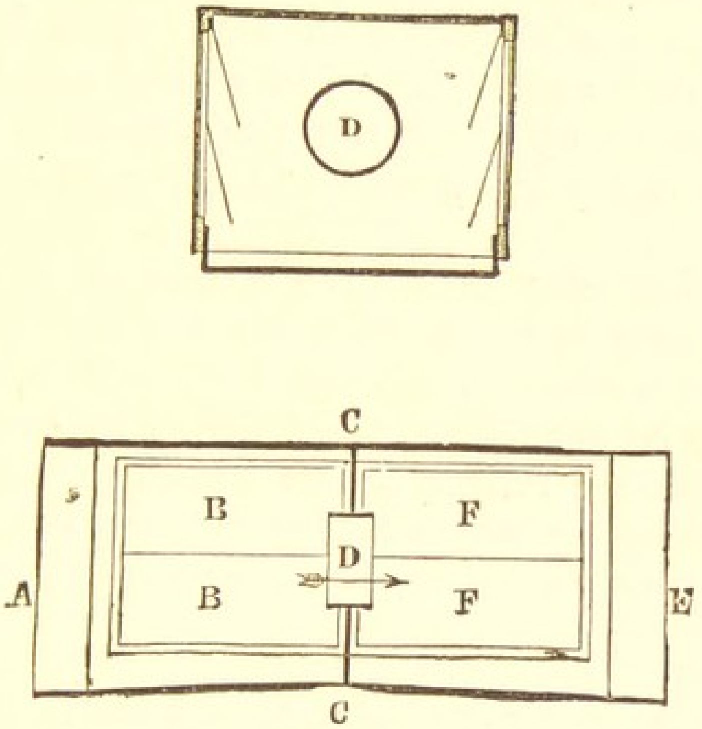


Fig. 97.

The wind is supposed in the sketch to come in at the side D, and go out through the small tube and the large pipe E,

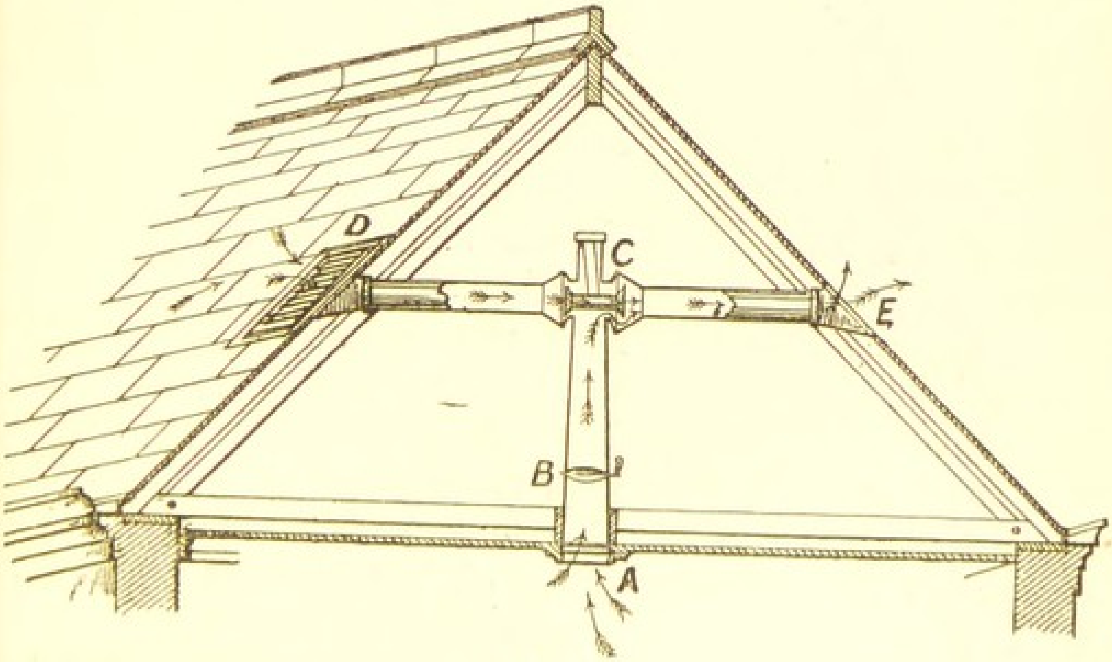


Fig. 98.

the air from the room coming up the pipe A. B is a valve for stopping the ventilation when wished.

The author does not consider these styles of outlets *below* the ridge so satisfactory as the styles of outlet ventilators *above* the ridge already shown. Ventilators have as good a right to be seen upon buildings as chimneys, and automatic wind-acting appliances work better when set up above the ridge so as to get the full benefit of the passing wind to increase their exhaust power.

The author may here give a caution to contractors, and a warning to the public, not to allow the foregoing exhaust ventilators, when fitted up with metal valve or damper, to be considered as finished without the party fitting them up fixing on an indicator brass plate, or its equivalent, to tell whether the pulling of the cord shuts or opens the valve, as for example:—

VALVE OPEN WHEN CORD SLACK.

or *vice versâ*, as the case may require. In a number of cases where this has been omitted the people pulled the cord and fixed it tight, and so closed the metal valve and stopped the ventilation, to the discomfort of all influenced.

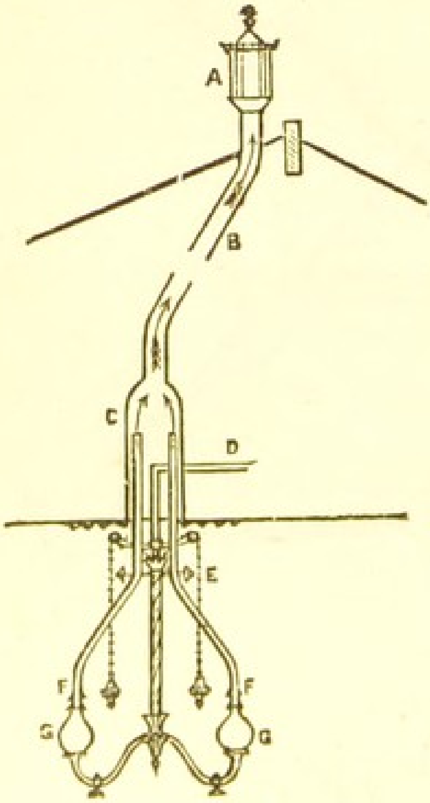


Fig. 98A.

Fig. 98A might have been shown in Chap. VIII., but it was overlooked. It illustrates how the writer put in special ventilating pipes, F F, for carrying off the products of combustion from a gasalier in a room, about twelve years ago. The glass globes in this case were contracted at top to barely $1\frac{1}{2}$ in. diameter outlet, the pipes F F being $1\frac{1}{2}$ in. diameter. With the usual globes the pipes F F would require to be larger.

CHAPTER X.

Micro-Organisms in Schools, Etc.

In treating upon the source of micro-organisms in schools it must first be understood, as demonstrated by Professor Tyndall, that when the air in an enclosure is still the dust and micro-organisms settle down in a few hours to the floor, and leave the air comparatively pure, so that a certain amount of physical disturbance is required in an apartment in order that micro-organisms may be present in its atmosphere.

In an experiment made in the High School at Dundee with one of the classes in a room, under ordinary conditions, the organisms amounted to 11 per litre. Upon the boys being told to stamp with their feet on the floor, a cloud of dust was raised, when upon being tested the atmosphere of the room showed 160 organisms per litre.* This stamping by the scholars could not be much worse than the abominable way in which many school-rooms are swept out, the air being often loaded with dust like smoke in the process. Some simple mode of preventing this on an antiseptic principle ought to have been introduced and forced to be carried out long ere this. The banishment of religious animosity, and a reduction in money-grubbing, with the display of a greater amount of practical good commonsense, would greatly benefit both the scholars and their teachers. How the rising generation is treated in the schools has a great deal to do with the progress of the race, physical poisoning producing mental decrepitude. "To the

* This shows that making the children stamp, tramp or beat time with their feet *in the school-room* is a mistake.

pure all things are pure" must be taken *cum grano salis* from a sanitary point of view, for the saint may succumb quite as quickly as the sinner in an atmosphere highly vitiated by CO_2 and its enervating associates.

Micro-organisms are not considered to be given off to any harmful extent in the expiration of healthy people. They are, however, in the cough and spittle of the unhealthy. They may, therefore, breed and multiply in badly-ventilated and improperly-cleaned rooms, and the older the school or room the more infected may it be, and more especially as, until quite recently, almost no schools were properly ventilated or cleaned as they ought to be, the air of some, if not even of many, being shamefully vitiated, not only by exhaled air from the lungs of the scholars but also by air from the drains, so that both teachers and scholars appear to have been killed as surely as if they had drunk liquid poison. A knowledge of the disease is half the cure; so ventilate the school efficiently and cleanse the floors and walls properly, and also watch the drains (see page 181), and the micro-organisms will be kept down and their power for evil prevented.

On page 129 of *Health*, for May 30th, 1890, Dr. Andrew Wilson gives some important information about the spread of typhoid fever. He says it has come to be generally admitted that the transmission of typhoid fever takes place principally, if not exclusively, through the water supply; but other ways may exist, as by the breathing of air contaminated with the spores of the typhoid bacillus or germ. He gives an example of several barracks, where the soldiers suffered severely from typhoid, which disappeared after the buildings were evacuated for a time and thoroughly cleaned and disinfected. An examination of the dust from the infected barracks, by Dr. Chour, showed an average of 14,000,000 germs per gramme (a gramme is fully 15 grains). This observation may serve to confirm the opinion that typhoid fever may be incurred through breathing sewer gas and drain emanations.

In reference to leprosy the remark is made that the period of its prolonged incubation—often of several years' duration—renders it difficult to trace the original source of infection.

It appears to the author that other diseases of a low type amongst us may arise from some fungoid germs taken into the system when living in houses the ground-flat of which is damp, or where beneath the floors the wood is rotten from damp and confined air, and other causes. Rooms, schools, &c., which are not asphalted underneath, and where the air is often musty, are not healthy.* A person may go on breathing the air of such for a considerable time before the bad effects are felt, although the seeds of after-disease may be sown. In this connection people are wise who err on the side of being particular—too particular, if you like—for each person, man or woman, has but one life. It is not always the ignorant who neglect precautions, for sometimes those who ought to know better refuse to take precautions. In fact, to hint at the necessity for such sometimes provokes anger, but Nature's grasp, if allowed to tighten, is often too firm to loose, and the daily paper by-and-by tells of another friend or acquaintance prematurely gone over to the great majority.

The following quotation from *Health*, for July 11th, 1890, on "Ventilation and Organisms in the Atmosphere," may be useful here:—

"Experiments were made by Dr. Stern in the Hygienic Institute of the University at Breslau regarding the influence of ventilation upon the number of organisms present in the air of rooms, from which the following conditions are summarized:—

* A new school has just been opened with great pretensions in the ventilating way. Its supply of *fresh* air comes from inside the walls and below the floor of the school; yet, notwithstanding, the architect, the ventilating and heating engineers, and the doctor all unite in asserting that the schoolrooms should have been asphalted underneath—such has not been done. Should the children suffer from this, the members of the School Board ought, in such circumstances, to be held personally liable.—Latest telegram: "School invaded by rats."

"1. Except by very strong winds bacteria are never driven off from moist surfaces.*

"2. For this reason only the organisms which are not killed by being dried are found in a living condition suspended in the air.

"3. In general it is uncommon to find isolated or single organisms in the air. They are usually present in numbers or colonies, clustered together upon coarser dust particles.

"4. In still air, because of their higher specific gravity, they quickly gravitate to the surface.

"5. A multiplication of bacteria does not occur in the atmosphere because of the absence of the necessary amount of moisture.

"6. In harmony with the last two facts are the observations of Hesse, Frankland, and Petri—namely, that in general the number of organisms present in the air is small. This is especially the case over moist surfaces and in sheltered spaces where the air has been but little agitated.

"Bearing in mind these facts, Stern endeavoured to arrange his experiments so as to have as nearly normal conditions as possible, but for purposes of accuracy he increased the number of organisms upon which to work to a degree rarely or never found in the air.

"A room with four ventilators was selected; two of which brought air to the room and two carried it away. In each case one ventilator for incoming and one for outgoing air were under the ceiling on opposite walls, the remaining two being just above the floor. By this arrangement diagonal currents from floor to ceiling (summer ventilation) or from ceiling to floor (winter ventilation) could be produced at will.

"He then closed all registers, cracks, and openings

* In 1874 the writer asserted that it was a mistake to suppose that disease germs would come through a proper water trap, or that they could jump out of the water—like flying fish—supposing they were in it. Further, the advantage of too strong an air current through drains and soil-pipes is questionable on account of the danger of this current drying the interior too quickly and dislodging and carrying along with it disease germs, or particles of matter containing such.

by which air could enter, thoroughly disinfected walls, floor, and ceiling with sublimate solution, and analyzed the air for bacteria. None were found.

"His next step was, by aid of an atomizer, to completely fill the air with a mixture of dust and bacteria, and determine what effect would be produced upon the number of organisms present in the air by—

"1. Allowing the air to be perfectly quiet for a given period of time.

"2. Moderate ventilation (renewal of the whole volume of air one to three times an hour).

"3. High degree of ventilation (renewal of air six or seven times an hour).

"4. Saturation of the air in the room with aqueous vapour.

"His conclusions were as follows :—

"*a.* When the air of the room was perfectly still the dust and bacteria sank quickly to the floor.

"Where ordinary dust (as from library or school shelves) was employed, the air was almost entirely free from bacteria after an interval of one and a half hours.

"*b.* With ordinary ventilation, that is a renewal of the air one to three times an hour, the disappearance of organisms from the atmosphere took place hardly more quickly than when the air was allowed to remain still. When 'winter ventilation' was employed, the diminution in the number of organisms was slightly hastened.*

"*c.* An increase in the degree of ventilation increased gradually the rate of disappearance.

"The lowest limit of ventilation which caused an appreciable acceleration in the rate of disappearance of the germs from the air was an exchange of from six to

* If "winter ventilation," or drawing off the vitiated air near the floor, only "slightly hastened" the diminution of the number of organisms, it is of little value in comparison with its faults otherwise, especially in this climate, and for the greater part of the year at least. This drawing off of the air at the floor is part of one of the mechanical systems, but as the machine is generally stopped for about sixteen hours out of the twenty-four, it is questionable where the advantage of it comes in as against a school *well* ventilated automatically, well flushed at the intervals, and where the ventilation can go on free of expense for the whole twenty-four hours.

seven times an hour of the whole volume of air in the room.*

"*d.* The rapid and complete removal of the germs from the air of a room can be accomplished only by the employment of very strong draughts.

"*e.* No degree of ventilation, however high, was sufficient to cause germs to rise from carpets, furniture, clothing, &c., into the air.

"*f.* Saturation of the air with aqueous vapour is not to be relied upon as a means of depriving the atmosphere of the germs suspended in it. It does, however, to a limited extent accelerate their disappearance.

"In consideration of these conclusions Stern feels justified in recommending as a means of disinfecting rooms which have been occupied by persons suffering from infectious diseases, that as soon as the patient has been removed, the room be closed and allowed to remain so for at least twenty-four hours, after which it is to be quietly entered, and floors, wall surfaces, and furniture mopped with cloths saturated in corrosive sublimate 1·1,000.† Under no consideration is dusting to be countenanced."

* When a school (or church, &c.) has got full and proper automatic provision for ventilation, then, with provision for ample flushing in the intervals of non-occupancy, the micro-organisms ought to be as low in it as in a mechanically ventilated school, if not even lower, both schools being kept equally clean otherwise. See pages 165 and 167.

† That is, diluted with water in the proportion of 1 of corrosive sublimate (bichloride of mercury) to 1,000 of water.

CHAPTER XI.

Odds and Ends.

We may here make a few further remarks on the ventilation of the ordinary living-rooms in houses in addition to what has been said on pages 51 to 57.

In his published lectures on "Dwelling Houses, their Sanitary Construction and Arrangement,"* Professor Corfield, M.D., &c., says: "In this climate we cannot change the air of a room more than three or four times per hour without causing draught, and so each person ought to have from 1,000 to 750 cubic ft. of space; the air of which should be changed three or four times per hour respectively. The way in which this space is arranged is also a matter of some importance. For instance, the air above a certain height is of little use for purposes of ventilation if combined with too small a floor space.† . . . . We are not able to insist on anything like 1,000 or 750 cubic ft. of space in all instances, and amounts varying down to as low as 300 cubic ft. per individual are adopted.‡ In the case of a family living in one room, which is so small

* Published by H. K. Lewis, 136, Gower Street, London.

† Mr. John Honeyman, F.R.I.B.A., Glasgow, has called special attention to this in connection with workmen's houses, or small flatted houses generally, in order to show that too high ceilings are not a benefit in working men's houses. In the author's opinion an apartment 8 ft. 8 in. high, and ventilated as per H and F, Fig. 23, would be much better for working men's houses in cities, than one 10 ft. high, and not so ventilated. Extra elbow-room, with good ventilation, would be much better than useless head-room without it.

‡ The present minimum in Glasgow is 300 cubic ft. for each adult, but 400 is aimed at. The smaller houses are ticketed, *e.g.*, "950 cubic ft., 3 adults," "1,240 cubic ft., 4 adults," and so on.

as to afford less than 300 cubic ft. per individual, it is usual to consider that the limit of over-crowding which should be allowed by law has been reached." At 300 cubic ft. for each person this would mean for six persons a room 15 ft. long by 12 ft. broad by 10 ft. high, or one 13 ft. by 12 ft. by 10 ft., and bed 6 ft. by 4 ft. by 10 ft. high. The air of an apartment this size with even two persons in it would soon get vitiated, and especially at night after the gas was lighted if provision did not exist for ventilation. Happily in such cases there is generally one provision for ventilation in the shape of the chimney, which carries off the air from a height of from 2 ft. 6 in. to 3 ft. 6 in. as the case may be above the floor. As the air may go up the chimney at the rate of from 60 cubic ft. to about 200 cubic ft. a minute, this makes from 3,600 cubic ft. to 12,000 cubic ft. an hour, which might do more good than it does in practice if this air went out of the room in the best way to promote real ventilation and benefit the whole of the room, but this is not generally the case, as one corner or side of an apartment will be much more in the air current than the other side; then if there is no provision for carrying off the air at a higher level than the fireplace, then all above its level is a cistern for containing and holding the bad vitiated air exhaled from the lungs and produced by the lighted gas, candles, or lamp.

Inhabited apartments—whether kitchens, parlours, dining-rooms, drawing-rooms, or bed-rooms—ought all, therefore, to have other and a higher provision for carrying off the vitiated air than the fireplace.

When the house or building is being erected it would be easy for the architect to make provision (if he either exercised or *were allowed to exercise* the forethought) for carrying off the vitiated air inside the walls* from near the ceiling on some such principle as that illustrated in Fig. 23, where upcast flues or pipes, H H H H, are put in inside the walls, and all the better if alongside and

* As to whether or not this would necessitate the walls being somewhat thicker is a question for the architect to determine.

between the vents, so that they get the benefit of the heat from the vents to increase the draught upwards. The outlets at top may either be as indicated at W, X, or R, Fig. 23, or they may all be as indicated at R, Figs. 23 and 24.

Fresh air may enter either at the windows, as shown at F, Figs. 22 and 23, or by some of the other styles of fresh air inlets.

In the case of erecting warehouses and other buildings where it is not intended to use fires, yet 9-in. or 10-in. or larger flues should be built in the walls and in the piers between the windows so that they might be utilised for ventilation.

In a large warehouse erected some years ago the architect put in such a flue in every third pier of the outer walls, missing two. By-and-by the building came to be altered, when more ventilation was desired. Had there been a 10-in. flue in each pier it would have been very serviceable, but there was not, so that much after expense had to be incurred.

It is not fair to the servants, and especially in kitchens having a close range, not to have some provision for carrying off the heated air in the kitchen at or near the ceiling. I have recommended a short piece of 4-in. diameter galvanised iron pipe about 6 in. long to be put into the vent below the ceiling with good effect. This small pipe has been acting well in the kitchen of my own house for the last eight years. In houses where the kitchen is sometimes used as a laundry and to dry clothes in, the clothes will dry very much more quickly where there is ventilation than where there is none, because where proper ventilation exists the vapour is rapidly carried off.

In the laundry of a large mansion house where the writer was working, the laundry maid complained of the long time the clothes took to dry, while she was always troubled with headaches when ironing there. Both complaints were cured by putting in a galvanized iron air pipe like C, Fig. 22. In this case the pipe was exposed.

In some inclosures, especially if more flats than one, and for workshops, &c., provision for outlet ventilation may sometimes be made by putting in one or more self-

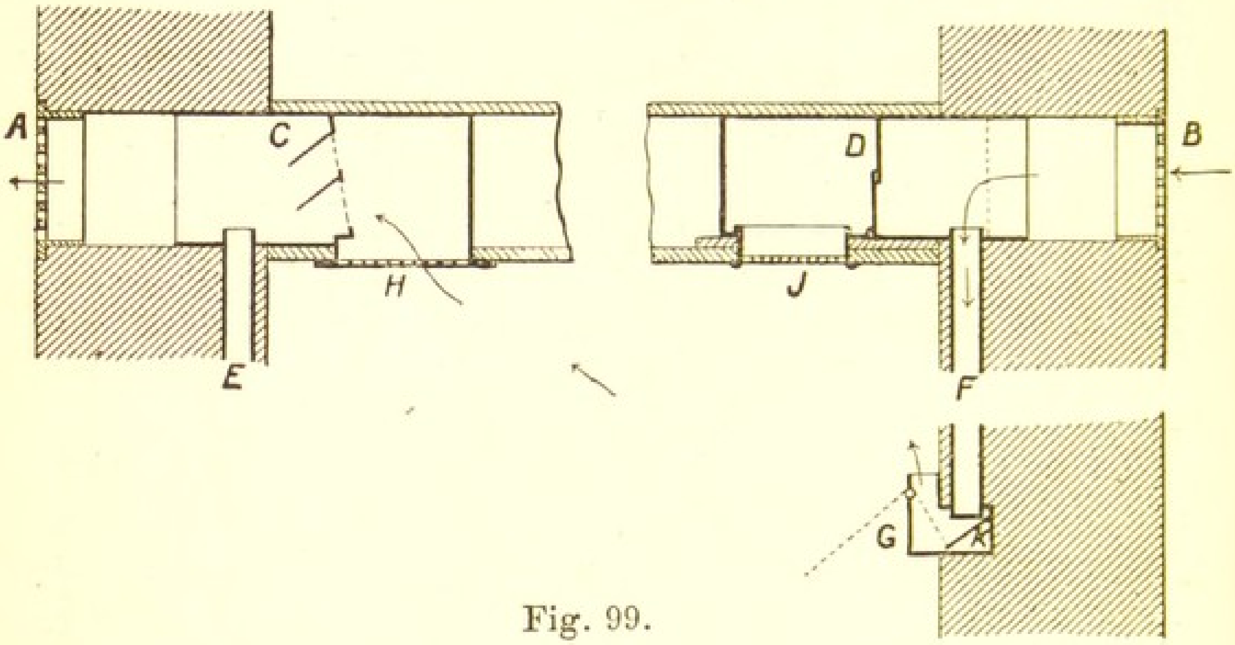


Fig. 99.

acting valves to open outwards, as per Figs. 99 and 100, one or more on each side of the building. In Fig. 99, the valve-boxes are placed above the ceiling, and between the joists. In Fig. 100 they are placed in the outer walls.

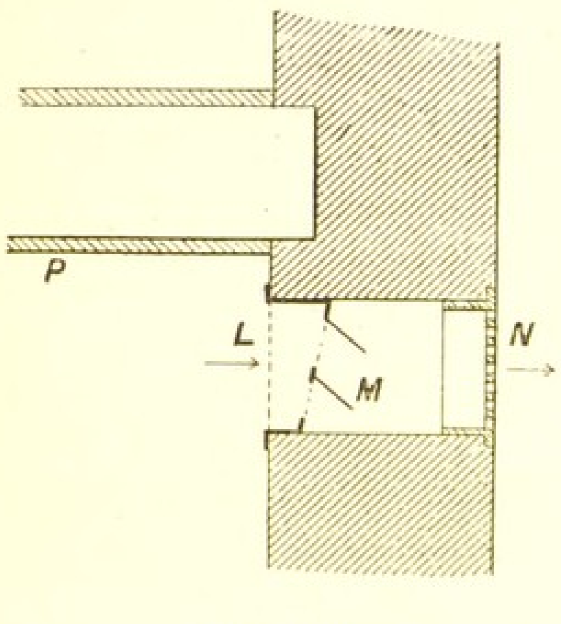


Fig. 100.

Ships require to have provision for ventilation fitted into them, as well as houses. In large ships, both inlet and outlet shafts are carried down to the various holds, as well as to the cabins and sleeping-rooms, on some such principle as roughly sketched in Fig. 101.

An ordinary style of ship ventilator, used either to act as an inlet or an outlet, according as the mouth B is turned to or from the wind, is shown in Fig. 102. In this case the top part rests upon a shoulder at A A,

Fig. 103 shows patent induced-current fixed ventilator, as used upon ships. These are much stronger than those used for houses, as they may have to stand the

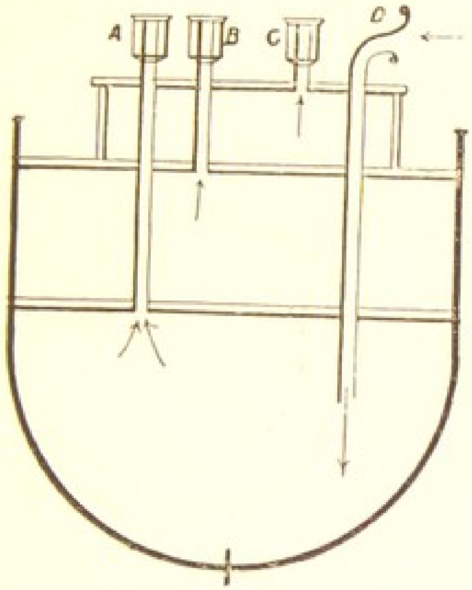


Fig. 101.

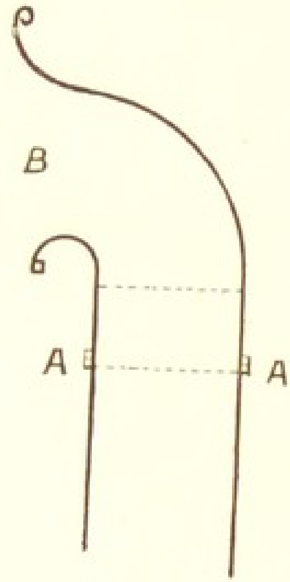


Fig. 102.

dash of the waves occasionally. They have also an extra inside guard plate at each opening, in order to make it more difficult for water or spray to get in and down the upcast shaft.

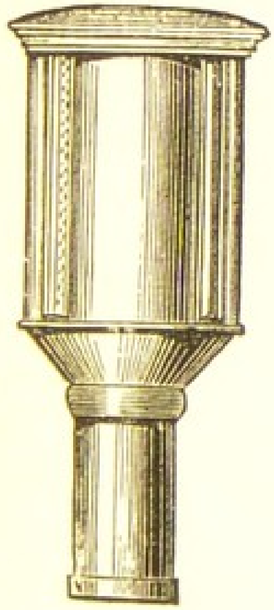


Fig. 103.

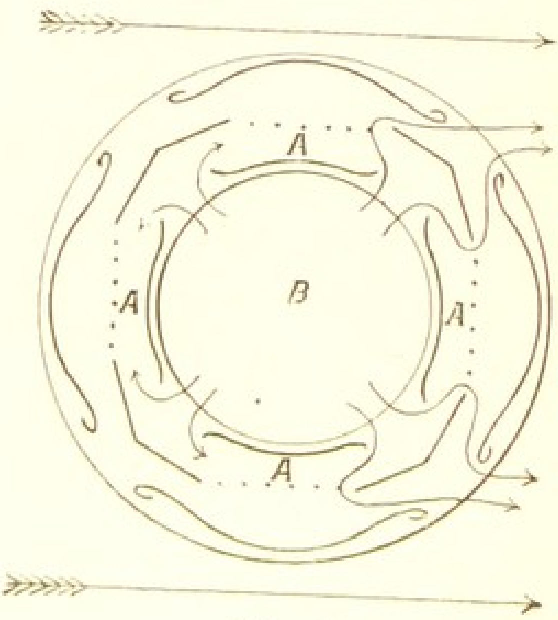


Fig. 104.

Fig. 104 shows cross-section of the body of the author's ship ventilator, A A A A being the four extra vertical guards (which do not exist in Fig. 89 style) for preventing the dash or spray of the waves from getting access to the pipe or shaft B, although the water did manage to get in past the perforated screens opposite. This ventilator was tested by the engineers of the Clan Line steamers against Fig. 107 one, to see which kept out the water best and allowed least down-draught, with the result that whereas Fig. 107 style allowed the water from one pail dashed upon it to get inside and

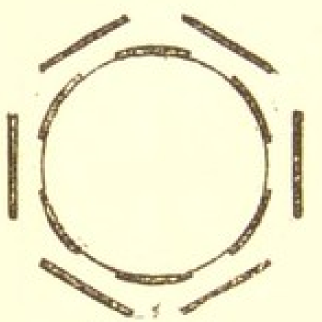


Fig. 105.

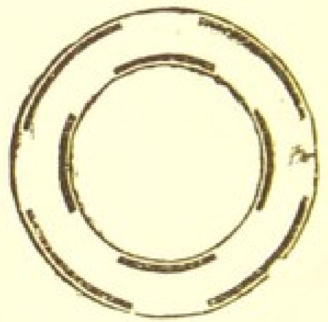


Fig. 106.

down its shaft, Fig. 104 defied two pails strongly dashed upon it at once; Fig. 104 also allowed much less down-draught than Fig. 107. The vertical outer guards of Fig. 107 were much too open, while also the inside arrangement was unnecessarily complicated, and the cross-divisions in centre, in my opinion, of no use.

Round-bodied fixed ventilators have been in existence

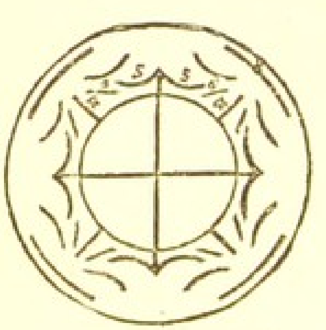


Fig. 107.

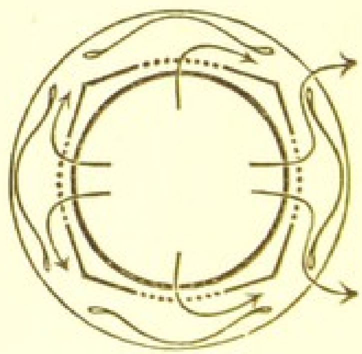


Fig. 108.

about thirty years or more, Fig. 106 style being invented by Finlay about 1860, and Fig. 107 by the late Mr. Robert Boyle in 1872. This latter one used to be well known in the market as Boyle's Air-Pump Ventilator, but it is now superseded by another one of simpler arrangement, and said to work better.

Fig. 105 is older than any of the foregoing. It was invented by Wilson about A.D. 1856, and is hexagonal in section. It had too many openings about it for a good extraction ventilator, as the wind gets in at the one side opening and out at the other too readily, instead of extracting from the centre pipe or shaft as desired. For this reason a ventilator made, as per Fig. 108, in the author's style, will be often exhausting very well when the others will be doing poorly, or allowing down-draughts. The results of many experiments, which were published in the London architectural and technical journals, proved that.

Fig. 109.

Instead of the perforated metal in the inner case, as per Fig. 108, a Λ piece may be used as per Fig. 109, but the author prefers Fig. 108 style.

Movable exhaust ventilators, or "cowls," both revolving and veering, used to be very popular, but as experience has shown that they are more liable to go out of order than the fixed ones, and, generally speaking, do not last nearly so long, it is a mistake to use them, and more especially since, in the elaborate experiments conducted by Mr. S. S. Hellyer at London, Fig. 85 fixed ventilator excelled all the other principal makers' ventilators tested, both fixed and movable. This is alluded to in the article on "Ventilation" in the new edition of the "Encyclopædia Britannica."

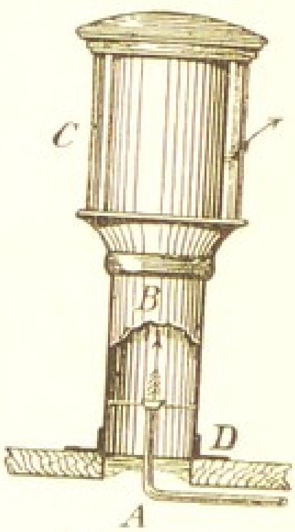


Fig. 110.

In regard to the large wind-acting, revolving ventilators, these may often be seen standing still when there is not sufficient wind to turn them; in which case their screw blades do harm by proving an obstruction to the current of air that may be coming up the shaft.

Fig. 110 shows the application of a forced air jet through the small jet tube A, for the purpose of increasing the out-current of air through the ventilator C, in calm or close weather. The forced jet may come from a fanner driven by steam, gas, or water power, or by a falling weight, or from an air-pump. This forced jet is used in some steam-ships, and in other places which have engine power. Verity's water-jet fan, invented in 1880, has been used for ventilation. Fig. 111 shows a ground plan, and Fig. 112 section. On the line C D in plan, E E are the fan blades, with the driving wheel (F, Fig. 112) between. At G the water-jet tubes are seen. In towns the use of the water has to be paid for, and a waste-pipe is required to carry off the waste water. Care has to be taken that

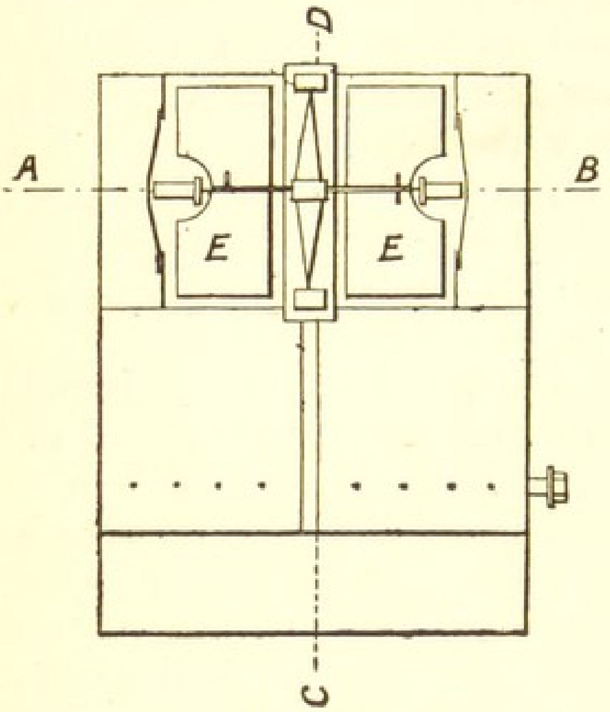


Fig. 111.

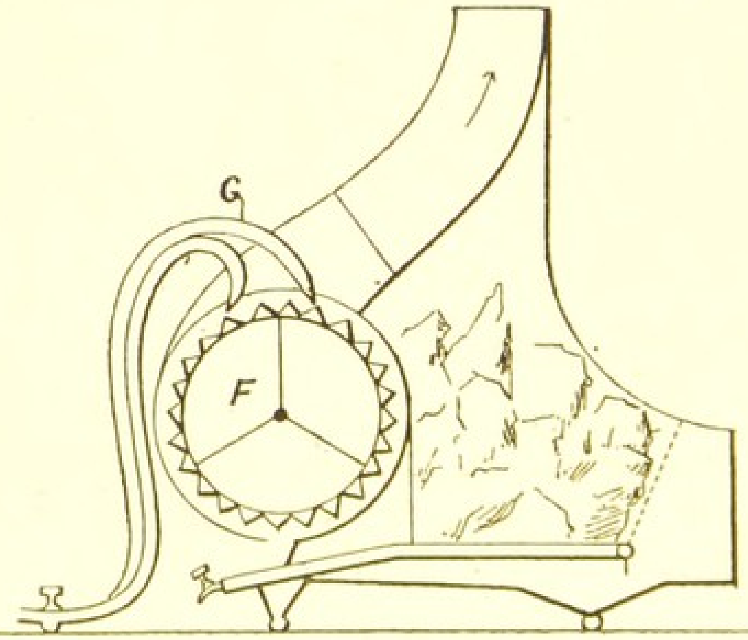


Fig. 112.

the waste pipe does not freeze up in winter, and damage the premises.

In supplying and fitting up ventilators these will not give satisfaction unless they are of a proper size in relation to the work that has to be done. The more people in the place to be ventilated the greater the provision required for ventilation. It is a good thing, where it can be done, therefore, to have a reserve force in hand for extraordinary occasions. To be able to increase the outlet ventilation by lighting a number of gas jets in the upcast pipe, as in Fig. 113, may often be very useful. See footnote, page 38.

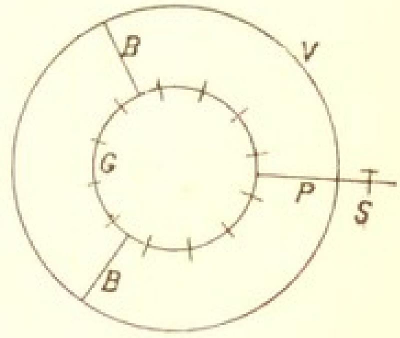


Fig. 113.

Where gas lights are used, as in Fig. 113, it is beneficial, to conserve the heat, and as a protective against fire, to wrap the pipe round with asbestos felt.

Fig. 114 shows an idea of the writer's, patented twelve

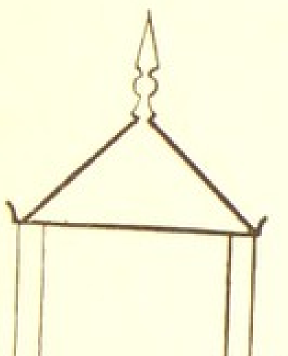


Fig. 114.

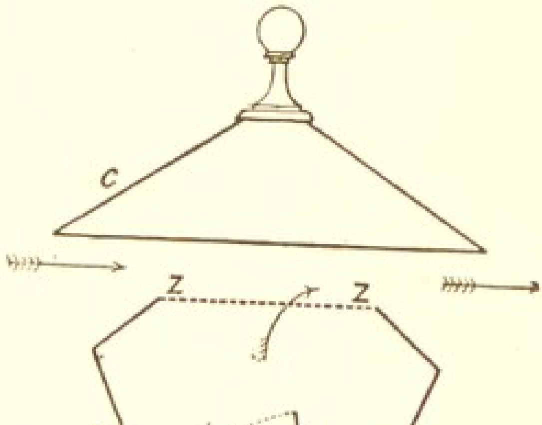


Fig. 115.

years ago, of putting a balanced metal or mica valve on the top of the outlet ventilating pipe, inside of the ventilator, to open automatically. For large-sized pipes especially, and because they could be better got at, and work better, the writer has preferred to use Fig. 90

style of silk valves. To get into the valves in Figs. 114 and 115 the ventilator would require to be taken down and cut open. For small pipes Fig. 115 might be useful in some cases.* Where Fig. 115 ventilator is used without the valve the pipe P is better to be ex-

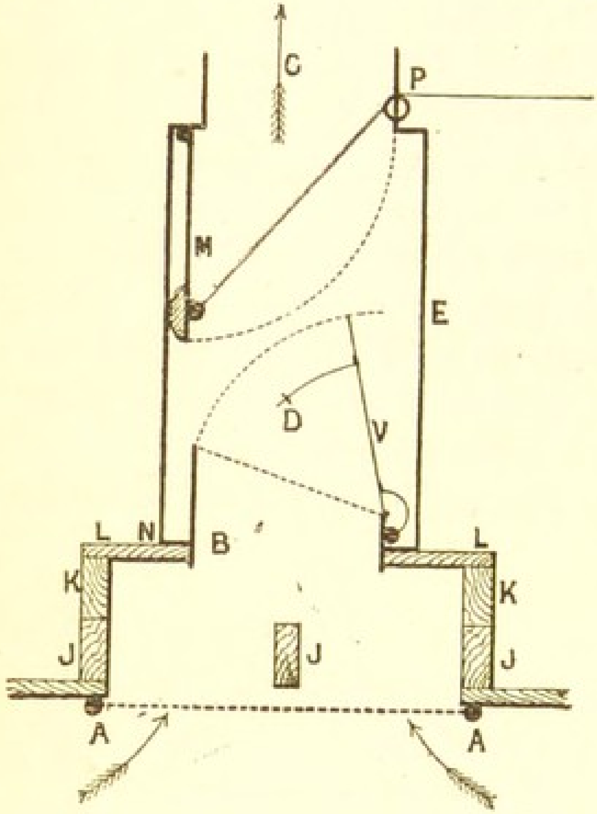


Fig. 116.

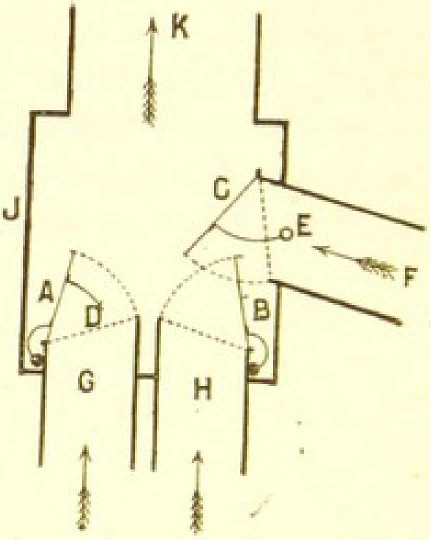


Fig. 117.

panded out at its top to the width of the perforated metal, Z Z. The small disc, D, when used, is for the purpose of causing the valve to shut more quickly. Around the top of the pipe, S, a soft substance may be fixed for the valve, V, to strike on when shutting, so as to cause less noise. Fig. 116 shows an application of the valve for a valve-box above the ceiling of a hall, or church, &c., as patented by the writer in 1883; but he prefers Fig. 90. Fig. 117, shows several pipes entering into one larger main pipe, or shaft, each pipe with its own valve; but see page 173 and Fig. 138 in this relation.

* A ventilator with an automatic valve in it has lately been recommended, by some persons ignorant of plumbing work, for the top of soil-pipes, but that is a great mistake. The ventilating pipe of a soil-pipe requires to let in air freely (to prevent siphonage of the water traps) as well as to let it out; hence ventilators as per Figs. 114 and 115, *with an automatic self-closing valve in them*, are *not* for use upon soil-pipes at all. Further, should the balance weight come off, then the valve may remain shut, and so the ventilation be stopped. It is easier seeing as to this in Figs. 90 and 116 than with Figs. 114 and 115.

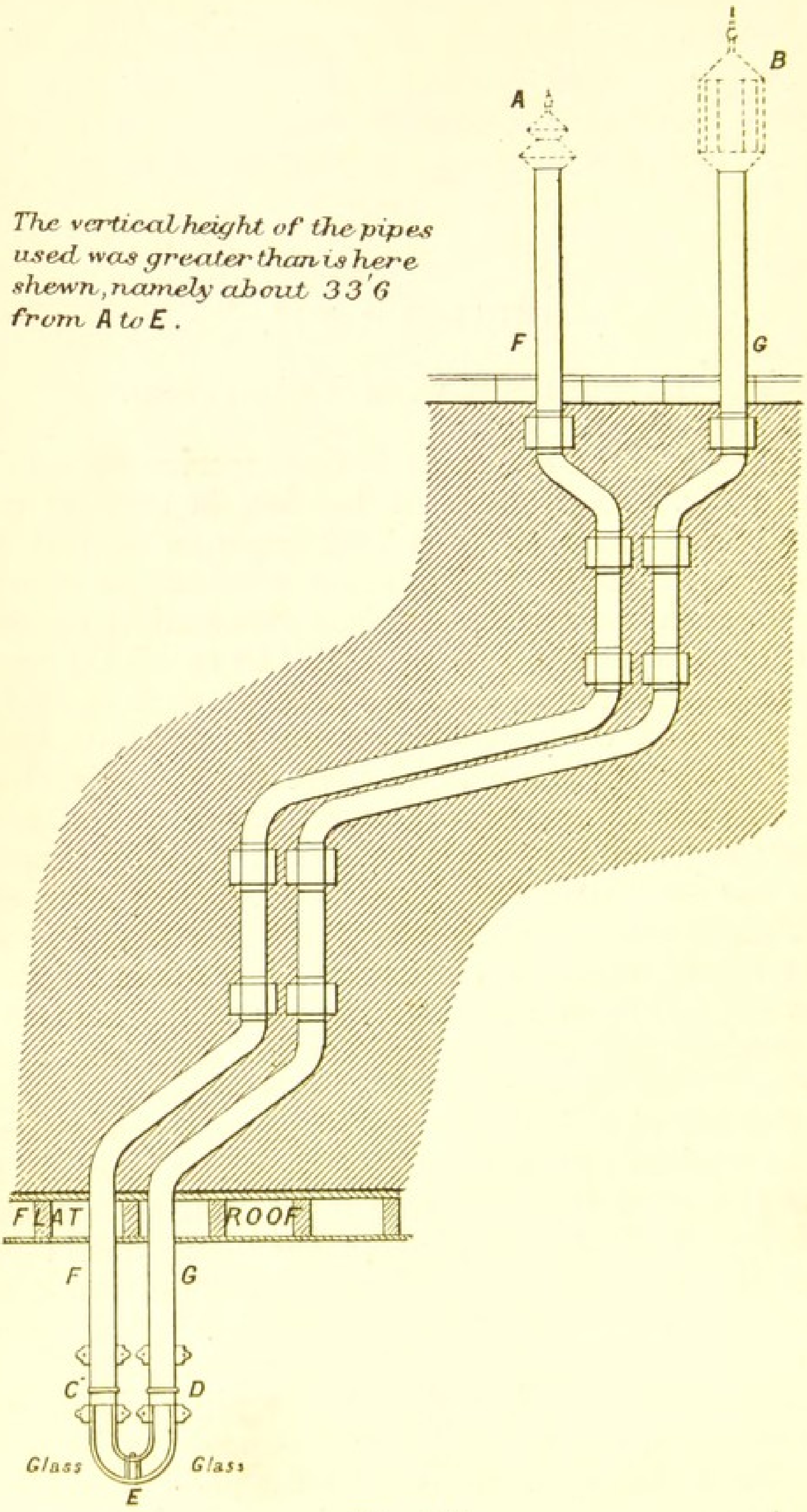
CHAPTER XII.

Experiments with Ventilators.

Reference has been made to the experiments carried out by Mr. S. S. Hellyer, of London, in 1880, at considerable sacrifice of time and expense, to test the comparative merits of the various wind-acting exhaust ventilators against each other, and also against the open pipe, to see which was best. Fig. 118 shows the *modus operandi* of testing. Two separate pipes, 4 in. in diameter, F and G, were carried up to a considerable distance above the roof, and upon the top of each an exhaust ventilator was placed, as per A and B, for a certain time. When the amount of air passing through each was separately tested and noted for an hour, say, then the A ventilator was taken off the F pipe and put upon the G one, the B ventilator being taken off the G pipe and put upon the F one, and then the amount of air passing through each for another hour was again noted.

After the pipes had been tested separately they were joined together at the foot, as shown at E, Fig. 118, when the two ventilators were set to pull against each other on this U-shaped pipe on the "pull devil! pull beggar!" principle. Sometimes no ventilator was put upon one of the pipes, the ventilator being tested against the open pipe.

The experiments showed that the pipe, with a good exhaust ventilator upon it, freely exposed to the wind, passed more air through it than the plain pipe set up equally high, while amongst the various ventilators



The vertical height of the pipes used was greater than is here shewn, namely about 33'6 from A to E.
A
B
F
G
FLAT
ROOF
F
G
C
D
Glass
Glass
E

Fig. 118.

tested the movable ones came off second best.* Of course the air passing up the pipes was less in calm weather than during a breeze.

Fig. 119, like Fig. 118, is taken from Mr. Hellyer's work "Dulce Domum," and shows the ten cowls or ventilators tested by him. Of these three were movable, viz., Banners & Scott-Dunn's veering cowls, and Howarth's revolving Archimedian ventilator. The other seven were all fixed ventilators.

As the result of the testing, Mr. Hellyer says:— "Taking all the tests, the palm of victory must be given to Mr. Buchan's." As the Buchan's ventilator tested was only 9 in. diameter in the body, while the Boyle's one was 12 in., this rather knocked the wind out of the idea that the bigger the head the greater its strength.

In one two-hours' test, while the 12 in. Boyle's ventilator drew up 37,558 linear feet a minute, the 9 in. Buchan's ventilator drew up 49,330, or 11,772 feet more; but had the Buchan's ventilator been a 12 in. one and fixed upon a 6 in. pipe, then the amount of air it would have drawn up at this speed would have been about three times the *quantity* taken up by the Boyle's on the 4 in. pipe.

The author has made many tests with numerous ventilators, but as yet has not come across one which beats his own one. Some of these experiments are referred to in "Plumbing," No. 191 of Weale's Series. Others were described in *The Building News*, *The Builder*, *The Sanitary Record*, *The British Architect*, *The Plumber and Decorator*, &c. Many of these tests were on ventilators pretended to be entirely free from down-draught, but none of them stood the test. Some of them even allowed down-draught badly during a breeze, under circumstances where the writer's sucked up well!

Figs. 120 and 121 illustrate how the writer experimented as to whether fixing or suspending a pipe, J, or

* As movable ventilators are more apt to go wrong, they ought to be discarded all the more readily that their exhaust power is less than the fixed ones.

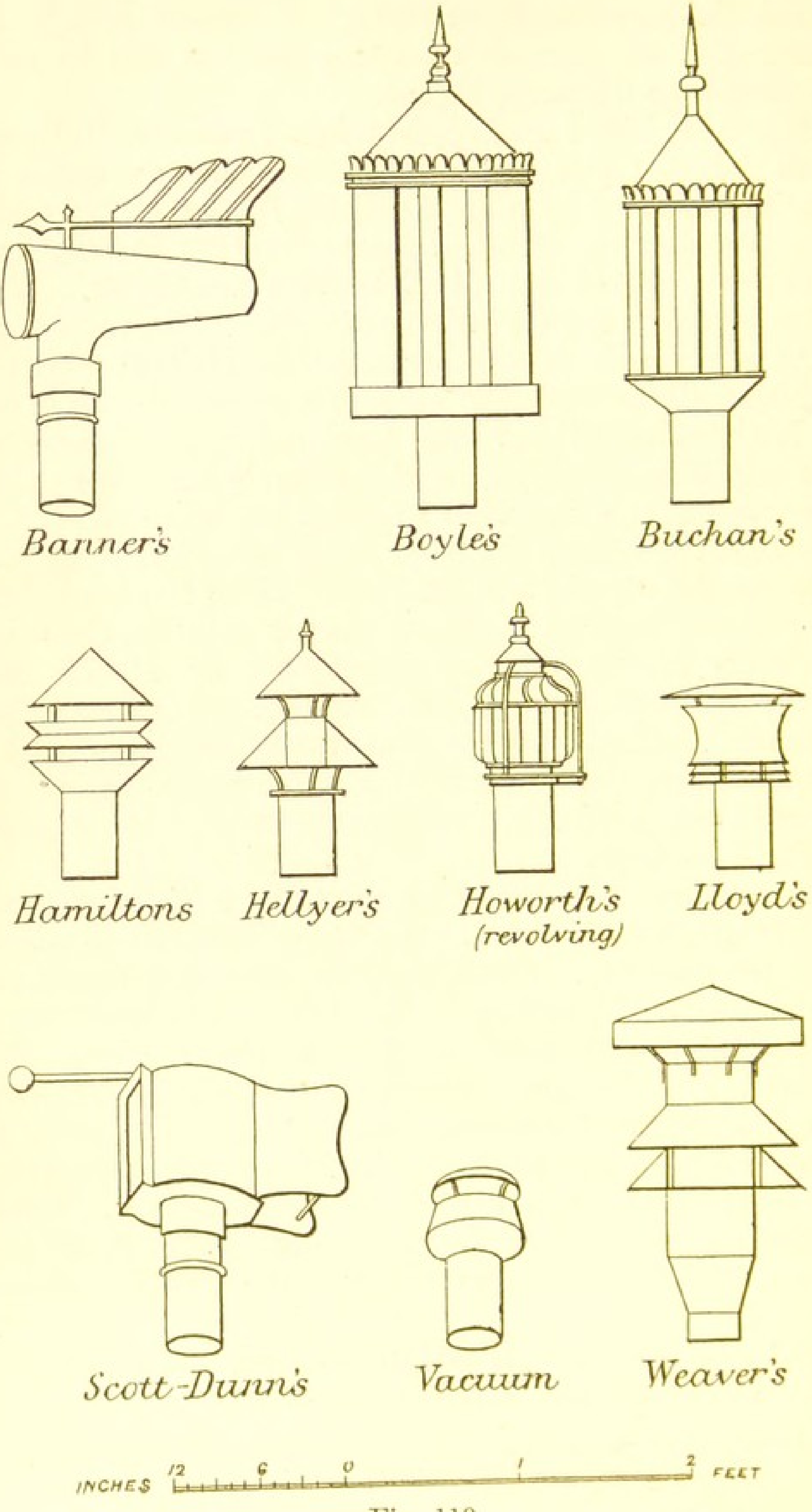

Banner's
Boyle's
Buchan's
Hamiltons
Hellyer's
Howorth's (revolving)
Lloyd's
Scott-Dunn's
Vacuum
Weaver's
INCHES 12 6 0 1 2 FEET

Fig. 119.

a piece of sheet iron, E, above one or more gas jets, F, would, or would not, increase the speed of the up-current in the large ventilating tubes, M or A.

The writer understands that various parties believe, or have asserted that, owing to the inner tube, J, or piece of metal, E, getting heated by the gas flame, or

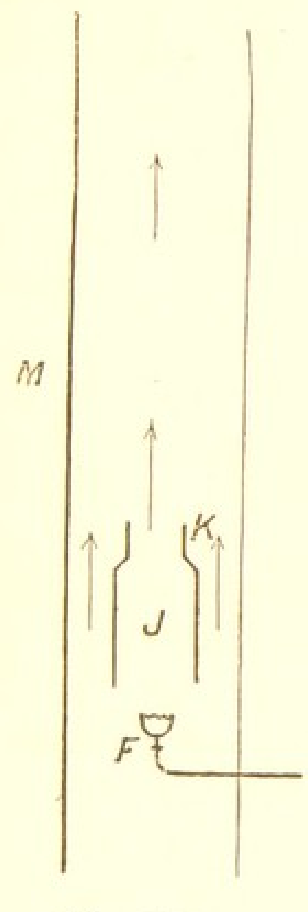


Fig. 120.

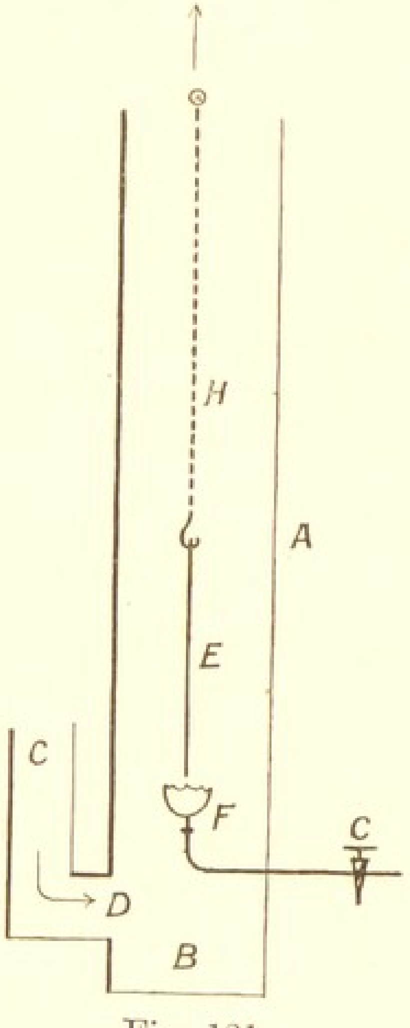


Fig. 121.

flames, the air, coming into contact with this heated metal, gets more heated than if the suspended tube or metal, J or E, were not there, and, getting more heated, the speed of the up-current is naturally *increased.*

Now it so happens that the experiments made by the writer indicate that the speed is not increased but *decreased!*

The writer took a tube, A, 6 in. in diameter and 3 ft. long, and put a close bottom on it. A short tube, C, 3 in. in diameter, was then soldered on at D, to suit the size of the anemometer and so measure the speed of the air fairly. Upon testing the speed of the air current entering at C, when the sheet of thin iron, 1 ft. long by 5 in. broad, was suspended, as shown, above the gas jet, F (and allowed time to heat before testing), the speed indicated was 555 ft. in two minutes; with the metal plate, E, out, the speed rose to 580 ft. in two minutes. Upon putting back the plate again the speed was again reduced.

After this a piece of 3 in.-diameter thin sheet-iron pipe—not contracted at top—1 ft. long, was suspended in the pipe, A, as shown at J, Fig. 120. The speed then, at C, was 520 ft. in two minutes. With the pipe out the speed rose again to 585 ft. in the two minutes.

The test was then made with the 3-in. pipe—contracted at the top—as shown at K, Fig. 120—when the speed indicated was 490 ft. in the two minutes with the pipe in, and 580 ft. with the pipe, J K, out. These experiments were made privately, but the first, with the plate as per Fig. 121, was repeated in the presence of Prof. Jamieson, C.E., F.R.S.E., in the electrical laboratory of the College of Science and Art, Glasgow, and with the same result, viz., that the presence of the plate, E, decreased the speed of the current.*

This is probably principally due to the increased friction. If it be correct that the number of particles of matter in the air above a lighted Bunsen burner may amount to about "400,000,000 in a cubic inch," then it will be all the more easily understood that the presence of suspended plates or pipes, as shown in Figs. 120 and 121, is quite superfluous and a pure waste of money, even although the number of particles from an ordinary gas jet be only a quarter, or a good deal less, of those from a Bunsen burner.

* Since this, viz., on Nov. 19th, 1890, the writer read a paper to the Philosophical Society of Glasgow, on "A Problem in Ventilation by Heat," with experiments with the pipe A, Fig. 121, in presence of the audience. With the 3-in. diameter pipe, 1 ft. long, suspended inside, the current at C was 270 linear feet per minute. With the 3-in. pipe out the speed rose to 300 ft. An old horseshoe hung up *outside* of the large pipe would therefore give better results than the 3-in. pipe or plate inside, as these latter are a continuous obstruction, whether the gas is lighted or not. In the discussion which followed Professors Bottomley, F.R.S., and Blyth, F.R.S.E., and other members took part.

CHAPTER XIII.

Ventilation Calculating Formula.

The following data, first published by the author in the autumn of 1887, will be found useful in considering and calculating the size of the main outlet pipes and ventilators to be used for various structures when the ventilation is to be carried out on automatic principles, and on the lines hereinbefore described.

As the sites and sizes of buildings are so various it is difficult to publish a working rule suitable for all cases, more especially when *monetary circumstances* form a factor in judging. A building, such as a church or school, &c., freely exposed to the wind all round, and especially if on raised ground, will be well ventilated with about half the provision for outlet ventilation that would be required for a similar building if in a sheltered position, and with high buildings near or round it.

Upon this understanding it may be stated that for the outlet ventilation of churches, chapels, and halls, seated for say from about 300 persons upwards, the rule may be to allow from half a square inch up to a square inch and a half of outlet for each person. The medium being one square inch of outlet for each sitter*. Another

* An architectural friend, who is an F.R.I.B.A., sugests 2 in. as the medium for churches, with a reducing valve in *winter*. I would be glad to see as much as 1 in. accepted *and acted up to*. Where more is wished the above 1½in. of maximum should be ample with *my* ventilators. Three 24 in. diameter main outlet pipes or two 30 in.—or their equivalent—would make a first-class job for a church—as ordinarily used—of 800 sittings. At the same time I should be glad to see as much as 2 in. properly tried.—W.P.B.

basis of calculation may be to allow from half-inch to one and a half square or superficial inches of outlet for each 120 cubic feet of space. It is generally better to have two, three, four, or more outlets in the ceiling than only one, and especially for low and flat ceilings. A regulating valve is used to stop ventilation when heating up, &c. Where there are two or more branch pipes the sum of their areas may with advantage be a quarter or so more than the area of the main outlet pipe. If the church or hall is liable to be occupied for longer than two hours at once, then extra provision ought to be made for that; *e.g.*, if one square inch and a half of outlet area for each sitter would be enough for services or sittings lasting no longer than two hours at once, two square inches or more might be needed if the services lasted three hours or longer at once.

Allowing the short allowance amount of the half square inch of outlet for each seat for a church seated for 800 means either one 24 in. diameter main outlet pipe with one of my 39 in. or 42 in. ventilators, or two 18 in. diameter pipes with two 30 in. ventilators. One square inch of outlet area, again, for each of the 800, would need either a 34 in. diameter main outlet pipe with 51 in. ventilator, or else two 24 in. diameter pipes with ventilators to suit. Of course, a half-filled church can do, *pro. tem.*, with less than a well filled one, but when the church or hall is full and too little ventilation provided, complaints are sure to be made, especially in warm and close weather. When such complaints are made see and put the saddle (or the blame) on the right horse.

The cubic capacity of some churches seated for about 800 is about 100,000 cubic feet, giving 125 cubic feet for each of the 800. In others the allowance is more or less, as the case may be.

In practice I have supplied three 30 in. ventilators, each with 17 in. diameter outlet pipe (and self-acting valve-boxes), for a well-exposed church, seated for about 900, being nearly $\frac{3}{4}$ in. of outlet to each sitter. In another case only two that size for 850, while in one case for an old church, seated for about 1,000, only *one* 17 in. diameter outlet pipe was ordered! If, in this latter case, *the attendance* was only 300 or so, then the one 17 in. outlet with 30 in. ventilator might do for a time, under such circumstances; but should the church attendance increase then more ventilation would be needed.

For some small country churches, seated for about 400, one 33 in. ventilator with 20 in. diameter main outlet pipe does very well, or two 24 in. or 27 in. ventilators. with 14 in. to 16 in. outlets. When well exposed and seated for 250, a 30 in. or 27 in. ventilator with 18 in. or 16 in. diameter outlet may do; *but all the better the larger*. If not well exposed a 36 in. or 33 in. ventilator should be used.

Churches, &c., open to the ridge require no piping, unless where, as often done of late, my self-acting valve-boxes are used, when a short piece of pipe about 2 or 3 ft. long is needed between the top of the open-roof valve-box inside and the ventilator outside, as shown in Figs. 57, 58, and 59.

For schools (and, to some extent, for small churches or halls holding less than 300) the allowance for outlet ventilation should be much greater per head than above, as schools are occupied for a longer time, and daily, and by young growing people, hence from 3½ to 5 square in. or *more* of outlet for each pupil is needed, and provision ought to be specially made to prevent down-draughts upon the heads and bodies of the children.* It is a crime to keep children sitting chilled and shivering below "ventilators" that allow oft-repeated or prolonged down-draughts. There is great room for

* Suppose a schoolroom, 28 ft. by 25 ft., and 14 ft. high, for 70 pupils, with an outlet of 5 square in. in area for each pupil. This means an outlet pipe of 21 in. diameter, which, if it were extracting at 200 linear ft. a minute (or about 480 cubic ft.), would change the air in the room nearly three times in one hour. I have just seen a West-end School Board schoolroom, for 120 pupils, with only one 12 in.-diameter pipe off the ceiling, which, extracting 200 linear ft. per minute, would take one hour and three quarters to change the air in the room! A 12 in.-diameter pipe for 120 is less than one square inch for each. There should have been two 20 in.-diameter pipes for this room. See "2," page 123.

improvement throughout the kingdom in regard to this. The pretended ventilation, again, sometimes provided by means of holes in the ceiling and outer roof, opening directly into the garret or space between the outer roof and the ceiling, is generally a sham and also a great nuisance owing to down draughts. See Figs. 9 and 10, &c., as to this. Each scholar in the board schools in Glasgow is entitled to 10 square ft. of surface area in the schoolroom, and the ceiling must be 14 ft. high at least.*

Police and law courts might rank somewhat as schools in regard to provision for their ventilation, but in respect of these courts being often occupied for a longer time at once than the schools, the provision for their ventilation should be greater, being from 4 to 7 square in. *or more* for every 140 cubic ft. of space, or for every individual in the court room.

When churches, schools, or other buildings of one storey are well ventilated—and asphalted—below the ground floor, less direct fresh-air inlets may be necessary. The sum of the area of the fresh-air inlets at

* In the *Building News* for June 27th, 1890, page 926, "G.H.G." says: "The Education Department give 80 cubic feet as minimum space per scholar, or 8 square ft. on the floor space. For senior schools the floor area is about 10 ft. For classrooms the requirements allow not less than 15 ft. super. of floor per pupil.

Professor Roscoe gives the following table[1]:—

	Cubic space per head. Cubic ft.	Authority.
Board Schools (minimum allowed)	80	Educational Department.
General Schoolrooms ,,	130	London School Board.
Graded Schools ,,	117	,, ,, ,,
Dundee Board School (average) .	152	
Common Lodging House (sleeping rooms)	300	Local Government Board.
British Army Barracks (minimum)	600	Army Regulations.
Prisons (seldom under) . .	750-800	Parkes' "Hygiene."
Non-textile Workrooms . .	250	Factory Act.
Army Horses (minimum) . .	1600	Army Regulations.
,, ,, (in infirmary) . .	1900	,, ,,

[1] In "On the Ventilation of Schools," a lecture by Sir Henry E. Roscoe, M.P., &c., published by T. W. Danks & Co., London.

their narrowest part may exceed the area of the outlets, the opening sashes of windows not being included.

Hospitals require extra good ventilation, and, according to Dr. Parkes, an allowance of from 1,500 to 2,000 cubic ft. of space for each patient—about eleven to fourteen times as much as for schools. So in same proportion that would mean for ventilation from 28 to 70 square in. of automatic outlet ventilation for each patient. Dr. Parkes says 60 square in., in addition to window ventilation, to be available when wished.

This 1,500 cubic ft. of space for each in the case of 27 patients would need a ward, say, 80 ft. by 26 ft. by $14\frac{1}{2}$ ft. And 60 square in. of special outlet for each means either four 20 in. diameter outlet pipes or two 28 in. with exhaust ventilators to suit. If, however, ample outlet ventilation made the patients sooner well, it would soon pay itself. Special provision ought to be made to protect the patients from down-draughts and chills.

For rooms in houses, &c., allow about 10 square in. of outlet area for the room, and then from 2 to 4 square in. more for each person in it. For billiard rooms about 180 square in., or more, of outlet area may be allowed for each table.* I have never seen too much outlet ventilation provided for either church, hall, school, or room, although often too little. The cry for better ventilation all round is now being heard, however, and the mistakes of the past will have to be rectified.

Ventilation for animals is now demanded as well as for human beings, and the farmer and other owners of such will find that it will repay them tenfold to provide it properly. For stables and byres from 60 to 72 square in. or more of outlet area should be provided for each horse or cow, and the outlet so fitted as that it will have fair play to act properly, and as an outlet.

Parties writing to a ventilating engineer for information about the provision requisite for ventilating a

* For the large billiard-room of the new Athenæum, Glasgow, with four tables in it, the total area of the outlet pipes is 730 cubic in.

building, as, *e.g.*, a church, should tell the size of the building, and if it has an open or a close roof, and how many persons it is seated for, and how lighted; also send plans, however rough, giving an idea of ground floor, and cross and longitudinal vertical sections.

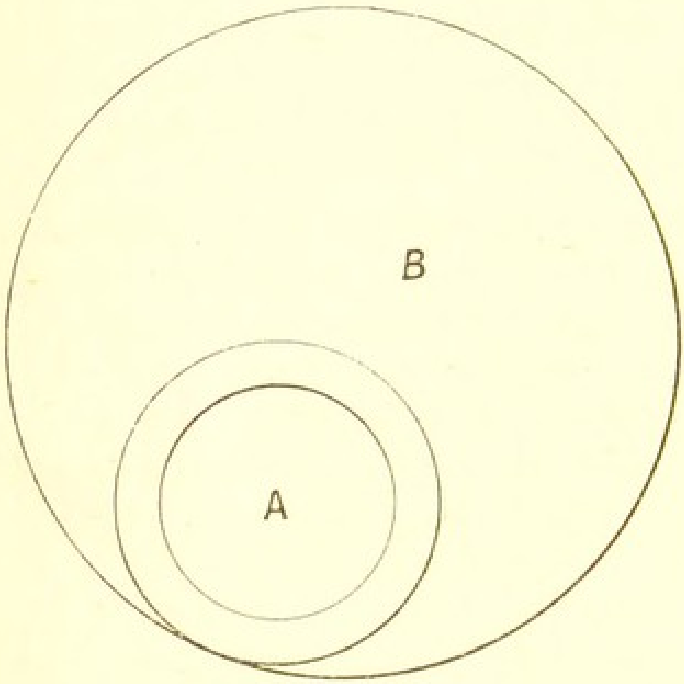


Fig. 122.

Except some half-dozen or so of new country schools, the author does not as yet know any schools automatically ventilated that have nearly as much permanent provision for the outlet ventilation as the lower rate above given. In some of the board schools, and others as well, the paucity of provision for carrying off the vitiated air from the lungs and bodies of the pupils is highly discreditable to all concerned.

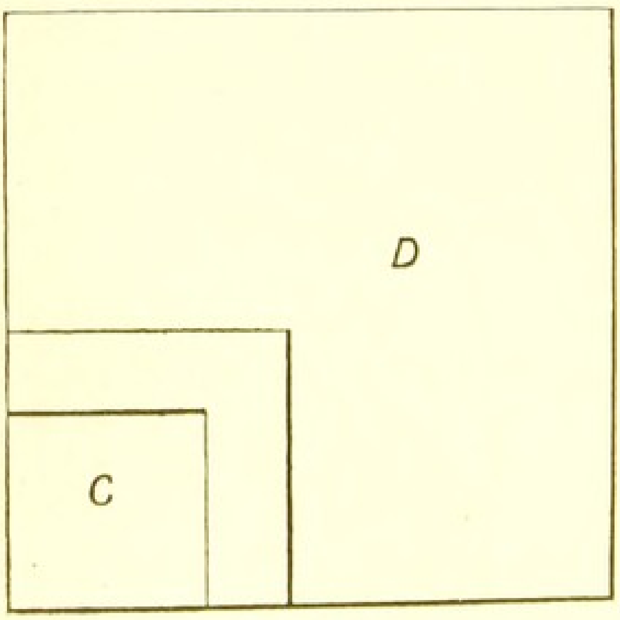


Fig. 123.

Figs. 122 and 123 are diagrams showing the difference between the existing provisions, as per small circles A or small squares C, and the proper proportion, which should be that of the large circle B, or large square D.

Seeing there is a law for 80 cubic ft. of space at least for each scholar, there ought to be a similar law that there should be $3\frac{1}{2}$ square in. at least of proper fixed outlet for each pupil in a country school, and 5 in. *or more* for each in a large town or city school; and this, too, with provision for preventing down-draughts. The prisons for our criminals are much better ventilated than many of the schools for our children, while numbers of our churches have no provision for ventilation at all!

Many of our architects in the past have been exceedingly selfish, and great sinners in this respect. If they got the outward appearance of the buildings to please them they cared not a rush for the comfort of their occupiers. Their idea was to erect as grand mausoleums as possible for their own names—at other people's expense. It was a hopeful sign, however, to lately hear one of our rising young architects state:—"I would now far rather erect a plain structure, which would be comfortable and well ventilated, than the most elaborately ornamented edifice that was yet uncomfortable and badly ventilated."

With words transformed into deeds the public would be greatly benefited, and the honour of the architectural profession enhanced.

CHAPTER XIV.

A Matter of Taste.

The large hall of a public building is to be ventilated. It is intended that for the outlet ventilation one or more wind-acting exhaust ventilators are to be set up above the roof thereof. Before deciding as to the particular style of *ventilator* to be used a natural question is, what is the style of the *architecture* of the building? Should this not be attended to, a style of ventilator suitable only for a classic building might be set up upon a Gothic one, or one suitable for a Gothic building might be set up upon a classic one. It is the province of the architect in this case to select or point out the design of ventilator that will be in harmony with the architecture of the building.

Supposing the building is a classic one, and, no consideration being given to this, a veering cowl is set up in a style passable, perhaps, for a large factory, something like Fig. 124. In this case it appears to the writer that the ventilating appliance, although it might serve as an outlet for the vitiated air, instead of being a thing of beauty, would be an everlasting eyesore, and in that respect might be entitled to be classed as a nuisance. Of course the ventilating practitioner in this case might assert that this was all a mere matter of taste, and if he thought this style would give better results he was justified in using it. This might be a mere notion, however, and it shows great poverty of resource not to be able to adapt the ventilating appliance so as to be suitable to varying conditions, and in this case to be suitable to this particular condition, case, or structure. It ought to be an axiom in erecting large ventilating appliances, and especially if these are to be set in a prominent position upon a respectable building, that the appliance should be a *fixed* one, and not movable, and more especially if the fixed appliance will serve better or as well. Even supposing the fixed appliance might be a small percentage less efficient at first, it should be preferred, as it will, if of proper design, give the most satisfaction in the long run.

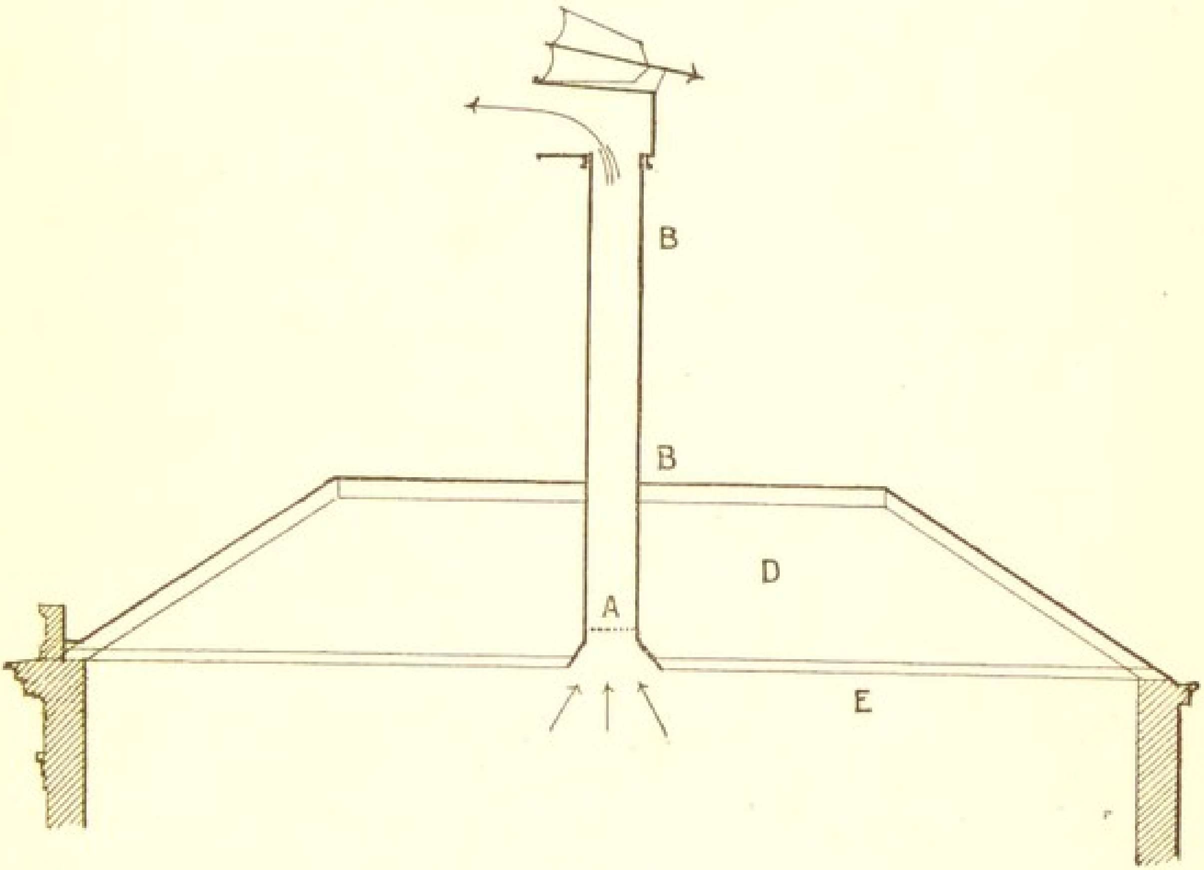


Fig. 124.

Movable appliances often stick fast and get out of order, and generally speaking do not last so long as good fixed ones. It is, therefore, a great mistake to use them where they can be dispensed with.

There is no justification in Mr. Hellyer's experiments for their use, so that to set up such a ventilating erection as is shown in Fig. 124, towering high above the roof of a classic building in any such way as is there shown is, to say the least, open to improvement.

Nature shows so many combinations of beauty with efficiency that the art which either cannot copy her or declines to do so must be very poor or conceited. True art can make the useful beautiful; the want of artistic taste may wallow in ugliness. To the untutored savage it is the hideously monstrous that is sublime.

Fig. 125 indicates one way of setting up a more appropriate while equally efficient appliance. The pipe or shaft, B, in both cases may be supposed to be 3 ft. in diameter, and gas may be used if needed at A in Fig. 125 shaft as in Fig. 124. Suppose the height of the garret space, D, in each case to be 10 ft., then there is

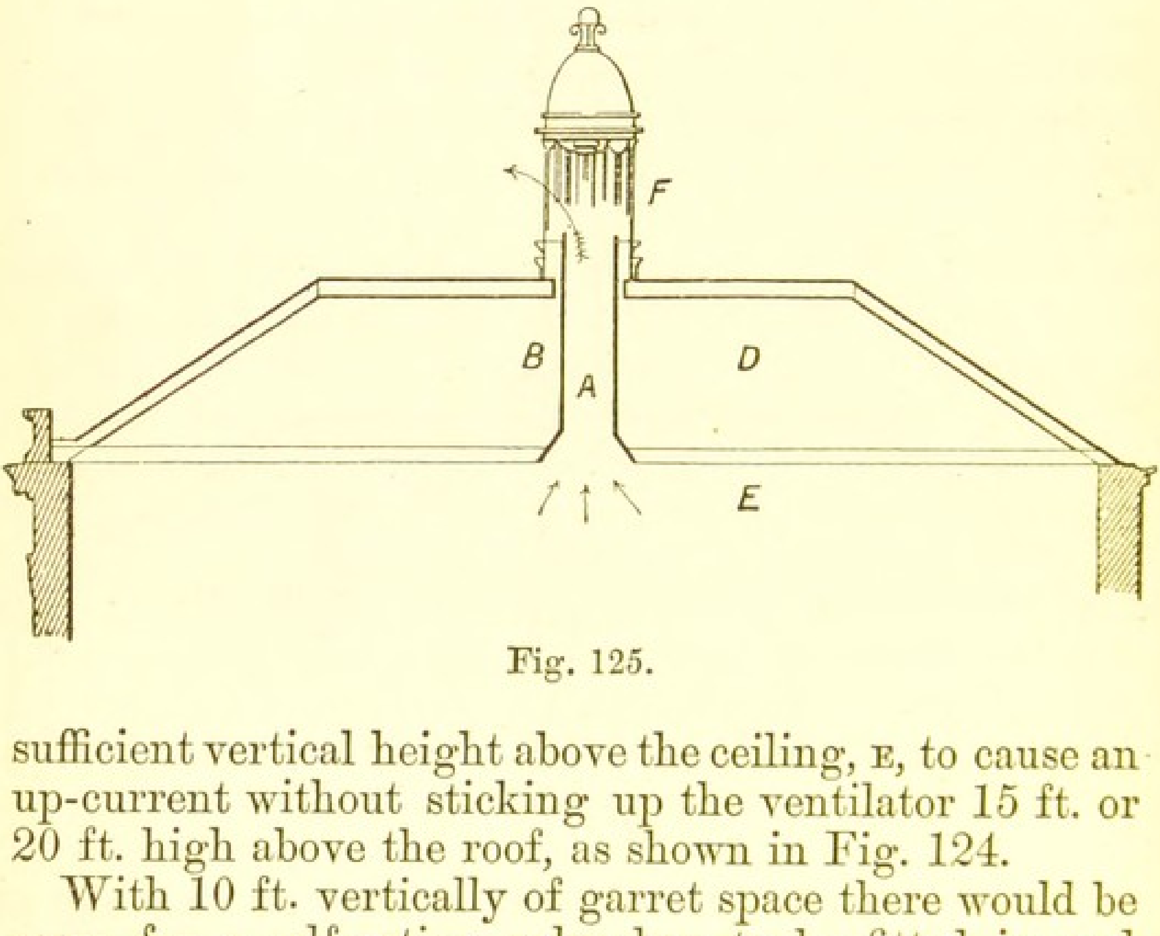


Fig. 125.

sufficient vertical height above the ceiling, E, to cause an up-current without sticking up the ventilator 15 ft. or 20 ft. high above the roof, as shown in Fig. 124.

With 10 ft. vertically of garret space there would be room for a self-acting valve box to be fitted in, and with the gas jets in the outlet pipe above the box, the gas jets being only intended for occasional use, to increase the up-current in close and calm weather.

Should it be desired to have a smaller ventilator than the 54-in. diameter one, shown at F, Fig. 125, then, instead of putting in one large 36-in. diameter pipe, either three 21-in. diameter pipes with 33-in. ventilators may be used, or two 20-in. pipes with 33-in.

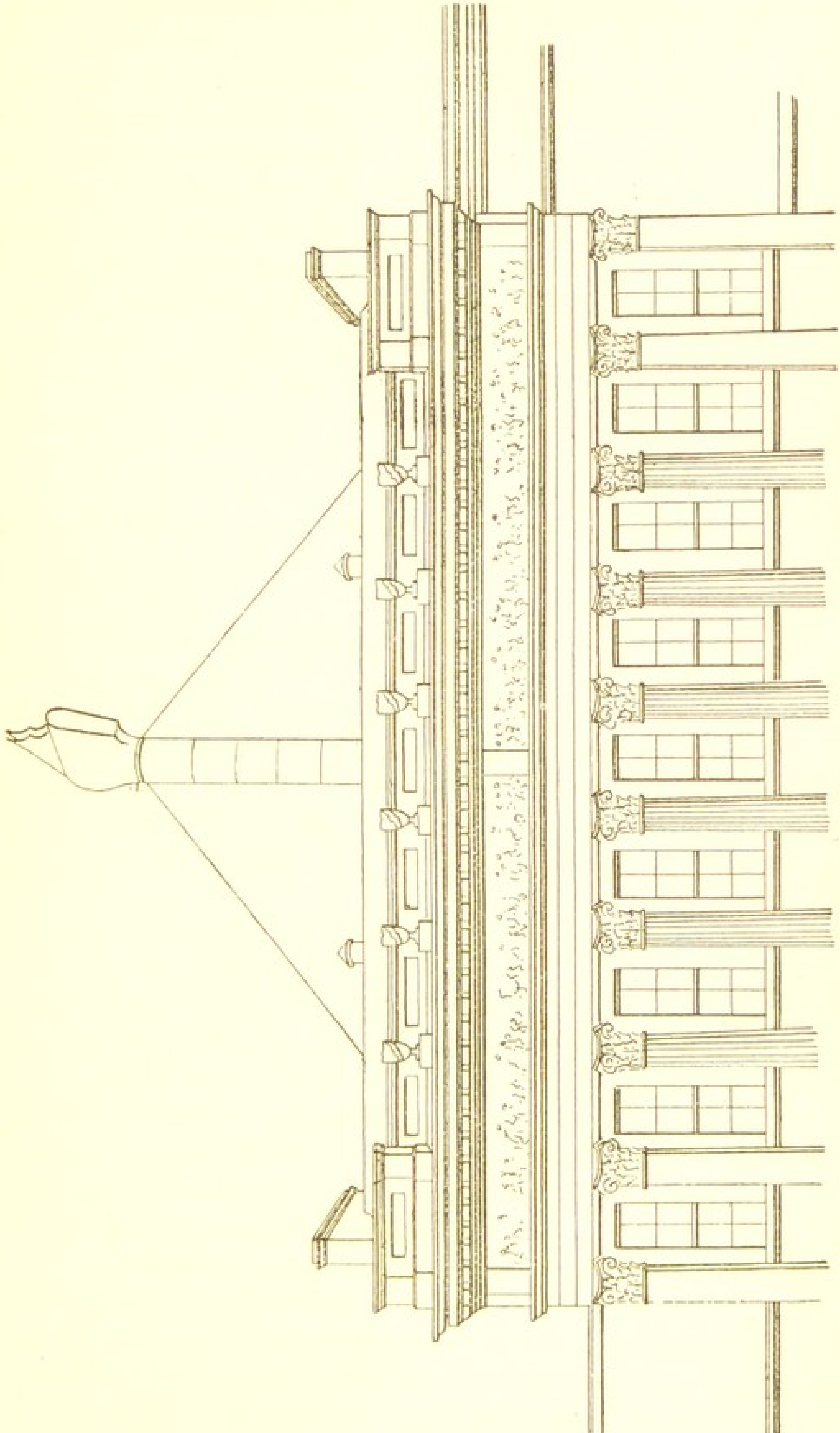


Fig. 126.

ventilators for each, and one 25-in. pipe with a 42-in. ventilator in the centre of the three.

Fig. 126 shows a large cowl lately set up upon the roof of a classic building for the purpose of ventilating a hall in its upper flat. The erection has called forth several adverse opinions in the newspapers, one journal considering that even a modern Archimedes might have some respect for Greek art. Of course "Archimedes" might retort, "A fig for your capitals and columns, your friezes and mouldings! Health is before ornament: so my sign has been set up on high as a testimony to all men of your negligence. You should not have left this in my power to do. You call me a Vandal—I style you all humbugs. If a building has nothing but ornament to recommend it, it is like—as Shakespeare says—'A goodly apple rotten at the heart.'"

The remarks in this chapter are merely made to draw attention to this question of taste in order to point out that there is, or ought to be, an "art" in good ventilation in more senses than one. We have a National Gallery of Art, and vast sums of money are spent in connection with it, but unless it teaches us to respect, appreciate, and love harmony and beauty, of what use is it?

CHAPTER XV.

ARTIFICIAL OR MECHANICAL VENTILATION.

THERE are two styles in which this is carried out, viz.—1st, the Plenum or propulsion system, in which the fresh air is forced or blown in; 2nd, the vacuum or extraction method, in which the vitiated air is drawn out of the enclosure.

In the former plan the air is driven in either by a fan or by a pump, or by water or air jets. In the extraction system the air may be withdrawn either by a fanner or by means of heat, such as hot-water pipes, gas lights, or by a fire or furnace, or by water or air jets. The most common motive power for artificial ventilation is the ordinary fireplace in our houses, &c., although, generally speaking, its use as a ventilator is more accidental than intended. A great fault of the fireplace as an outlet, as has been already explained, is its lowness, and this fault is all the more felt in houses, &c., after the gas is lighted if no additional means exist for carrying off the heated and vitiated air. As the ordinary fireplaces have been already dealt with, the artificial systems of ventilation here referred to are independent of these. In this country the continuous use of mechanical ventilation has been deprecated by various authorities; *e.g.* in the fifth edition (A.D. 1878) of "Parkes' Hygiene" we read:—"In temperate climates, in most cases, especially for dwelling-houses, barracks, and hospitals, natural ventilation with such powers of extraction as can be got by utilising the sources of warming and lighting, is the best. Who, in fact, would not attempt to make use of those vast powers of nature which are ever ready to serve us? Incessant movement of the air is a law of nature."

Now, while there is a great deal of truth in this, experience has shown that unless the "vast powers of nature" are properly directed and adequately used, they are of little service. To load a gun with a heavy charge of powder and putting the ball in first, is simply a waste of energy, while using a large ball and only a pinch of powder is like fitting up an extra large wind-acting ventilator with a microscopic pipe leading up to it. Bad and sham systems of carrying out natural ventilation have unfairly helped to decry its value; nevertheless — although natural ventilation can be made to do good service—as Dr. Parkes says, there are circumstances in which artificial ventilation is either a necessity altogether, or else of high importance as an auxiliary to the means provided for ordinary ventilation.

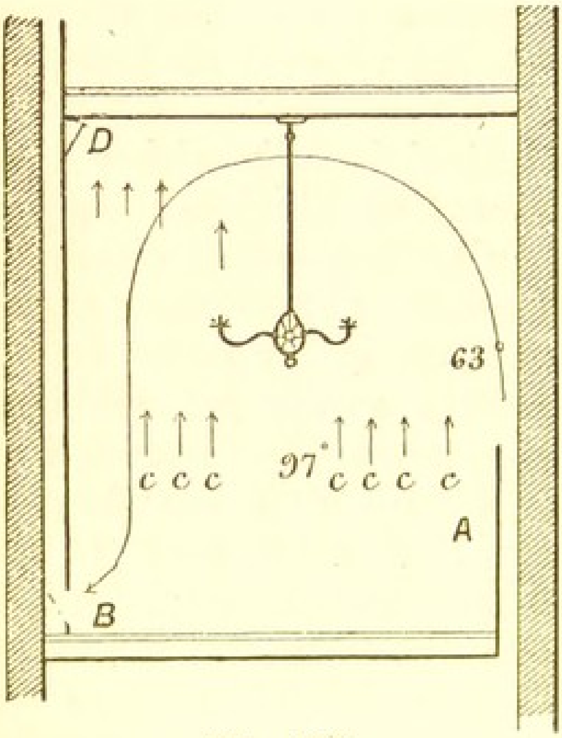


Fig. 127.

As to whether the propulsion or extraction system of artificial ventilation is the best authorities differ. Péclet and Grassi approved of propulsion, but General Morin asserts that propulsion is much inferior to extraction. Professor Carnelley seems to prefer propulsion, while Dr. Billings goes in for extraction.* A great objection made against the propulsion system is the taking away of the vitiated air at or near the floor level, as shown in Fig. 127.

* The agent for a certain ventilating fan remarked to me:—"Extraction is much cheaper than propulsion. Propulsion requires almost a lower flat for itself to give it justice."

In Fig. 127, A is the vertical inlet duct (say 3 ft. by 9 in., or it may be the length or width of the room, and say 3 in. wide), carried up about 6 ft. or less above the floor, while B is the outlet (say 21 in. by 18 in., as shown in face of the wall, the flue or shaft being only 21 in. by 10 in. in cross section inside of the wall) from near the floor, the outlet flue being carried up to above the roof.

C C C indicate positions or level of the heads of the individuals in the room when sitting, and the small darts show the vitiated air exhaled from their lungs rising up towards the ceiling. As the air comes from the lungs at a temperature of about 97°, while the incoming fresh air blown in at A may be from 57° to 65° or so, according to circumstances, it follows that the vitiated air, being from 32° to 40° warmer, naturally rises towards the ceiling, and not getting out there has to be forced down by the incoming air before it can or will go out at B. As the air exhaled from the lungs contains one hundred times more carbonic acid gas than that inhaled, it follows that in a room like Fig. 127, if there are a number of people in it, a very large amount of air requires to be driven in and taken out to prevent the vitiated air accumulating. It must also be remembered that the heat and emanations from the bodies have to be taken into account. If there are many people present the vitiated air is therefore bound to increase to a certain extent, on account of being warmer, as explained, and so rising to the top of the room where there is no outlet. The incoming fresh air of course dilutes the vitiated air, but in doing so and forcing it down towards the low outlet at B, the *mixed* air has to be rebreathed by the occupants of the room or hall. If a sufficiently large amount of fresh air is made to come in at the A inlet or inlets it is possible that in many cases, *in practice*, especially when the room is large and few people in it, the result may be better than a look at Fig. 127 would lead one to imagine. It must be remembered, however, that should the machinery break down or be stopped, the ventilation stops also, when, as I have experienced, the effect is anything but agreeable.

When the vitiated air is carried off, as at B, Fig. 127, at or near the floor, about three times as much fresh air requires to be blown in as when the vitiated air is carried off at the ceiling.

Then, again, the amount required to dilute the atmosphere of the room or hall sufficiently in the daytime, when no gaslights are burning, would be far too little after the gas was lighted. One benefit pointed out in favour of the Plenum system, and drawing off the vitiated air near the floor, is that the heat of the apartment is more easily kept up;* but, on the other hand, there is considerable risk of the temperature being maintained at the expense of the purity and freshness of the air. A little impurity from carbonic acid gas may be better than a great deal of cold, but the less impurity the better. To keep the ceiling outlet tightly closed on a warm or summer day is simply absurd, unless, indeed, an old horseshoe were fixed on the shut valve to make up by faith for what was lost by works.

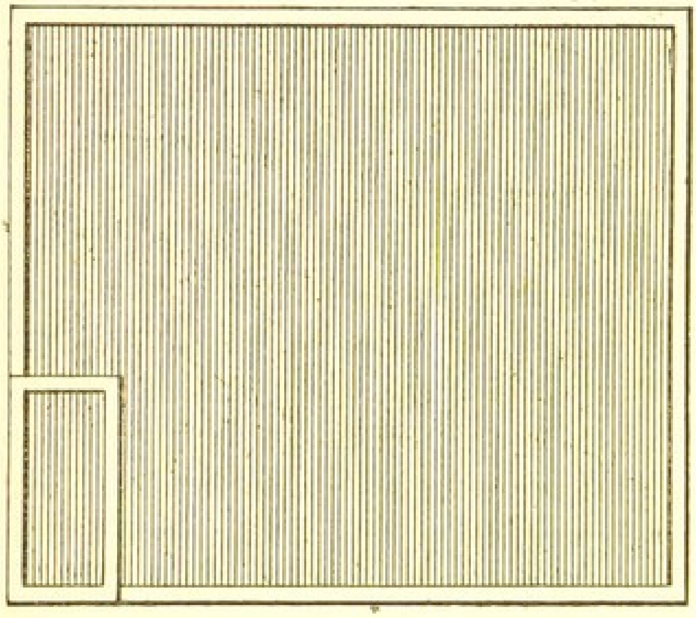


Fig. 128.

In order to give the blowing-machine all the credit the windows are kept shut, so that, as one medical gentleman expressed it after visiting a hospital on a warm day in June, where this Fig. 127 system, with outlet at the floor, was in full play: "I felt as if I was in a box, and wanted all the windows open—I wanted *fresh* air."

A great point at one place, held forth in favour of

* This being of most benefit in winter.

the propulsion system, was that the incoming air to the fanner was all strained, but when I visited the premises the strainers were out of position, being all dirty and choked up. The party in charge stated he had to take them out to allow the fanners to get air. In this case the strainer was some sort of cloth, the expense and

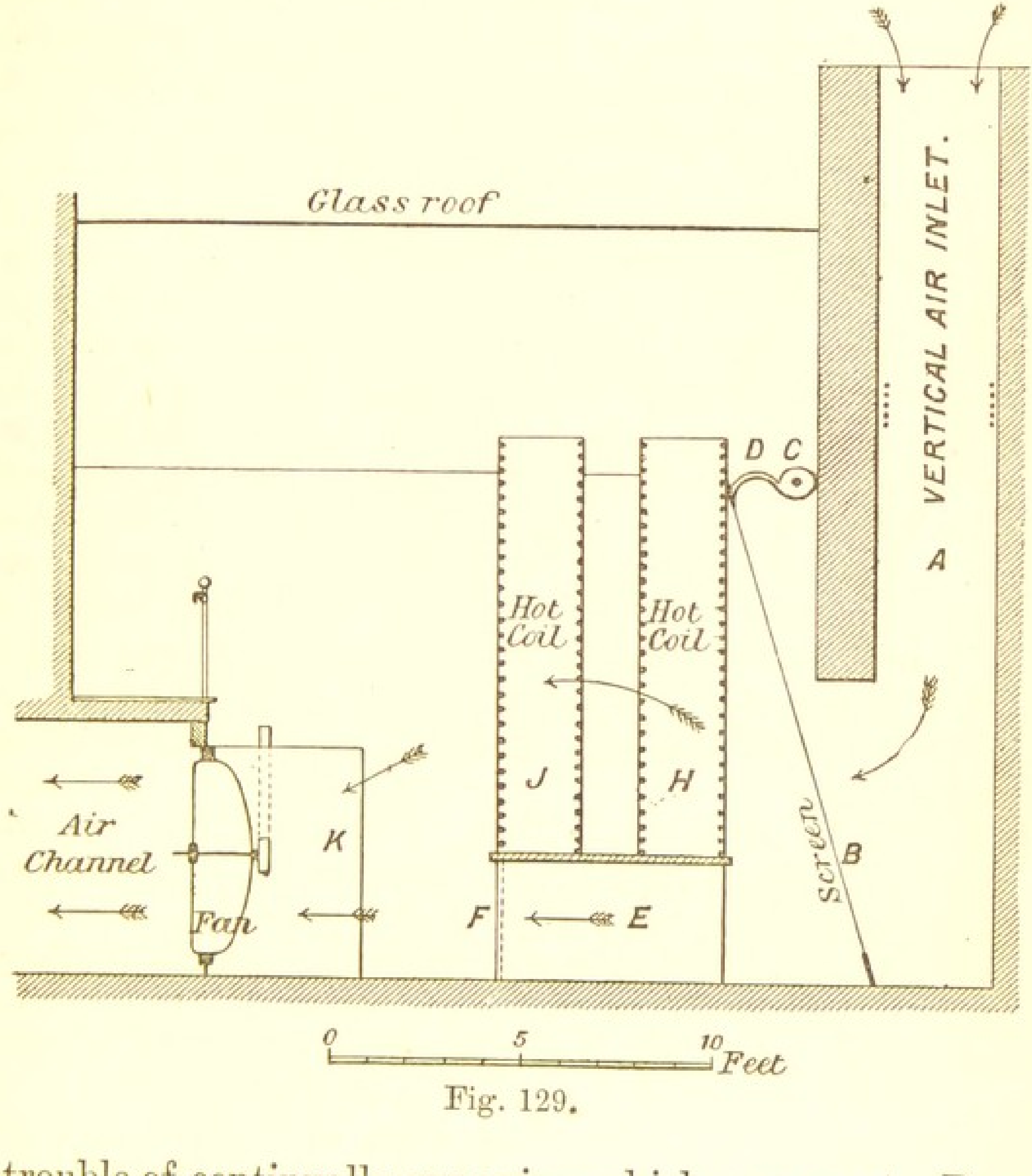


Fig. 129.

trouble of continually renewing which was great. Possibly something better has been got now.

In the new Victoria Infirmary, Glasgow, which has adopted the Plenum system, the strainer is a large horse-hair and hemp stringed frame, with the strands fixed near each other as per Fig. 128, and sloping slightly as per B, Fig. 129. Over the top of the screen water can be made to trickle down from the small trough, C, by means of the damp flannel syphon, D, in order to cool and purify the air and wash the strands. The long trough, C, is supplied from small cistern at same level.

The incoming air enters through the vertical channel, A, Fig. 129 (which is 16 ft. long by 3 ft. 2 in. wide, built of white glazed bricks, open to the sky), and after being sucked in by the two Blackman fans—one 5 ft. diameter and one 4 ft.—through the screen, B, is made to pass through a series of 1-in. diameter steam-pipes, as shown at H and J, and is then sent along two large horizontal subways, each 6 ft. high by 4 ft. wide, dug out of the ground beneath the building. From these subways, or large air-channels, vertical air-shafts, with regulating-valves at bottom and top, are led up to the various wards and rooms in the building, as per A, Fig. 127. Each fan is driven by a 4-horse-power Crossley gas-engine, the 5-ft. fan, M, Fig. 130, driving the air into the principal wards, the 4-ft. fan, N, sending the air in another direction to other parts of the building. Inside the two large horizontal air channels, and at the bottom of the vertical air-ducts, leading up from them, there are hot pipes for raising the temperature if wished. Inside the large air-inlet, A, Fig. 129, there are some steam pipes for heating the incoming air in frosty weather, so as to prevent freezing up of the water in the screen, B. K, Fig. 129, is a hinged wooden division between the two fans. F, Fig. 129, is a wooden door or facing which can be opened or removed in warm weather to let the fresh air in without it passing through the hot coils. Provision exists for carrying off the vitiated air at the ceiling of the wards, &c., as at D, Fig. 127, when wished, but the valves there have hitherto been kept shut, the 21 in. by 18 in. valves or outlets at B, near the floor, being used as yet.

Fig. 131 is vertical cross section of one of the two large outlets for the vitiated air above the ridge of the building.* There are louvre boards on each of the four

* As p. 183 "Robin's Technical School and College Building," A.D., 1887.

sides, as per P P, and inside the louvres there is a wooden barred frame erected with cloth valves, suspended as shown at A A, which open outwards, but shut against any attempt of the wind to blow in. This was set up in 1889.

Fig. 132 is illustrative of the Blackman fan or air-propeller, indicated at M and N, Fig. 130.

In conversation with Mr. Key, the engineer who planned the elaborate system of heating and ventilating here, which is very good, I could not agree with him in

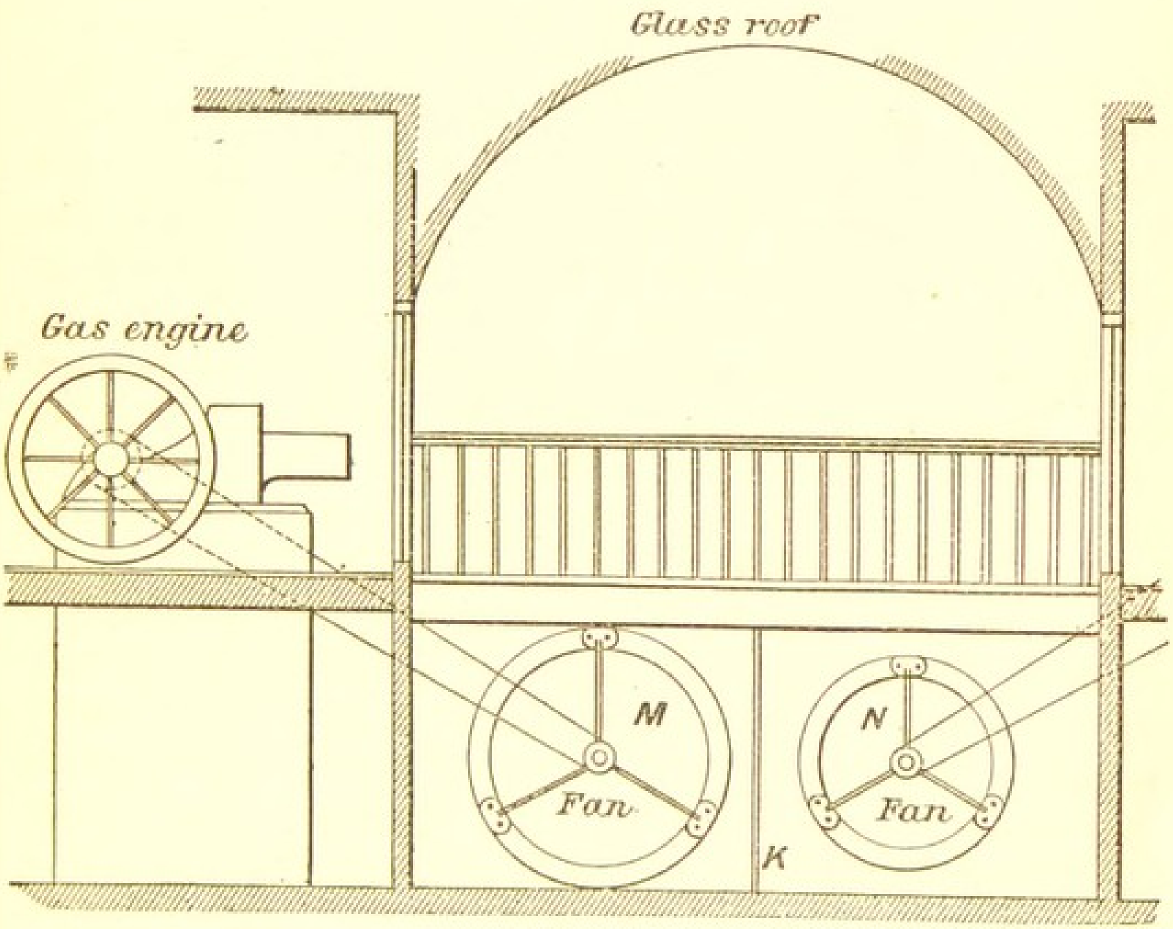


Fig. 130.

his idea that the outlet at the floor was the proper one for constant use. In summer especially, and in mild weather, the outlet at the ceiling should be used. It may be regulated so that the floor one may act too, if wished. This would be like a room with a fire in it, and having also a ventilating outlet at the ceiling, as, *e.g.*, in Figs. 22, 23, and 24.

The cost of the ventilation here was under £3,000. I am not aware what the yearly expense is. The first outlay was more expensive in this case than it might have been, owing to it being an afterthought.

Fig. 133 is a vertical section of the Hillhead public school, under the Govan Parish School Board, west end of Glasgow. This school is ventilated upon the

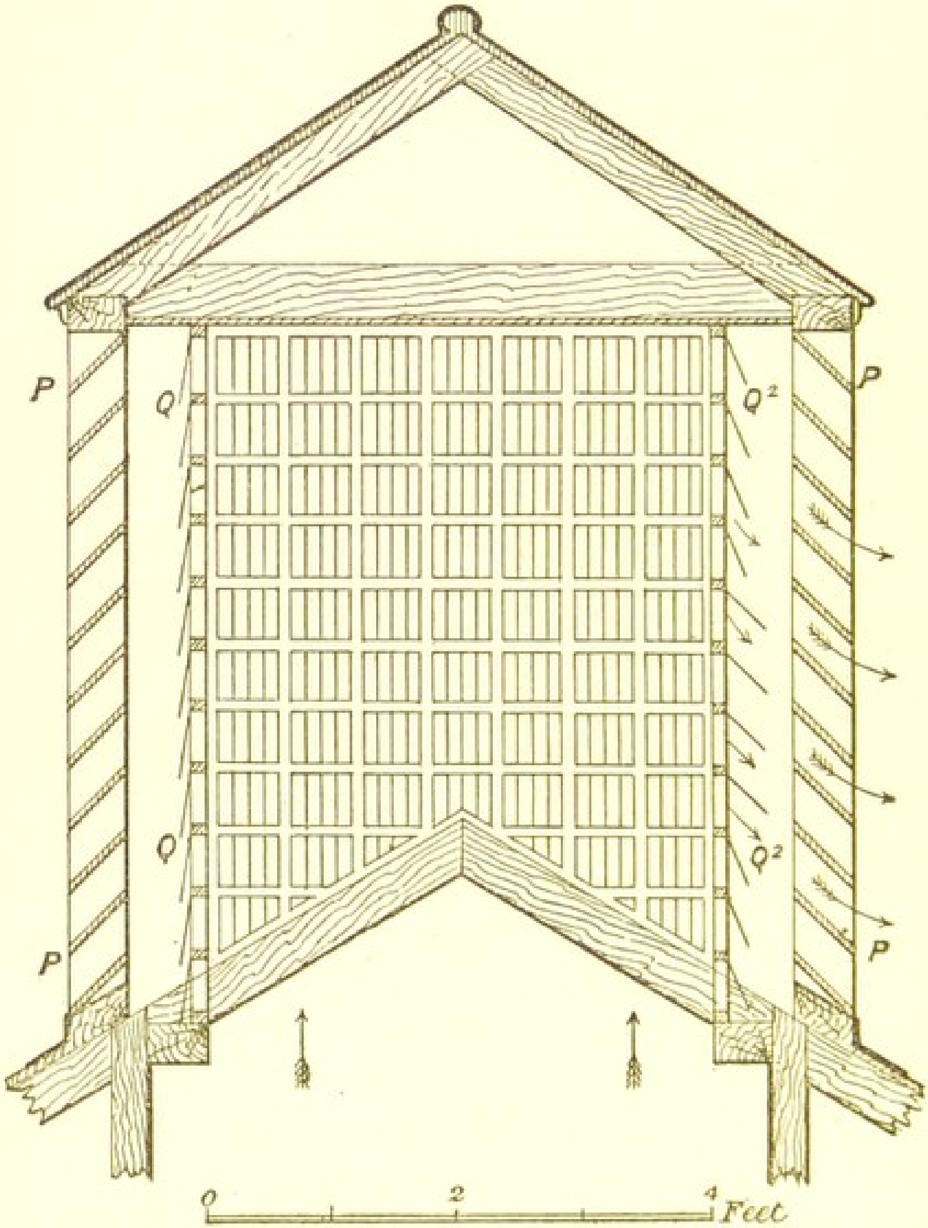


Fig. 131.

mechanical extraction system, by means of a 48-in. diameter Aland's paddle-wheel fan, which draws in the vitiated air from the large ducts C C on each side of it, and sends it out at the open-to-sky outlet, K. This outlet is 6 ft. 4 in. long, by 2 ft. 6 in. wide. To keep the rain from doing damage, there is a gutter, G, put in as shown, right below the outlet K, and also a small gutter at bottom of slope on each side of G.

There was a large ordinary wooden horizontal louvre-boarded ventilator put on at K at first, but, as these often do, it proved a nuisance, and had to be taken off.

The fan is worked by a 2-horse-power Otto gas engine E (cost of such now with water vessel, £123), which is shown as seated upon the same level of floor as the drawing class. In reality, however, the floor

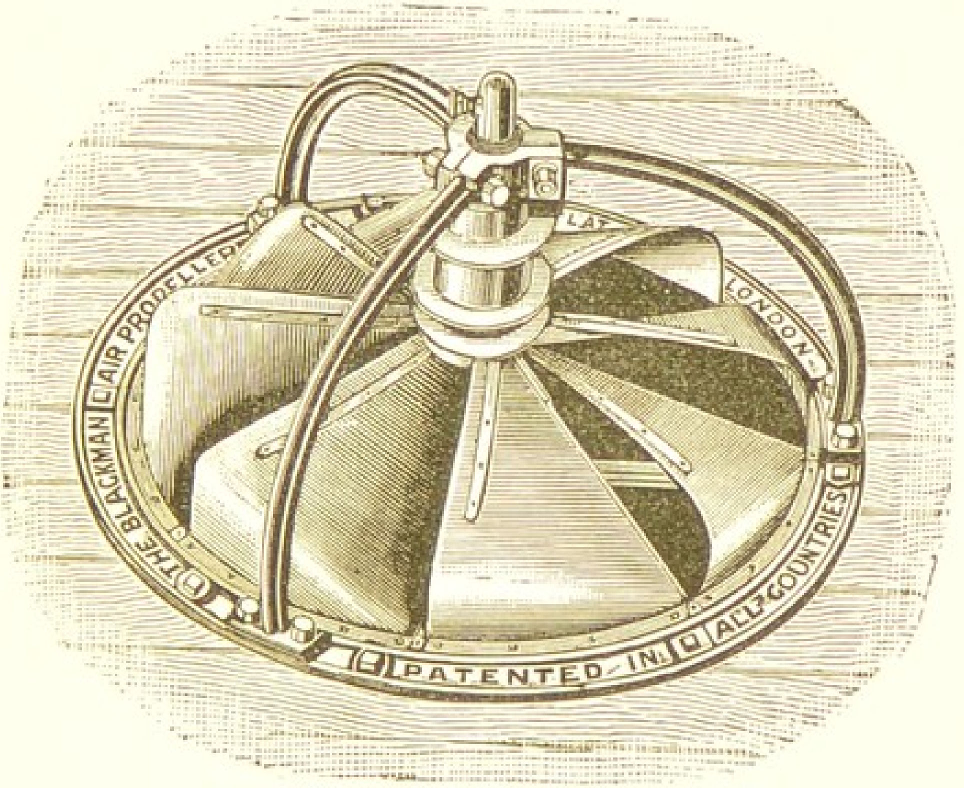


Fig. 132.

on which the engine sits is several feet higher than is shown.*

The vitiated air from the various rooms is led off by 18 vertical rough brick flues, A A A A (each 10 in. by 9 in.) in centre of walls, and also by the long 7 ft. by 6 in. vertical ducts, B B B B, which, as seen in horizontal section or plan, Fig. 134, debouch into the large horizontal flues, D D, and from D D by the pas-

* Professor Carnelley says:—"A 2 h.p. gas-engine is amply sufficient for driving a 4-ft. Blackman or Aland fan." At some schools a 3 h.p. engine is used, price of which, with water vessel, is £158.

sages C C* to the fan, and then out through outlet K, Fig. 133.

In the principal rooms on the ground floor and one stair up, the outlets for the vitiated air are seen

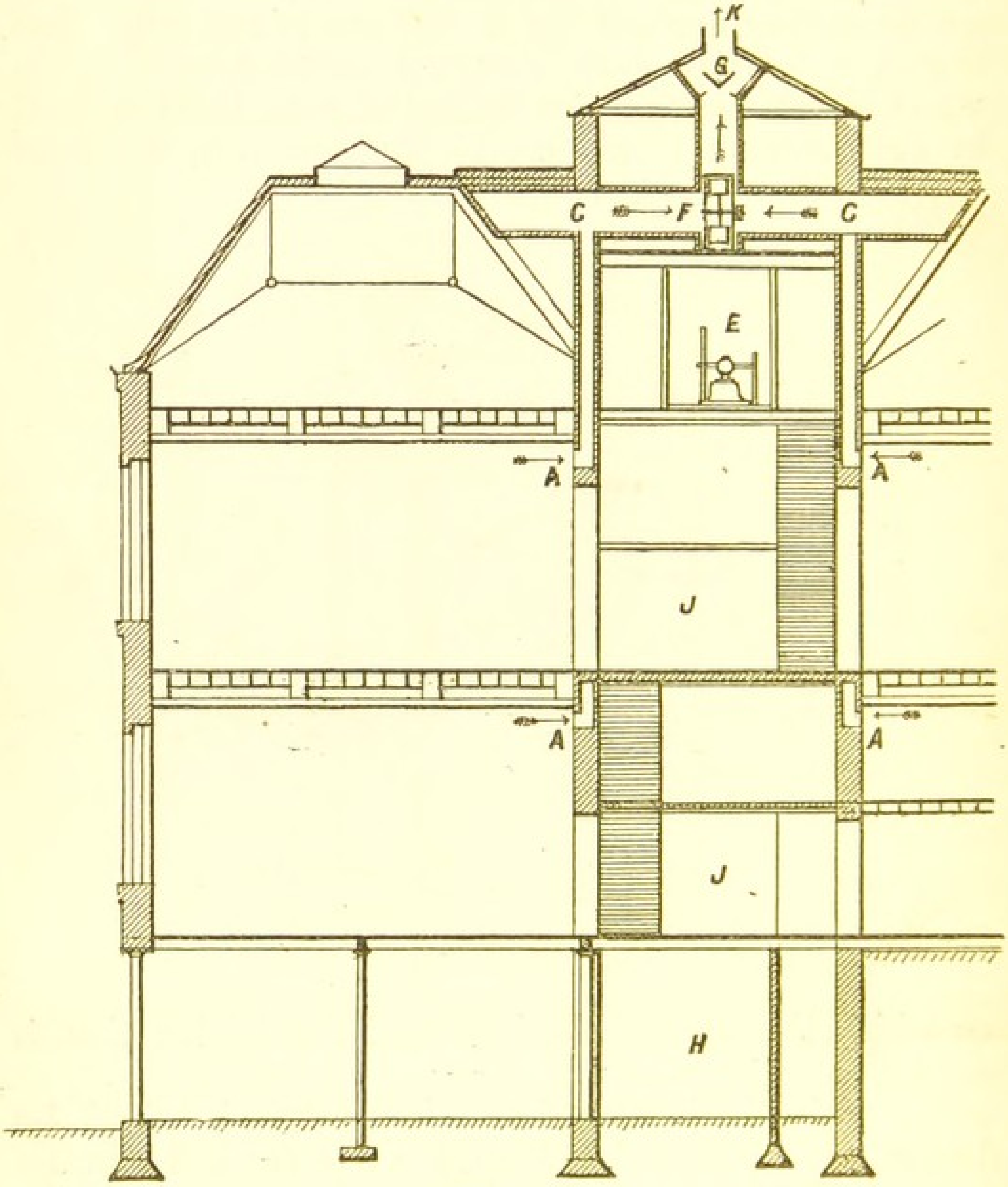


Fig. 133.

to be at one side of the room, just under the cornice. There is one long opening in centre in Greek open

* The two passages or flues, C C, do not go in straight to the fan as shown in sketch given to me, but they expand towards the fan to its full width.

fretwork, about 6 ft. long by about 5 in. deep, and at each end of this, a few feet apart, there is an opening about 10 in. square. In the science and drawing classes in top flat next the roof, the ventilating outlets are a long slit, about 6 ft. by 4 in., off the ceiling of each room, filled in with perforated zinc, allowing the

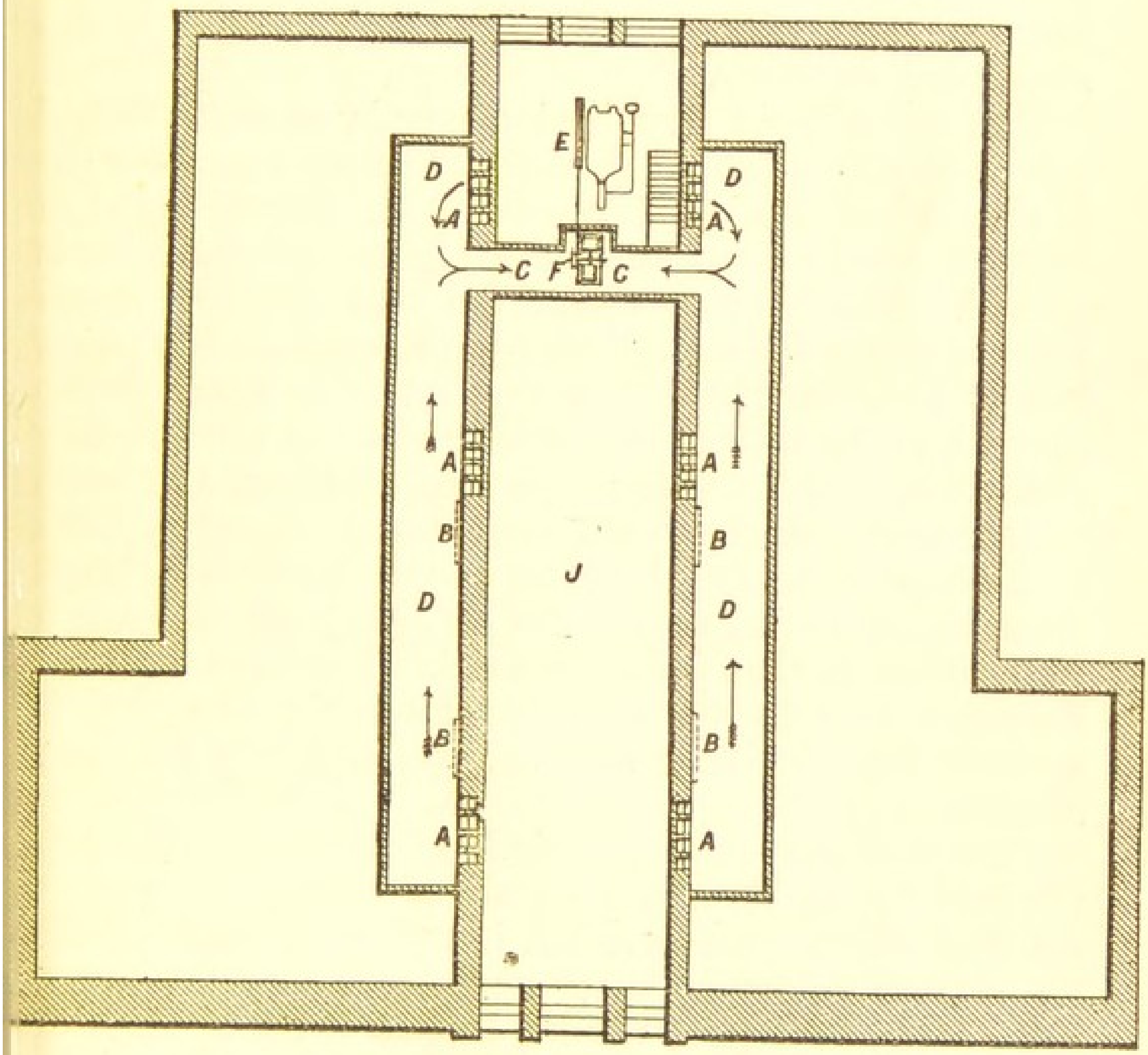


Fig. 134.

vitiated air to flow up directly into the large ducts D D.

J, Figs. 133 and 134, indicates the large staircase and lobby in centre of the building.

Fresh air is warmed in the chamber H in basement, from which flues are carried to rooms and admitted at floor level. There are also hot-water pipes in the rooms. The air capacity of the school is 200,000 cubic ft., which is said to be exhausted by the fan in thirteen minutes. When I tested the speed of the outgoing air at K, with the fan on, it was about 1,000 lineal ft. per minute ; when the fan stopped, the outlet was only about 200 lineal ft. a minute. The children had gone out then, so that room doors and windows were partly open, but, even with this, the outlet was five times as much with the fan on as with it off. It was all needed, however.

The same day I examined a new large three-flatted school ventilated automatically. The air was not what it should be. To put in a small 9-in. diameter pipe in 1890 to carry off the vitiated air from a school-room is absurd. The top rooms next the roof could be ventilated pretty well automatically with large enough pipes, but it is more difficult to ventilate the lower rooms properly. In a large street-flat room the air was only going out at the outlets at the rate of about 120 cubic ft. a minute, which would have taken about an hour and a half to empty the room once. These long brick flues, rough inside, retard the outgoing air very much by friction, so that when the brick flues from different flats are led into the same ventilator, the flue that is nearest the ventilator and the shortest has the best chance.

In one of the rooms the windows were open, allowing the cold air to blow in upon about seventy little girls, some of whom must have felt it badly, but had not the sense to complain.

To give satisfactory results, large schools of three or four flats and a thousand or more children should be mechanically ventilated.

The new Stewartville public school, Partick, is being ventilated on the same plan, as shown in Fig. 133.

When I visited Fig. 133 school, lately, in the afternoon, the air was very good in all the rooms except one, which was not as fresh as the rest, owing to some deficiencies in the fresh air inlet to it. Improvements could be made with the inlets generally. The architects were Messrs. H. & D. Barclay, Glasgow.

In his report on this school, Professor Carnelley says: "The temperature over all the school was almost perfectly constant, viz., 58° F." This school, as stated above, is not under the Glasgow School Board, although Hillhead is looked upon as virtually part of Glasgow. In regard to the Glasgow schools, Professor Carnelley appears to have been told that their ventilation was satisfactory, but he seems to have been rather dubious as to this,* for he says: "But whether this is the case or not it is difficult to say, as no analyses of the school air appear to have been made."

In the opinion of the writer he was quite justified in this disbelief, as many or most of the Glasgow schools have neither proper nor sufficient provision for their ventilation. In fact, some of them, so far as the writer can judge, are veritable manufactories of influenza.† The writer regrets that he cannot point to even one of them as a model of satisfactory automatic ventilation. No doubt a report in the newspapers of some opening address, giving a glowing account of the ventilation of some new school, might be pointed to, but this might be of no more value than an after-dinner speech. The writer has read high accounts of the ventilation of some place where his own appliances were fitted up, but if these were too small, &c., this mere verbal recommendation of them would not make them work any better, or do what, as fitted up, they could not do.

* The Glasgow School Board, although it has, *inter alia*, a number of large three-flatted schools, has not as yet gone in for mechanical ventilation. The plans of a new three-flatted school about to be erected at the east end of the city were sent to the writer, who stated, that to get really satisfactory ventilation in it, supposing such could be done by natural means, the provision for ventilating it automatically ought to be made larger and better arranged than in the schools hitherto erected, but the writer recommended that mechanical ventilation, either wholly or partially, should be adopted. If partially, the top flat to be automatically ventilated, and the two flats below it mechanically ventilated. This, if properly done, would not only give good results, but would also afford opportunity of judging as to the comparative merits of the automatic and mechanical systems in the same school.

† In justice to the architects, it should be stated that they have not been allowed a free hand—for several years back, at least—to deal with the ventilation of the schools which they design.

Even supposing the wind-acting ventilators used * were the best in the kingdom, the outlet ventilating pipes are far too small. To use a 9-in. pipe where the necessities of the case require an 18 in., cannot give real satisfaction. Probably improvements in this respect will be made by-and-bye.

Professor Carnelley gives the following as the relative expense of heating and ventilating schools on the natural and mechanical systems:—

		Cost of heating and ventilating only.	
		Per head.	Per school of 1,000 pupils.
		s.	£
Natural Ventilation	Open fires †	4	200
	Small hot-water pipes (high pressure)	8	400
	Large ,, ,, (low pressure)	10	500
Mechanical Ventilation	As applied to schools suitably designed	17	850
	As applied to ordinary schools	20	1,000

To fit up a school *for* 1,000 *children* with mechanical ventilation would seem, from the above table, to cost

* The writer happened to call upon a brother tradesman recently who was going to fit on a £4 14s. wind-acting exhaust ventilator (not an ornamental one), for a 9-in. pipe upon a school. This ventilator was supposed to have wonderfully exhaustive powers. Permission was asked to test it against one of mine, for same size of pipe. Unfortunately I had not a ventilator for a 9-in. pipe in stock at the moment, but anxious to see the test I ventured one of mine for an 8-in. pipe, price £1 18s., against the other party's 9-in. one at £4 14s. The cheaper one won by about five per cent., notwithstanding the disadvantage of the check given to it by its smaller pipe. Now one of my ventilators could have been got for a 13-in. pipe for less than £4 14s., which, at the same rate, would have drawn up more than double the quantity, which would be a great matter in an automatically-ventilated room, *e.g.*, a 9-in. diameter pipe only gives one square inch of outlet for each pupil in a room for sixty-two, while the 13-in. pipe would give fully two inches; or in a room for thirty pupils, while the 9-in. pipe only gives two square inches for each, the 13-in. pipe would give fully four inches, which approaches the necessities of the case as stated in the formula, p. 143. Inefficient ventilation at a high price is as bad as short allowance and a long grace.

† Heating by open fires is radiation; by hot-water or steam-pipes, conduction—the air getting heated by coming into contact with the pipes. The so-called steam or hot-water "radiators" heat principally by conduction, as may be easily proved by suspending one thermometer, say, a foot high right above the "radiator" and another right in front of it and six inches from it. Blowing heated air into a place is heating by convection. See Walter Jones' "Heating by Hot Water," published by Messrs. Crosby Lockwood & Son.

about £500 more than if automatically ventilated, which at 4 per cent. is £20 a year. The difference in the *first cost* of the two systems might, however, be a good deal less if the provision for automatic ventilation were properly carried out. But when done, the automatic ventilation *per se* might be said to be costless afterwards, whereas the expense of gas for engine and repairs to it are a constant factor.* Where, however, there is a man constantly on the ground, at any rate, then for a large school of three or four flats the expense of the mechanical system (especially if on the extraction method, as per Hillhead School) is really very little per annum. The doctors' and the undertakers' fees are less to the parents, and the attendance and attention of the children at and in the school are better where the ventilation is good.

The expense per pupil of mechanically ventilating a small school of, say, 500, is much greater than for one of 1,000. In his "Comparison of Natural with Mechanical Systems of Ventilation," Professor Carnelley says: "A comparison of the results obtained in

* The following may be of interest in regard to the Hillhead school referred to above:—

Revolutions of engine per minute	156
,, fan ,, ,, ...	290

	£	s.	d.
Gas, per hour. 2d.; oil, per week, 6d.; 1 lb. of white cotton waste per week			
Gas, per 1,000 cubic ft.	0	2	10
33 hours per week of fan going, cost of gas . . .	0	5	6
Cost for one year of 42 weeks, independent of breakage	13	2	6

To save the gas in some schools the engine is stopped at the intervals, but that does not give fair play to either the ventilation or the children. The engine ought to be kept going during the interval, so that the children may have really fresh air when they come back.

Where a school for 1,000 children is only *one* story in height, then it might be well enough ventilated automatically, if situated in an open space where the wind can get freely at it; but when the school is in *three* flats, and the architect or his superior looks upon satisfactory ventilation as a bugbear or a nuisance, and not worth considering in the structural arrangements, then it is very difficult to get proper provision put in for efficient automatic ventilation, supposing it were possible to do it.

naturally ventilated, with those obtained in mechanically ventilated schools, taken as unity, shows distinctly that the latter is far more effective, thus :—

Excess over Outside Air.	Dundee Schools. (Carnelley, Haldane, and Anderson.)		Aberdeen Schools. (Brazier, Thompson.)	
	Mechanically Ventilated.	Naturally Ventilated.	Mechanically Ventilated.	Naturally Ventilated.
Temperature . .	1	0·66	1	0·9
Carbonic Acid . .	1	1·7	1	1·6
Organic matter .	1	7·0	..	..
Micro-organisms .	1	9·2	1	7·2

"The above table shows that, notwithstanding the very great improvement in the purity of the air, the temperature is considerably higher in the mechanically ventilated schools than in those under the ordinary systems. To produce such an improvement in purity by the ordinary methods of opening windows, &c., would reduce the temperature to a very uncomfortable and dangerous degree." *

Professor Carnelley goes on to say: "Mechanical ventilation reduces the number of micro-organisms in the air, not merely during the time it is in action, but it has been proved to have also a very marked effect after it has been stopped and replaced by natural ventilation, this effect extending over a period of many days at least.

"Mechanical ventilation, also, as shown by Professor Brazier in the Aberdeen schools, keeps the composition of the air more or less constant in the different parts of a room; whereas, with natural ventilation, it is liable to be much less pure at one part than another."

* This remark does not give fair play to automatic ventilation, for we have here recently-done mechanically well-ventilated schools, compared with older schools, whose ventilation on the natural system is a mere sham, or very inferior to what they should and might be, if properly done.

Now this depends a good deal upon circumstances, although it may be allowed to be pretty true, as there are so many badly naturally-ventilated schools at present in existence. It so happens, however, that there are or were some mechanically-ventilated schools the air of some of the rooms in which, when I visited them, was bad.

On page 47 it was stated that Professor Hay had found diseases of the respiratory organs especially rife in schools among the girls. Since mentioning that, I happened to be visiting a large Board school, and came across a room with about forty young ladies, or girls from about eleven to fifteen, in it, which seemed to me to show how the girls suffered most. The boys in school keep their jackets on; the girls, in this case, were sitting without theirs, while the windows were down about two feet from the top. There was no proper provision for the ventilation of the room otherwise, and so the girls had and have to suffer.

At another school the ventilation is by casement windows opening inwards and allowing the cold air to blow in upon the backs or sides of the children. In some of the rooms there are no flues or pipes for carrying off the vitiated air. One large room for 120 girls had only one small pipe off it, giving about three-quarter square inch of outlet for each child—a ridiculously small amount. Yet these are west-end schools. The history of more than one pupil might be fairly sketched as :—To-day frisking as a lamb—a shiver and a struggle—to-morrow nothing but a memory. These words may raise a saddening echo in the breast of many a harassed and bereaved parent.

Then what about the teachers? Is it right that they should be forced to fill their lungs with vitiated air at every inhalation while they are speaking to and teaching our children? Is there no room for a little chivalry to be shown to them, not even to the ladies among them? Do we allow our mechanical engines to get rusted and clogged to get the best work out of them?

All this must be rectified, for it won't do to allow our schools to be turned into "Black Holes" and manu-

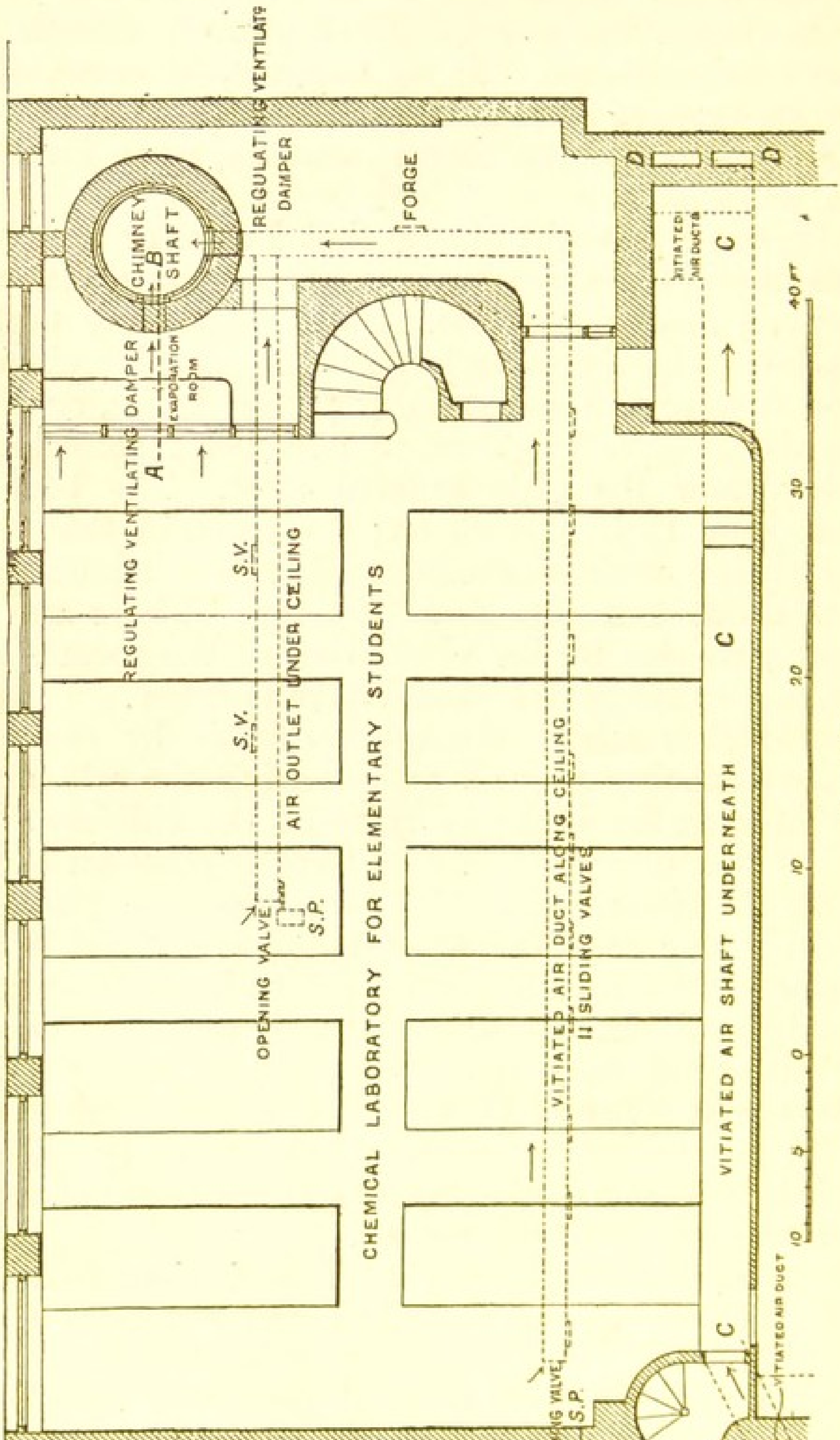


Fig. 135.

factories of consumptives. Many of our School Boards ought to do penance for their sins in this respect, but the only sentence worth anything is rectification.

Figs. 135, 136, and 137 show style in which the newer portion of the Allan Glen's Technical School at Glasgow has been ventilated, Mr. William Forrest Salmon, F.R.I.B.A., being the architect. In this case the vitiated air is carried off from the chemical laboratory by the two horizontal wooden ducts, 18 in. by 12 in., fixed up below ceiling, as indicated by the dotted

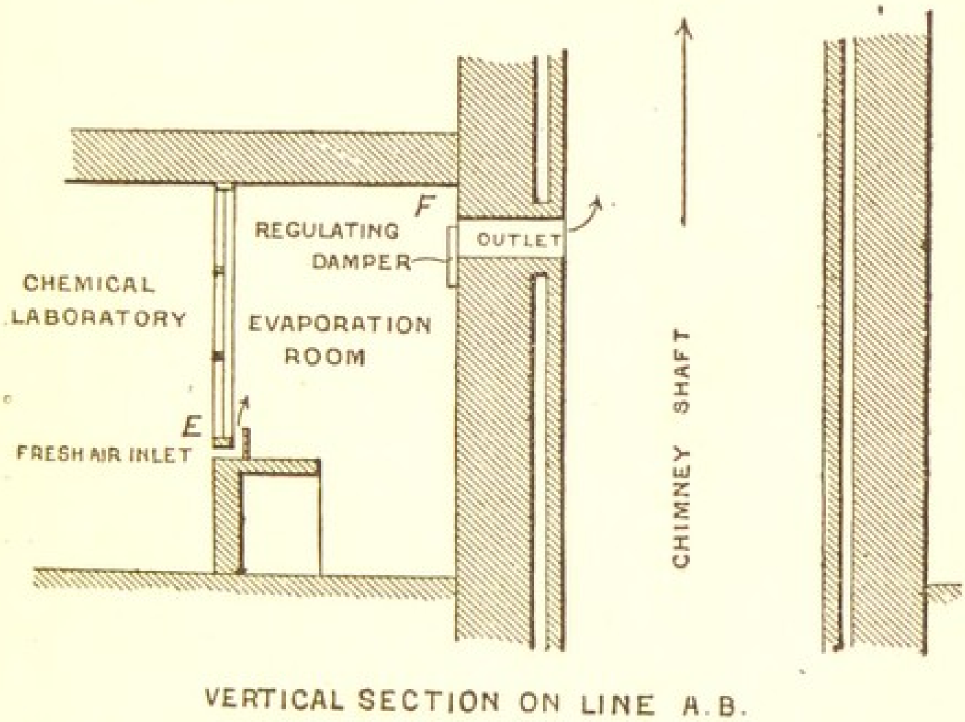


Fig. 136.

lines in Fig. 135, and through the evaporation room, as indicated at E and F, Fig. 136. S P, S P, Fig. 135, indicate positions of two chemical "stink presses." The one nearest the chimney has its ventilating outlet pipe $4\frac{3}{4}$ in. by $3\frac{1}{2}$ in. in cross section; the other one is 6 in. by $4\frac{1}{2}$ in. in cross section, delivering into the vitiated air duct. The openings with sliding valves on the side of the vitiated air ducts are 10 in. by $6\frac{1}{2}$ in. when full open.

They are not all open at once, but are regulated to suit. When I tested the speed at these outlets the rate was 700 lineal ft. per minute at the end inlet of the 18 in. by 12 in. shorter duct nearest the chimney, and 850 lineal ft. per minute at the second of the side inlets of same duct, the valve being only 3 in. open.

At the far end of the longer duct the speed was only

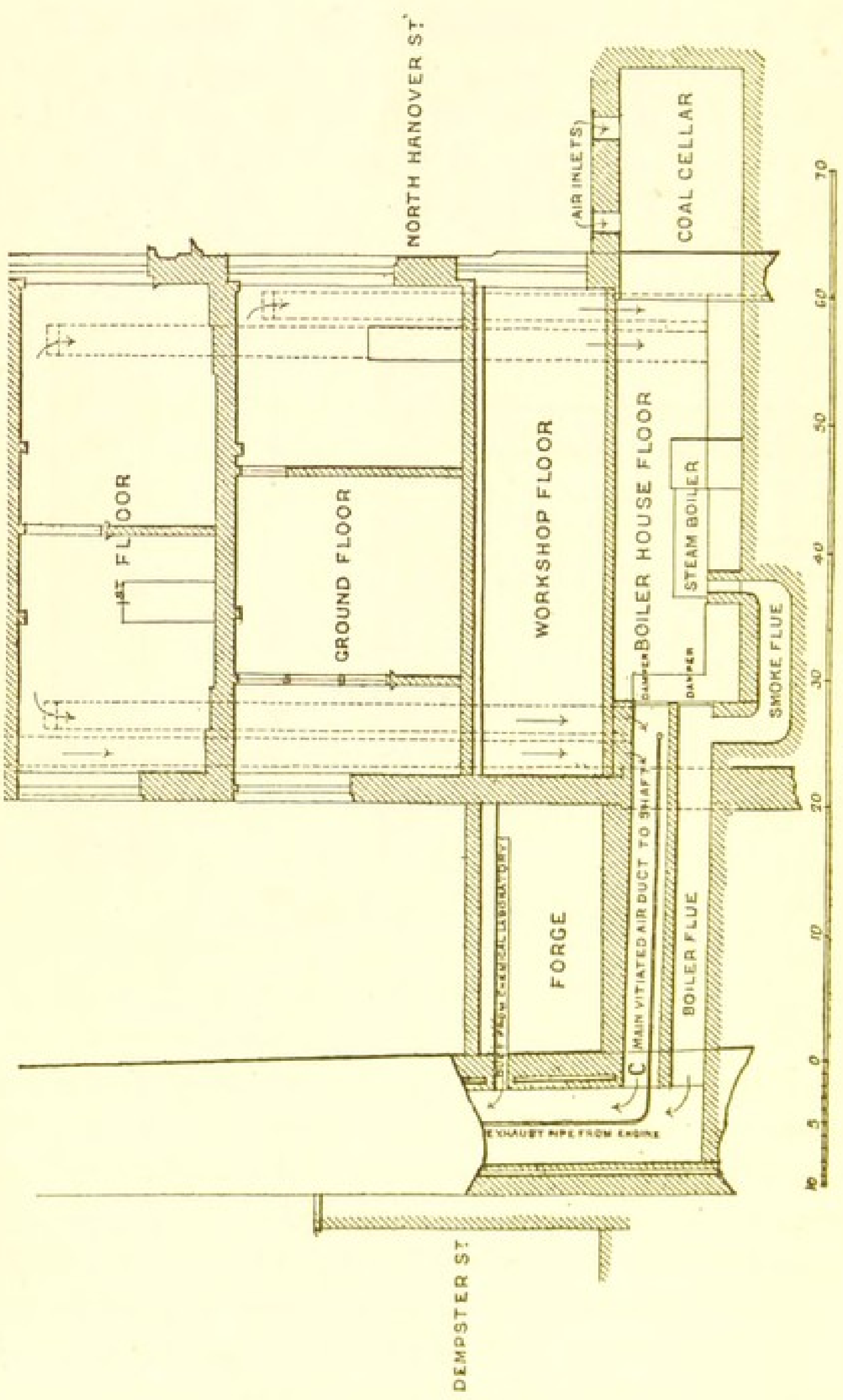


Fig. 137.

30 lineal ft. per minute. At the third opening from the far end of same duct the speed was 140 ft. per minute. At the seventh hole from far end, 370 ft. per minute; at the ninth hole, 570 ft. per minute.

The nearer the chimney the quicker. At the 18 in. by 12 in., opening F (right into chimney in the evaporation room), which was full open, the speed was 2,000 lineal ft. per minute. The large duct, C C C, which goes along underneath the floor, receives the vertical ducts D D D, &c., which carry off the vitiated air from near the ceilings of the rooms above. The large duct C C C, as shown at C in Fig. 137, delivers into the large chimney about 9 ft. lower than the duct from the chemical laboratory. The height of the ceiling of the laboratory is about 9 ft. It is supplied with fresh air passing over hot-water pipes, also through opening windows on the hopper principle.

Fig. 138, had I got it in time, might well have followed Fig. 11. It illustrates how natural ventilation can be spoiled by mistaken fitting up. In this case, E is the seat for a ridge ventilator, with 20-in. diameter outlet at F. Into the bottom of E five pipes join, as per Fig. 139. Of these three are shown in Fig. 138, viz., A, B, and D. A is 12 in. in diameter, say, and B and D each 9 in. A, as will be seen, is a short pipe coming off the ceiling of the top-flat room. It is of metal, and smooth inside. B, from the bottom of E to the top of the vertical wall, is of metal, but the flue it joins on to is of brick, and rough inside all the way down to the inlet below cornice in street-flat room at C. Now it stands to reason that, especially when there is little wind, the wind-acting ventilator seated above F will be able to pull very little through a smaller pipe from an opening situated so far away as C is, when it can get so large a supply from the top-flat schoolroom through the larger pipe, A, near it.

Upon testing pipe as per A lately, the air was going out at A at 450 ft. a minute, but when I went down to C, the indication was less than 40 ft. a minute. This speed at the outlets in the lower room would have required about two hours to renew the air of the room once, while the top room would have been renewed three times in the hour. While, therefore, the automatic ventilation of the upper room G was comparatively good, that of the room H, two flats below, was very bad. The outlet pipe of the top-flat room next to G was smaller than A (9 in. diameter), and went into a

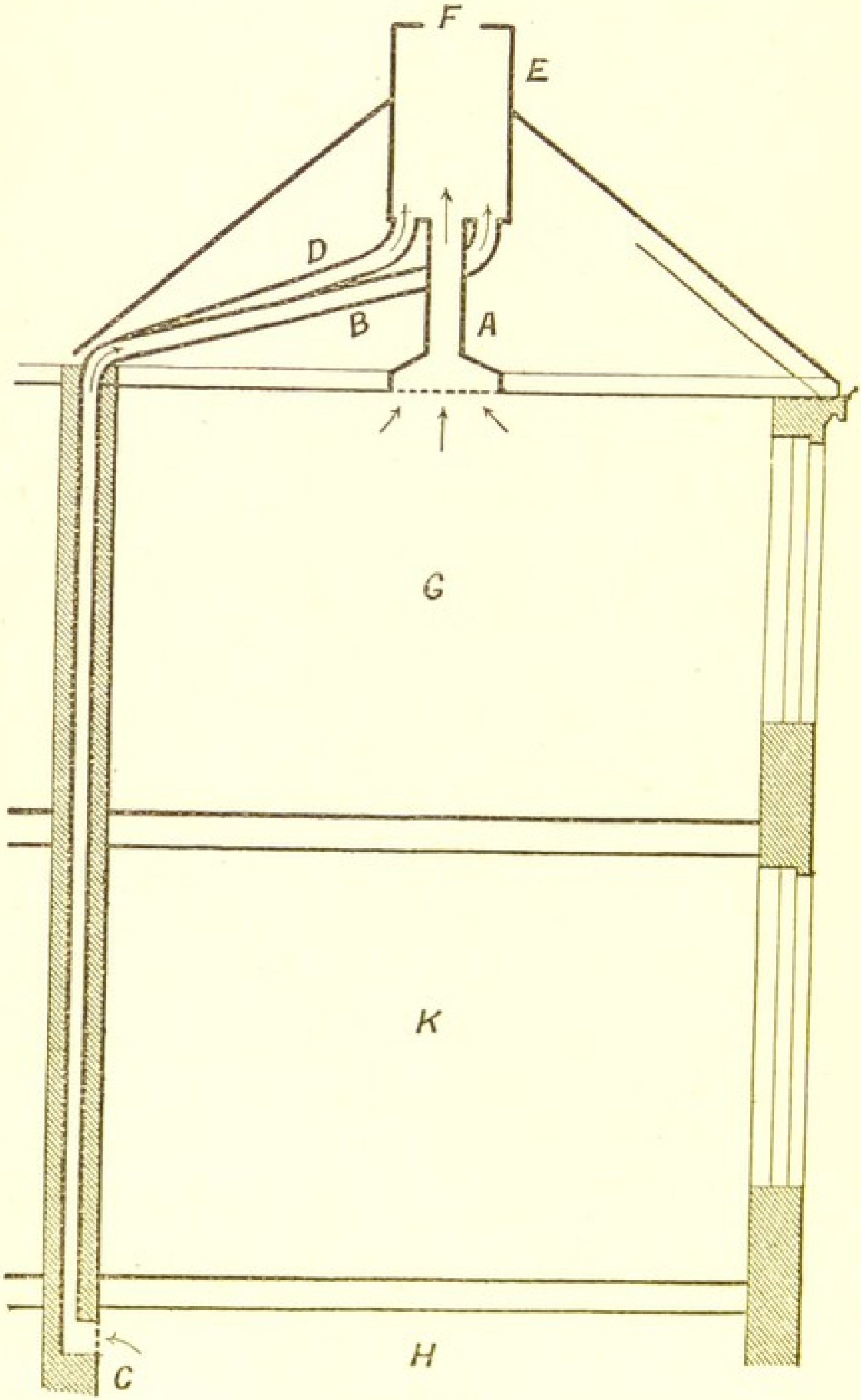


Fig. 138.

23-in. main pipe having six branches; it only indicated 100 lineal ft. a minute with the windows shut, which gave far too little quantity of outlet for a schoolroom.

Fig. 140 shows the style of fitting in and connecting the flues in the walls, for carrying off the vitiated air as adopted by Mr. J. Murray Robertson, architect, of Dundee, for the new Technical College there. In this case two flues or ducts, P P, one from each side of the same room, are led up from the inlets, I I, near the ceiling of the room, R, and both join at J into the outlet pipe of the No. 1 curved-topped Buchan's Ventilator, V. No other flues, except the two shown from the room R, join into the ventilator, V, so that all the air passing out through said ventilator, V, comes from the room R. The outlet ventilation of the room R, Fig. 140, is therefore carried out on a much better principle than that of the room H in Fig. 138.

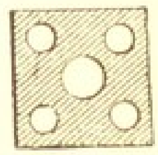


Fig. 139.

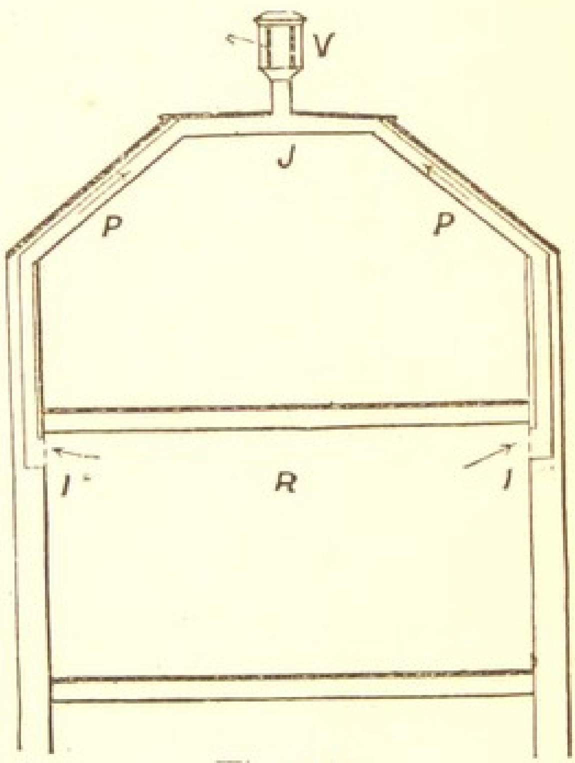


Fig. 140.

When pipes from different rooms are connected into the same *wind-acting* ventilator, as per Fig. 138, then, should the windows in the room connected with the pipe B be open, when those of room connected with pipe D are shut, the air may rush up pipe B and little or almost none go up the pipe D. Should the windows in room G, again, be opened when those of rooms K and H are shut, then the ventilation of those two latter rooms is virtually stopped for the time being, so that Fig. 138 is another example of "How not to do it," so far as automatic ventilation is concerned.

It would be a good rule that every school-room should have a thermometer hung up in it.

CHAPTER XVI.

Railway Carriage Ventilation.

When some woman poisons her husband, or a husband poisons his wife, a great outcry is made. The crime is everywhere denounced, and rightly so; but should hundreds of people be killed by being forced to sit in draughts, nothing is said about it. He or she caught a severe cold in the train, which resulted in death; but while the active criminal is punished, the far worse—judging by the effects—negligent one escapes. There is something wrong here, but there may be faults on both sides.

The railway companies may be wrong in purveying carriages which, owing to the want of simple and proper means for ventilation, readily allow their customers to catch cold in them. The public again are to blame for too tamely continuing to pay for and use these carriages.

As this apathy on the part of the public may be greatly the result of ignorance, we shall here say a few words tending to show the danger from badly-ventilated carriages, and suggesting a remedy.

In most of the compartments of our railway carriages there are two doors, as at A and B, Fig. 141, and in each door there is a window, and above each window a small ventilator, as at S and T, Fig. 142. The roof of the carriage is about 15 in. or so higher than this door-ventilator. Supposing the train is going in the direction of the arrow C, while the wind is blowing as indicated by the arrow D, it follows that if the window or ventilator is open on the side A, the wind will have a tendency to blow in with considerable force in the direction of the curved arrow L. Supposing the compartment is fully seated, then the persons E and F next the window may be those who will be least affected by the incoming air, and those seated at G, H, and I the worst, while J, K may also be annoyed, or J and K may be worst. The person sitting at F, especially if he is

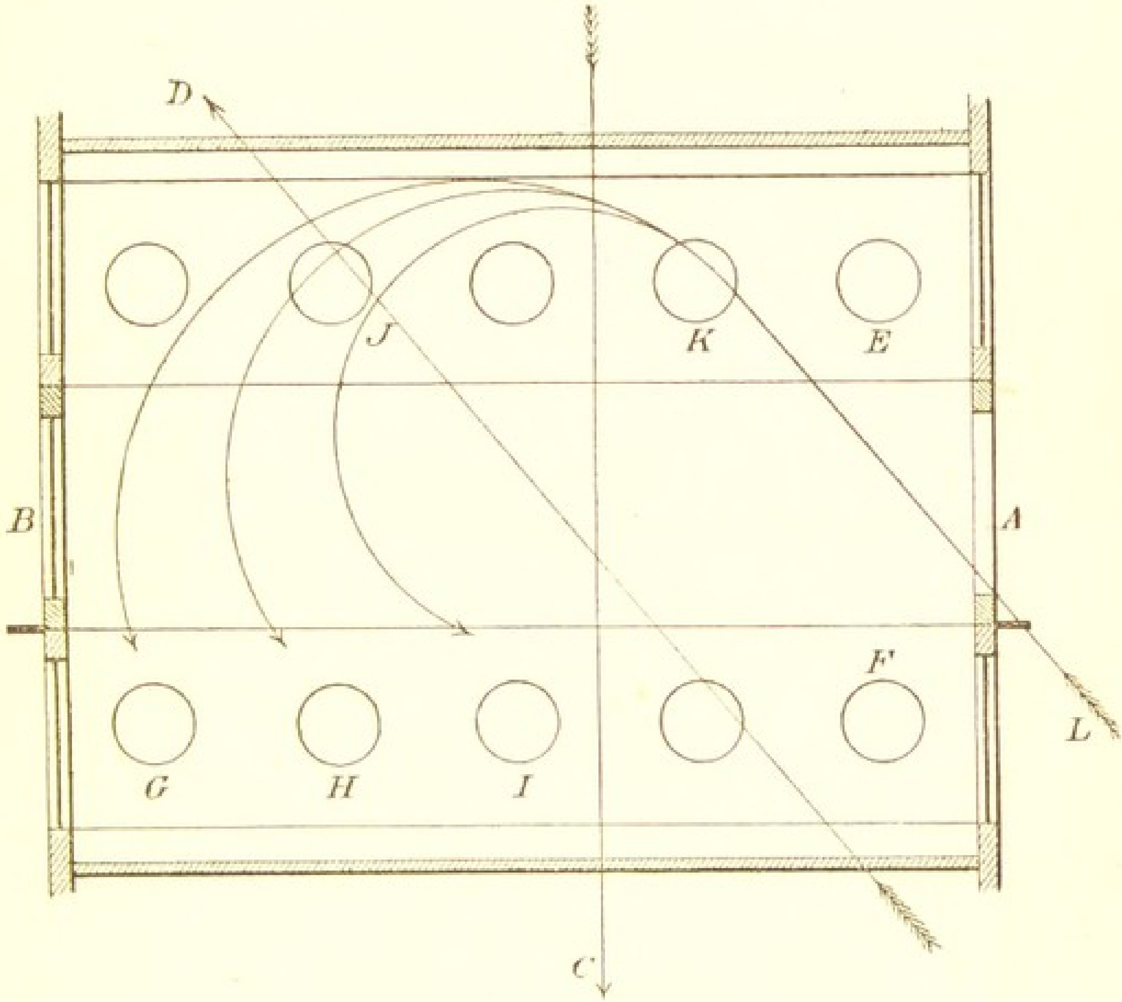


Fig. 141.

on the sunny side, may put the window down and be sitting in selfish comfort, quite regardless of the annoyance and danger to his fellow-passengers; but a little consideration should enable him to understand that when the wind is blowing in the D direction, and the smoke from the furnace of the engine is seen out of the B window, that it is the B window on the leeward side that should be open, and not the A window on the windward side.

When the wind is strong, and especially if the air is cold, even when both windows are shut, if the ventilator in the door on the A is open, the wind will sometimes rush in through its slits at a great rate, and in a way to be very annoying and dangerous.

Railway travellers ought therefore to understand the

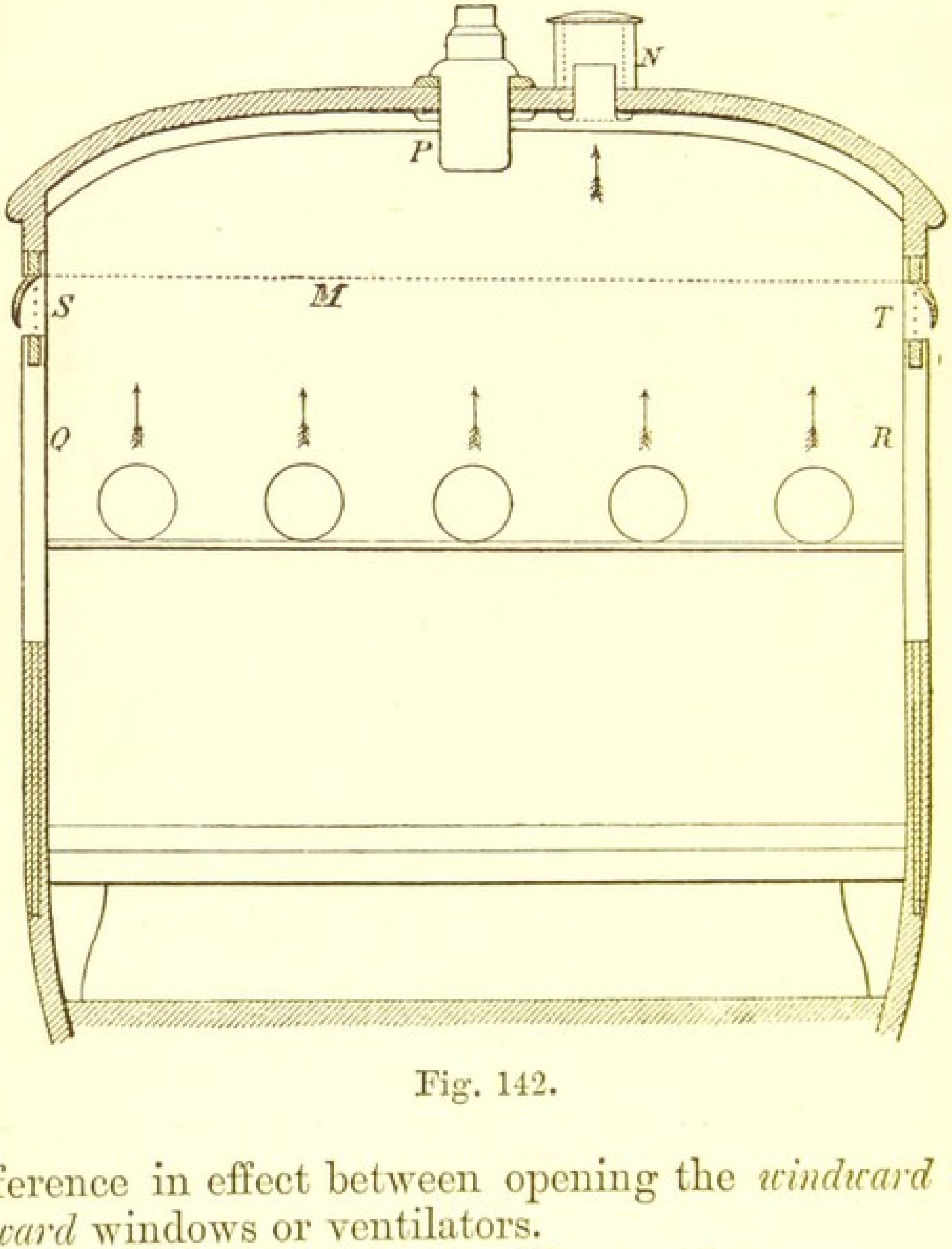


Fig. 142.

difference in effect between opening the *windward* and *leeward* windows or ventilators.

Of course many will say, "We must have some ventilation, surely?" This is undoubted, and it brings one to the point, where I assert that the sanitary requirements of the generality of our railway carriages are shamefully neglected in this respect. There ought to be provision made to carry off the vitiated air exhaled by the passengers *at the roof*, and *not* merely at the sides, *and some distance below the roof*. When the sun is shining in summer the atmosphere of the compartment is often most disagreeable, owing to the large quantity of warm air heated up by the hot roof, which cannot make its escape as there is no outlet in the roof to let it out. The health of the public demands that this should be seen to, and that all compartments of railway carriages should have a proper ventilating outlet in, or through, the roof, with hit-and-miss valve to open and shut it, similar to what some special first-class carriages or sleeping-compartments have got.

The member of Parliament or other person who will cause this to be done will be a public benefactor.

In many of our schools the cubic space allotted to each pupil is 140 cubic ft., but in the compartment of a railway-carriage seated for ten persons, as per Fig. 141, which shows ground plan, and Fig. 142, which gives a vertical section, we have only about 26 cubic ft. for each person, or only about 260 ft. for the whole ten.

A compartment I travelled in to-day measured 7 ft. $5\frac{1}{2}$ in. long by 5 ft. 2 in. wide and 7 ft. $1\frac{1}{2}$ in. high in the centre, all inside, but the sizes vary a little. There being no ventilating outlet in the roof, it follows that all above the dotted line M is unventilated, and forms a cistern for the warm, vitiated air from the lungs and bodies of those present to gather in. This is wrong, and to cure it there ought to be a ventilating outlet in the roof as at N, Fig. 142, to one side of the gas or oil lamp P. Q and R are the windows, and at S and T we have the ventilating sliding slits. It stands to reason that with this outlet at N far less opening of the windows Q and R would ventilate the compartment than without it.

The atmosphere of most smoking compartments is not fit for a pig to breathe after several persons have been smoking in it for a time, owing to the want of a proper outlet ventilator on the roof. In fact, were anyone to force horses or cows to breathe such an atmosphere, it would be looked upon as cruelty to animals.

Ventilate our railway carriages, therefore, in such a manner as to keep their atmosphere as pure as possible, without causing either discomfort or danger to health or life to any of the passengers.

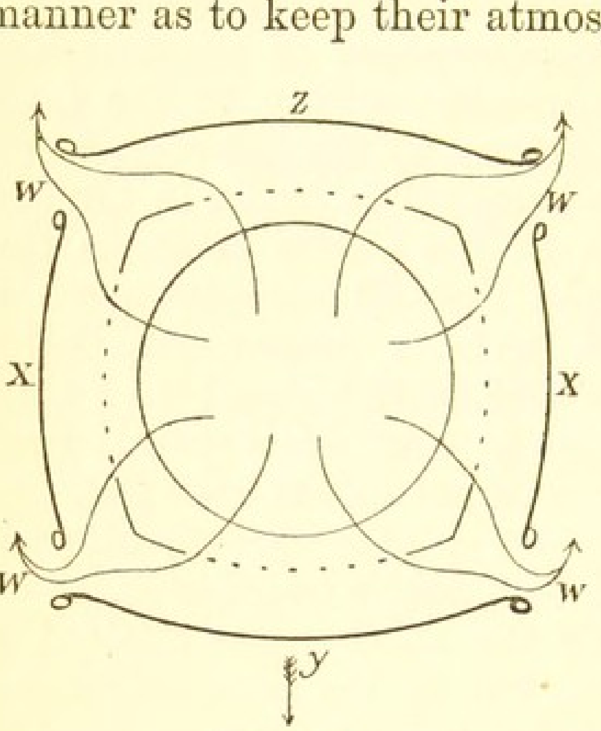


Fig. 143.

Fig. 143 shows a modification of Fig. 89 exhaust or outlet ventilator suitable for the top of a railway-carriage, the vertical outlets being at the four corners, W W W W, but on the sides X X. It will be noticed that the front and back plates, or wind-guards Y and Z, are broader than the side plates X X. This is in order to all the better keep rain or snow out of the inside of the ventilator when the carriage is moving rapidly against the wind. The dart or arrow at Y indicates the direction in which the train is running.

CHAPTER XVII.

Ventilation of Drains, Sewers, etc.

The systematic ventilation of the drains and soil-pipes of houses, &c., upon approved hygienic principles is of quite recent date. Until a few years ago the general practice was to ventilate the drains into the houses. This might not be intentional, but all the same it was the result of ignorance, carelessness, and callousness—the three ghouls who have preyed upon humanity for millenaries. When, however, Nature does get upon the right track she often attempts to make up for lost time with a rush. We see this in our nineteenth century improvements in travelling and intercommunication, as well as in our perhaps more prosaic subject.

During the last dozen years there have been no hygienic texts more preached upon than the trapping and ventilation of drains, although of late especially another rival for public attention has been coming prominently forward, viz., the smoke-test. Between trapping, ventilating, and smoke-testing drains the owners of property have had a sad time of it. They have been forced to do evil that good might come. Yet notwithstanding their self-sacrifice, the public are ungrateful! By-and-bye, when every man is his own landlord, he will be forced to lay, rectify, and keep up his own drains at his own expense; and in case he might lift this book on "Ventilation," expecting to find some information in it about drains, it would be a mistake to disappoint him. Drains are distinguished from sewers in that the former have generally to be supplied and kept up by the proprietor of each house, tenement, or building, whereas the latter are generally put in at the general expense of the town, or, at all events, are generally kept up at the public expense.

As the public sewers in the streets receive into them the discharged waste waters, &c., conveyed by the drains from the houses of the healthy and the unhealthy alike, it follows as a rational precaution that each house should be safely protected from all bad emanations coming into it from the public sewer. The recognised practical

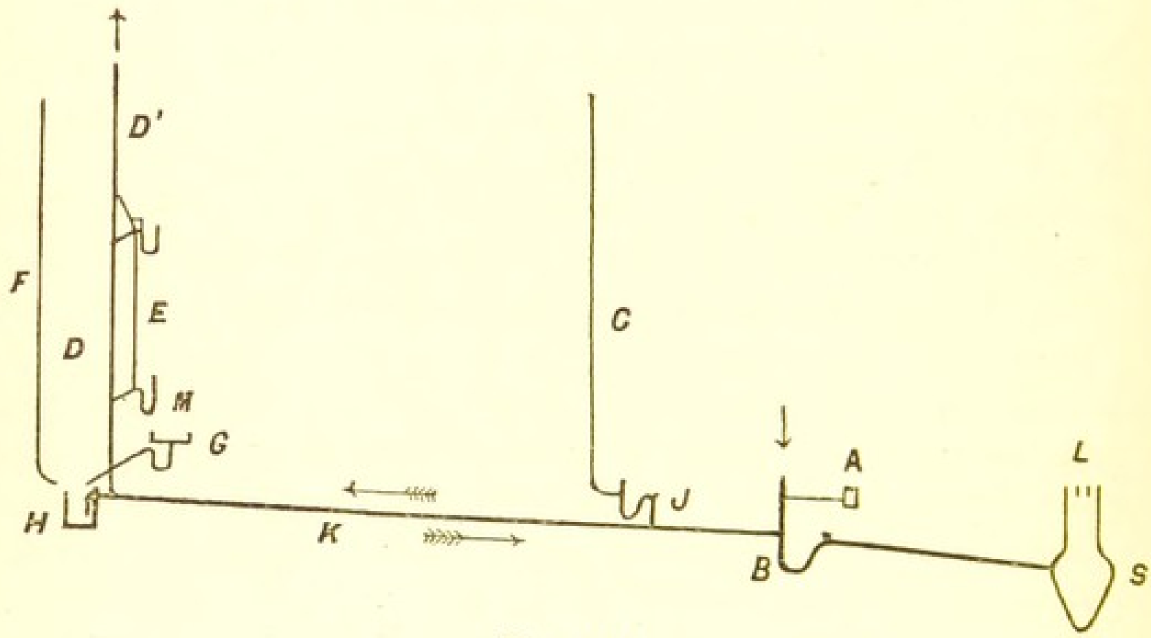


Fig. 144.

mode of doing this is by putting in upon the line of the drain between the house and sewer some efficient intercepting trap, as indicated at B in vertical skeleton sketch, Fig. 144, where S is the public sewer in street, B the 5-in. or 6-in. intercepting trap on drain, C the front rain-water pipe, with a 4-in. trap at its foot; D is the soil-pipe for the water-closets, with an air-pipe off the water-closet traps. The soil-pipe in this case is supposed to act as the ventilating blow-off for the drain, K;* F is the back rain-pipe, delivering above ground over the trap, H; G is the sink, whose waste-pipe may discharge into trap, H, or into grease trap as per H, Fig. 145.

* A three-gallon flush of water could fill 6 ft. of a 4-in. diameter pipe, nearly $2\frac{1}{2}$ ft. of a 6-in., and 13 in. of a 9-in.

The fresh air for ventilation of the drain, K, is supposed to enter either at the top of the trap, B, or, *what is better*, from a side air-inlet, A,* proceed along the drain, as per the upper arrow, go up the soil-pipe, D, and out at the top of its ventilating pipe, D^1. The sewer, S, is ventilated by the grating, L, in middle of the street.† Fig. 145 is ground plan of a larger house than the foregoing, and indicating more in detail the fittings used now in executing the drainage of a large house upon improved principles, and showing two different ways of carrying out the ventilation of the drains. At the back of the house the ventilating air-current in the drain is shown as going *the same way as the water-flow*, the blow-off for the drain being at D.

At the front of the house the ventilating air-current is shown as going in the opposite—and more customary—direction from the water-flow, the blow-off being at B. The writer has executed the work satisfactorily in both ways.

In Fig. 145 we will suppose the house stands due east and west, with front to the south. In that case the manhole at the south-west corner contains both a 6-in. No. 6 or No. 8 Buchan's trap, J, in two pieces, and also a single branch access pipe, K. This access pipe has a strong iron lid, sealed down with lime and a thin coating of cement on top of the lime. The small outer eye of the trap is also sealed down with lime. The trap and the access pipe are better to be both set in Portland cement concrete. The fresh air inlet to the trap and drain along front of the house may be at A, on surface of the ground, by an iron grating, say 10 in. square, or so. In some cases the side fresh-air inlet may be from a 4-in. iron pipe set up at end of house 6 ft. high or more, and near F. The trap J in the manhole prevents all aërial communication between the drain going along the back and west end of

* See Fig. 147 and remarks upon it.

† Other styles of ventilating the sewers are referred to in Figs. 153 and 154, and pages 323 to 327 of "Plumbing and House Drainage," 5th Edition, No. 191 of Weale's Series.

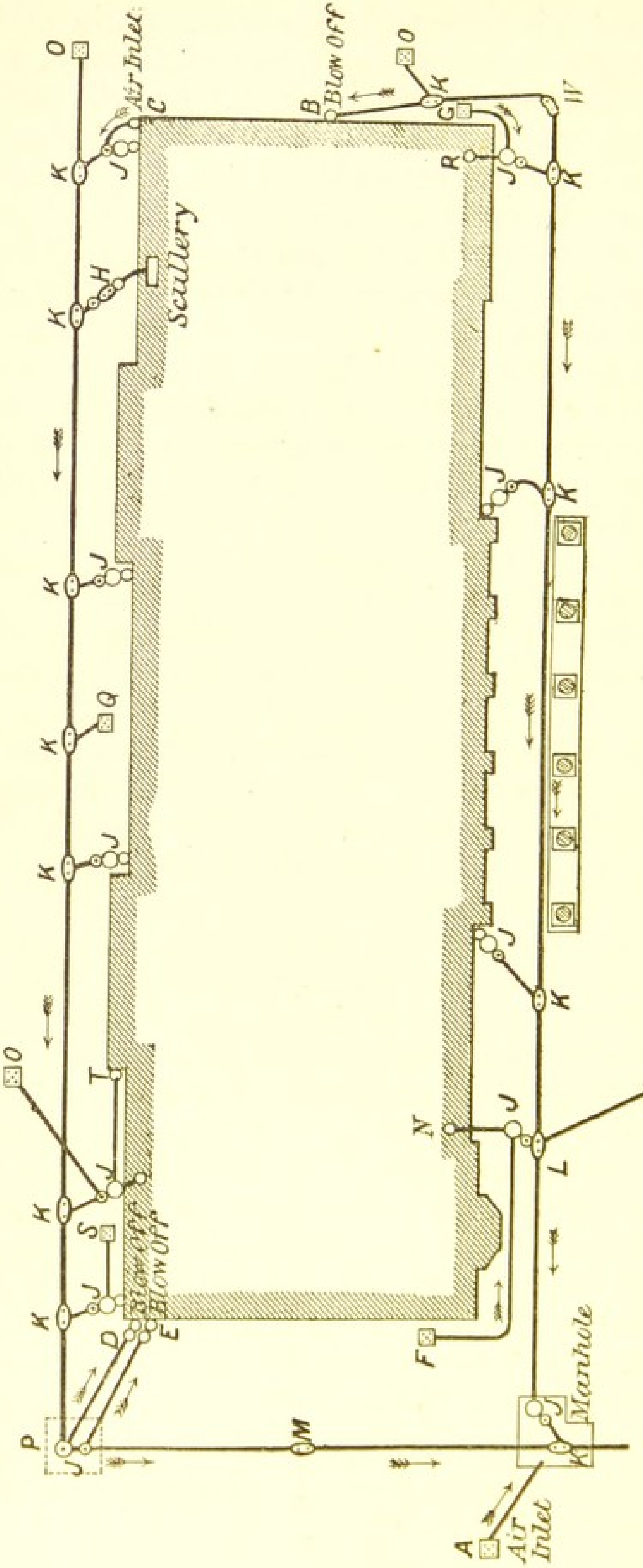

Air Inlet
Blow Off
Scullery
Blow Off
Blow Off
Manhole
Air Inlet

Fig. 145.

the house, and the drain along the front of the house. When the lid K in the manhole is lifted, the water from both drains is seen uniting and passing on. This pipe here may be 7 in. diameter, or if it has a good fall of an inch or more to the yard from the manhole, 6 in. may do. Both main drains coming into the manhole may be 6 in., or partly 6 in. and partly 5 in.; some of the branches being only 4 in. L is a 6-in. double-branch access pipe. N shows position of the soil-pipe in a large mansion house,* which delivers into a Buchan's trap with a small 8-in. iron access plate above it, the fresh air inlet being round the corner at F, as shown. The two traps, J J, on each side of the entrance are supposed to be 4-in. No. 2 Buchan's traps for rain-water pipes. R may be either a soil pipe or a bath or basin waste pipe, with fresh-air inlet at G. W is an access bend; O, a little farther along, a box trap with slop stone for surface water, as are all the gratings marked O. B is a 4-in. strong iron blow-off pipe, painted with red lead inside to prevent rusting up.

The access pipes, K, L, and M, enable the interior of the pipes to be viewed at any time to see that they are all clear and clean inside.

At P, Fig. 145, there is another 6-in. Buchan's trap with the drain from the back of the house delivering into its side. This trap may either be set in an inspection chamber or manhole or not, according to its depth. If it be less than 3 ft. deep, and in easily and readily dug up soil, a manhole may be unnecessary or merely optional: hence it is indicated merely in dotted lines. It will be observed that a side pipe leads off from both vertical openings of the trap. The one off the outer eye of the trap leads to the 4-in. or 4½-in. iron blow-off pipe E, which ventilates the main drain or sewer beyond all the traps. The other pipe leads to the 4-in. or 4½-in. blow-off pipe D, which ventilates the drain going

* At "Stracathro," the residence of James Alex. Campbell, LL.D., M.P., the relative positions of two of the soil pipes and their foot air pipes are as shown at N and F.

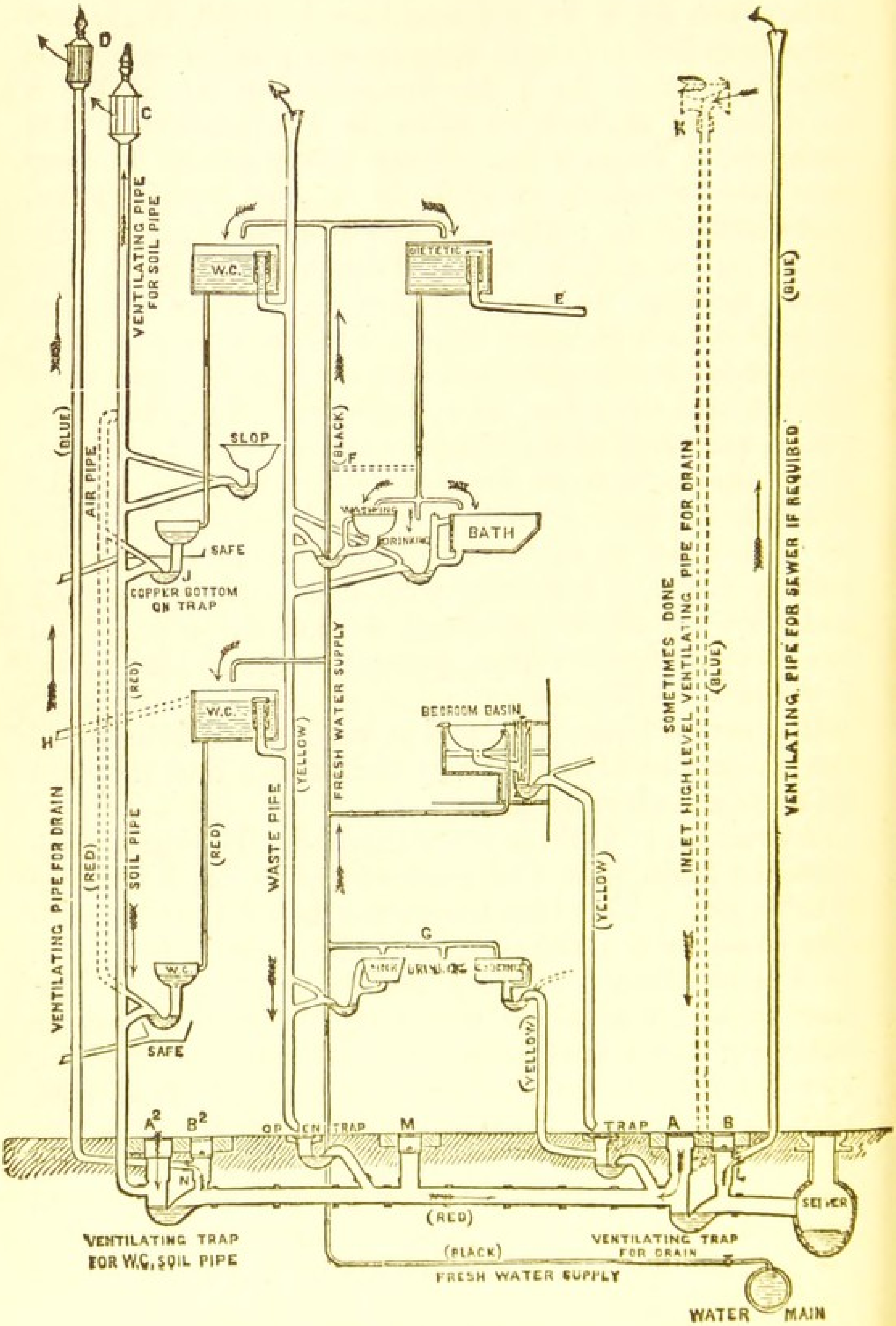

D
C
VENTILATING PIPE FOR SOIL PIPE
W.C.
DIETETIC
E
(BLUE)
AIR PIPE
SLOP
(BLACK)
F
WASHING
DRINKING
BATH
SAFE
J
COPPER BOTTOM ON TRAP
(RED)
H
W.C.
BEDROOM BASIN
FRESH WATER SUPPLY
(YELLOW)
WASTE PIPE
SOIL PIPE
(RED)
VENTILATING PIPE FOR DRAIN
(YELLOW)
G
W.C.
SAFE
SOMETIMES DONE
INLET HIGH LEVEL VENTILATING PIPE FOR DRAIN
(BLUE)
VENTILATING PIPE FOR SEWER IF REQUIRED
(BLUE)
A2
B2
N
M
TRAP
A
B
SEWER
(RED)
VENTILATING TRAP FOR W.C. SOIL PIPE
VENTILATING TRAP FOR DRAIN
(BLACK)
FRESH WATER SUPPLY
WATER MAIN

Fig. 146.

along the back of the house. The fresh air in this latter case enters at C, which may either be an iron pipe set up about 6 feet high, or an iron grating at ground level.

As indicated by small circles at D and E, it is useful to have a 4-in. eye near foot of the blow-off pipes, which is closed with a lid, so that access can be got at any time to the foot of the blow-off pipes to see if they are all clear, or to stuff them at foot temporarily when smoke-testing the drains.

When the blow-off is at the lower end of the drain, as at D, both openings on top of the trap are closed, each by a round iron lid, the smaller or outer one being most securely sealed down.

S is a side fresh-air inlet on the ground for the No. 2 or No. 8 Buchan's trap, J for a water-closet soil-pipe. T is either a 3-in. iron pipe acting as fresh-air inlet or a rain pipe, the trap J in this case serving for a wash basin and bath.

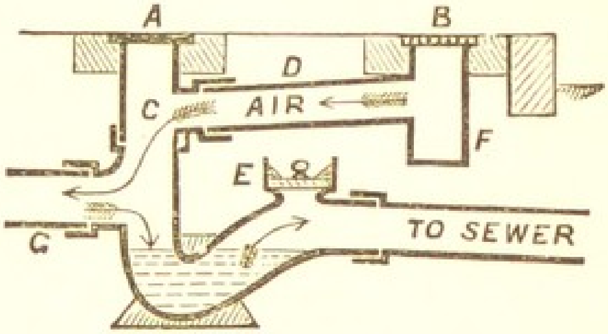


Fig. 147.

H is a Buchan's grease trap for the scullery sink. Near the air inlet C at head of drain there may be a rain pipe delivering into either a 4-in. No. 2 Buchan's trap or a Field's flushing tank.

Fig. 146 shows vertical section of drains and soil and waste pipes of a house; the drawing pretty well explains itself, but if further information wished, it may be got in the author's text-book on "Plumbing and House Drainage," No. 191 in Weale's Series.

Fig. 147 shows vertical longitudinal sectional sketch of side fresh-air inlet D B, referred to when describing Fig. 144. In this case an iron access plate A is put over the house side of the trap, while the fresh air enters through the iron grating B. When the grating is put in at A, right over the trap, and especially if the trap be under the pavement where children play about, they will sometimes choke the trap by putting in pieces of wood or umbrella wires down through the grating, but when the grating is placed to one side of the trap, as at B in Fig. 147, then the children cannot choke the trap, as the sticks or wires fall into the small pit F.

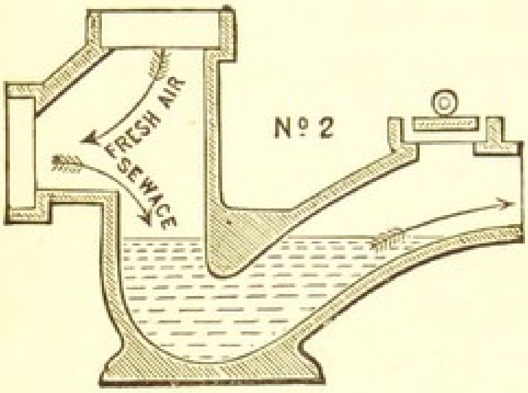


Fig. 148.

This side fresh-air inlet is also of advantage in preventing occasional puffs-out of smell being so easily, if at all, felt when a water closet is let off, as the fresh air in the side pipe D and C has to be pushed out first, and by the time it is out the closet may have stopped running. In some houses the water-closets and baths are put up in a special projecting wing of the house, with a short intervening passage and door, and with a window or windows in the passage. The joists of this passage or lobby are laid across it (not with their ends into the main building) so as the better to prevent gases from the pipes passing into the house between the joists.

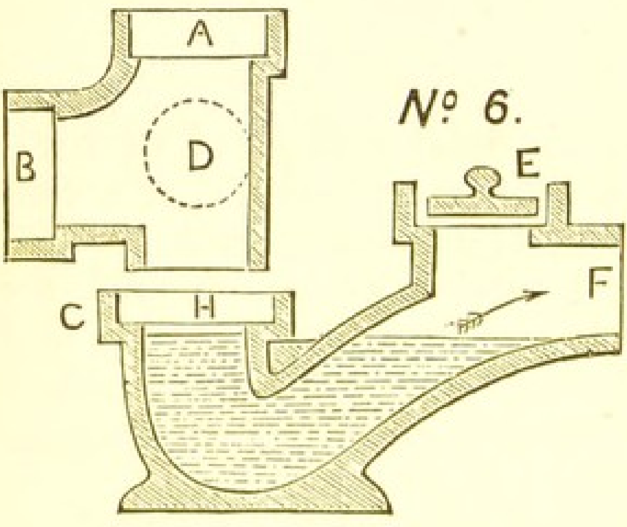


Fig. 149.

Figs. 148 to 151 show the styles of Buchan's patent traps referred to in Figs. 145 and 146. In Fig. 148, styled No. 2, the inlet and outlet ends and the well of the trap are all the same size, and so they are in No. 6. Only while No. 2 trap is all in one piece, No. 6 is in two pieces, so that the top part and side inlet B, Fig. 149, may be turned in any direction desired.

Fig. 150 is the same as Fig. 149, except that in Fig.

150, styled No. 10 trap, the well H is small, *e.g.*, supposing the inlet and outlet B and F to be 6 in. diameter, then in Fig. 150 the well H is only $4\frac{3}{4}$ in. diameter; the intention of this is to make the trap more self-cleansing.

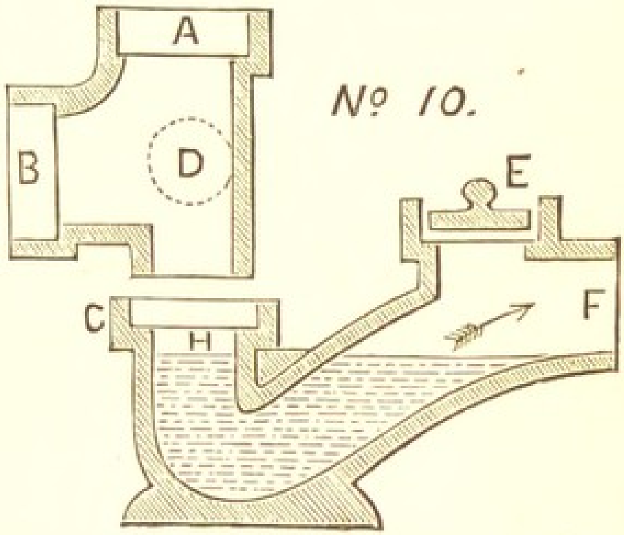


Fig. 150.

In Fig. 151 again, known as No. 8 trap, while the well C is about $4\frac{3}{4}$ in. diameter when the inlet and outlet ends B and D are 6 in., the top fresh air inlet and inspection opening, A, is larger, *viz.*, 9 in. diameter. This gives more scope for inspection and cleansing, and allows the head of a man to be put in to look along the drain coming into the trap to see if it is all clear, and no cement sticking up at any of the joints, and no tools or bricks, &c., left inside the pipe to choke it. These traps are made in various sizes, and are in use all over the world. They not only lock off sewer gases from the house, but also keep out sewer rats. Quite oblivious of these advantages, one responsible public official, some years ago, actually advocated the use of the soil pipes and rain pipes of houses as ventilators for the public sewers, quite overlooking the destruction to property that might have been caused by the invasions of the rat armies, and the increase in the death-rate from the bad air following in their wake. Fortunately, the higher intelligence of the sanitary authorities prevailed.

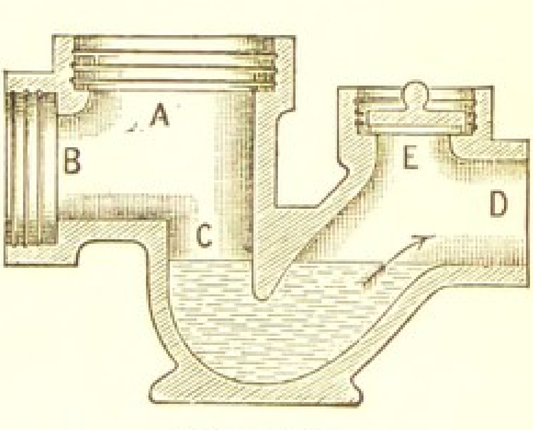


Fig. 151.

Fig. 152 is vertical section of the Buchan's grease trap, indicated at H, Fig. 145. This is the one used at Balmoral Castle, and at many hotels, workhouses, and mansions throughout the kingdom. It may be had in two sizes. Illustrations, showing modes of fitting it in, may be seen on pages 302 and 303 of "Plumbing," or from the makers, Messrs. J. and M. Craig, of Kilmarnock, Scotland, who also make and supply the following patent access pipes, shown at K, L, and M, Fig. 145.

Fig. 153 shows a plain access pipe, C, in position. At the faucet end it has a solid attached block, A, which rests upon the ground, or upon the concrete, if a layer of concrete is laid down for the pipes to rest on. When the pipes are to be concreted they should first be properly laid, jointed, and smoke-tested, and then they can be concreted all round, if wished up to top of the longitudinal faucet F. This faucet F holds the iron access lid E. The small sketch D, "Fig. 4," shows cross section through the access pipe, and we see that the full section and height of the pipe inside are preserved. The iron lid E is sealed down with lime and a thin coating of cement on top of the lime.

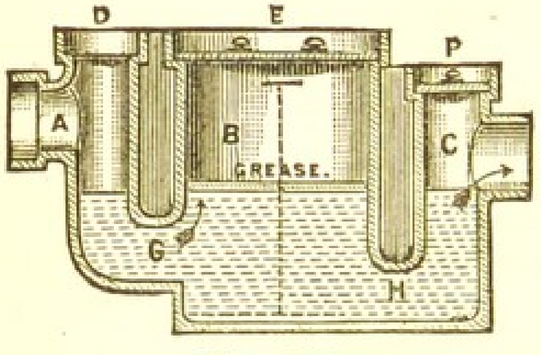


Fig. 152.

Some architects have advocated the use of an access opening on the top of each drain pipe, or of having the entire upper half of the pipe in pieces, so as to get at the bottom joint of each pipe inside with the hand, but as may be seen by a glance at Fig. 154, this is quite unnecessary. Supposing it were really necessary to get at the interior of each joint with the hand, this can be done, as in Fig. 154, by having each alternate pipe an access pipe. The spigot end of the intervening pipe L being got at from the access opening D, while the faucet end of L can be got at from the access opening C, each access opening giving access to two joints. It is not really necessary, however, in general practice to have

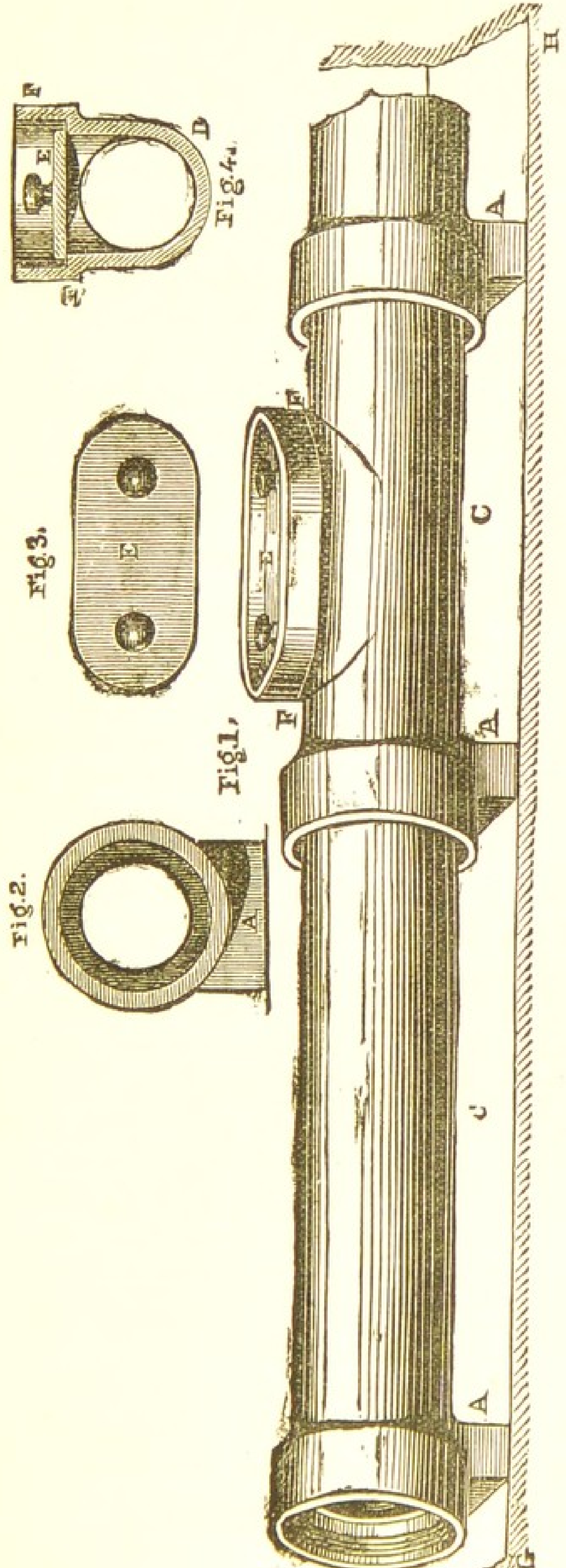


Fig. 153.

the access openings so close (only 5 ft. or so apart) as shown in Fig. 154. To have them about 10, 15, or 20 ft. as shown in Fig. 145, is much more sensible. It would be a pure waste of money to have an access pipe at every second pipe, as shown in Fig. 154; while as for the notion of having a drain pipe laid in two halves, that is a pure waste of cement, and makes a very weak pipe, and with such an enormous amount of jointing that there is far more scope given for aërial leakage than is at all necessary. When drain pipes are laid about or through a house in two halves, the word "Incompetency" should be printed in large type upon the backs of all connected with the work. If a

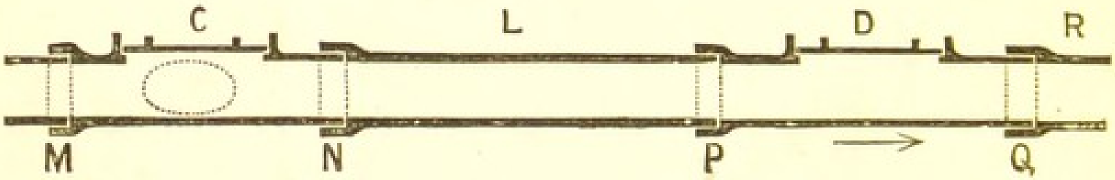


Fig. 154.

workman cannot lay drain pipes properly and tightly with access openings at intervals, as shown in Fig. 145, he should not be allowed to lay drains for the sanitary fittings of a house at all.

Plumbers are now being registered as a token of competency throughout the kingdom.* It is high time

* This registration movement, which originated at the Health Exhibition in London, in 1884, is now commanding public attention. The Worshipful Company of Plumbers, London, deserve great praise, and, in fact, the thanks of the whole community, for the trouble they have taken, and the money they have expended in working out and spreading this movement throughout the kingdom. Its clerk, Mr. W. R. E. Coles, has been devoting the greater part of his time for some years past in connection with the movement. Its progress has also been helped on by the labours of Mr. Alex. M. Scott, Writer, Glasgow, who has been Secretary of the District Council for Glasgow and the West of Scotland since its formation in January, 1888, and who, in addition to writing the "Plumber's Catechism" already referred to in the fifth edition of "Plumbing," also framed bye-laws which are used as a model over the kingdom.

A congress of delegates from all the district councils of Scotland, was held in Edinburgh, on 31st July and 1st August, 1890. A number of important subjects in connection with the movement were discussed, and it was felt that the Congress should become an annual institution, beginning next year with Glasgow.

that masons also who lay drains should be registered, for the amount of sickness and death that have been produced from their bad workmanship is incalculable. From the child of the peasant to the prince at the throne no one has been safe from them. In thousands of cases still, just as surely as the sun sets, the angel of disease and premature death follows in their wake.

As for the intentional scamper who pretends to have laid pipes where there are none, he is a virtual murderer, yea, verily, an assassin, and should be treated accordingly. Buchan's traps and smoke-test are amongst the best detectives for these gentry.*

Fig. 155 is an enlarged view of the single branch

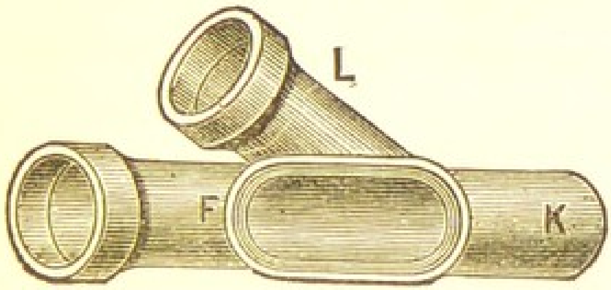


Fig. 155.

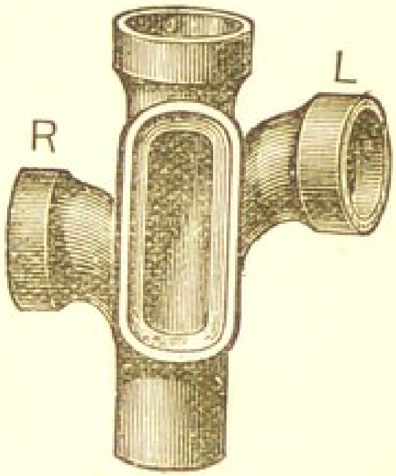


Fig. 156.

patent access pipe shown at K, Fig. 145. In this case the branch L is to the left. Of course the pipe can be had with the branch to the right, and also with two branches as at L in Fig. 145.

Fig. 156 shows an access pipe with rounded branch R and L (= right and left) on each side to catch drains coming into the main drain at a right angle.

Fig. 157 shows a patent access bend. In this case the bend is said to be to the left. The longitudinal

* The machine-applied smoke-test for drains and soil-pipes, invented and first introduced by the author about fourteen years ago, is now a recognised public institution. It is referred to by our Judges on the Bench and in Acts of Parliament relating to the public health. Reference was made to it *inter alia* by the writer in the *Sanitary Record* for May 24th, 1878. It appeals to the senses of both sight and smell, and has caused thousands of houses to be transformed from fever-breeding dens to healthy homes.

access openings in Figs. 155, 156 and 157 are all closed in with a strong iron lid, which is made tight with lime and a thin coating of cement on top. In cases where the access pipe is in a manhole or small brick access-chamber, and especially when inside the building, a layer of sand one inch thick may be put in above the lime and cement on the lid, to act as a filter, and as an extra precaution should a slight crack occur in the cement over the lid.

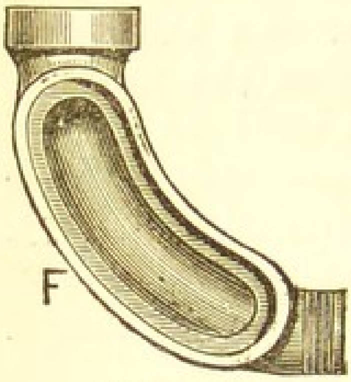


Fig. 157.

Fig. 158 is a modification of the access pipe and pipes shown in Fig. 153. In this case a couple of ribs are cast on the bottom of the pipe as shown at A A, Fig. 159. The space H between the ribs may be filled in with Portland

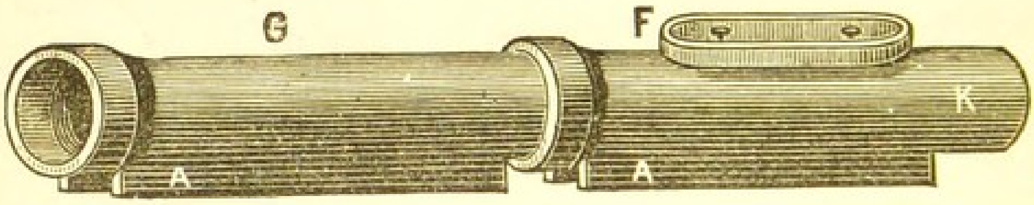


Fig. 158.

cement or concrete for greater strength, especially when laying the pipes in soft ground. This pipe is known as Buchan's patent improved *ribbed* drain pipe,

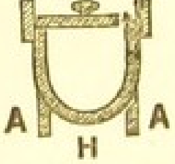


Fig. 159.

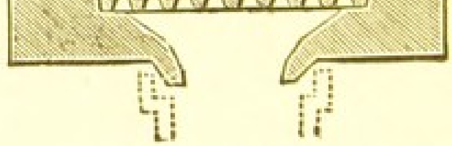


Fig. 160.

and it may be had from Messrs. J. and M. Craig, Kilmarnock, Scotland.

Fig. 160 is a cross vertical section of one of my fire-clay slop stones with projecting pap in bottom for allowing the water to drop clear off and not soak the ground, as is so customary with the flat-bottomed slop stones which have no such pap.

Reference was made in Figs. 144 and 146 to ventilating the sewers by gratings in the *middle* of the street. This does very well in many cases. It is a most abominable and dangerous practice to ventilate the sewers, as is done in some towns, up through the *iron rain-water or gulley gratings at the edge of the pavement.* Many people have caught disease and some have been killed by standing to speak on the pavement close to one of these gutter gratings. Children bending over them or sitting near them, as they often do, are apt to be poisoned and killed by the emanations from these gratings—"and a good thing, too," says the political economist. The plan is both selfish and cowardly, however. All these gulley gratings should have a water trap below them.

In some cities even the gratings below street water taps or drinking fountains are untrapped, so that drinkers may get food gratis in the shape of disease germs when they come to drink. This should not be.

In certain towns, such as Wimbledon, the sectional system of ventilating the sewers has been introduced, while at Torquay the high-level system of sewer ventilation is in use, ventilating shafts being carried up to blow off the sewer air above the heads and houses of the people, not below their noses. Of course care has to be taken not to have the blow-off pipes of either soil-pipes, drains or sewers below or near windows.

Fig. 161 shows high-level system of ventilating a street sewer, as proposed by me in vol. V. of the "Transactions of the Sanitary Institute of Great Britain." In this case the "down pipe" may be either a 4-in., or 6-in. or so, cast-iron pipe, of strong soil-pipe strength, which admits fresh air to the sewer. The "up pipe" is of same size and strength, and may either be finished with an exhaust cowl, as at C, or the pipe may be carried to above ridge and finished, as at D. The access to sewer from the street is covered with a strong iron plate, P. This plan was published in 1883.

Instead of finishing the tops of the pipes, as shown in

Fig. 161, they may be done as in Fig. 162. The mouths of the pipes in this case are set to perpetually face the middle of the street, or the one mouth may look to the street at an angle up the street, and the other mouth down the street, and so on with the rest; so that whichever way the wind blows it may tend to make the out-

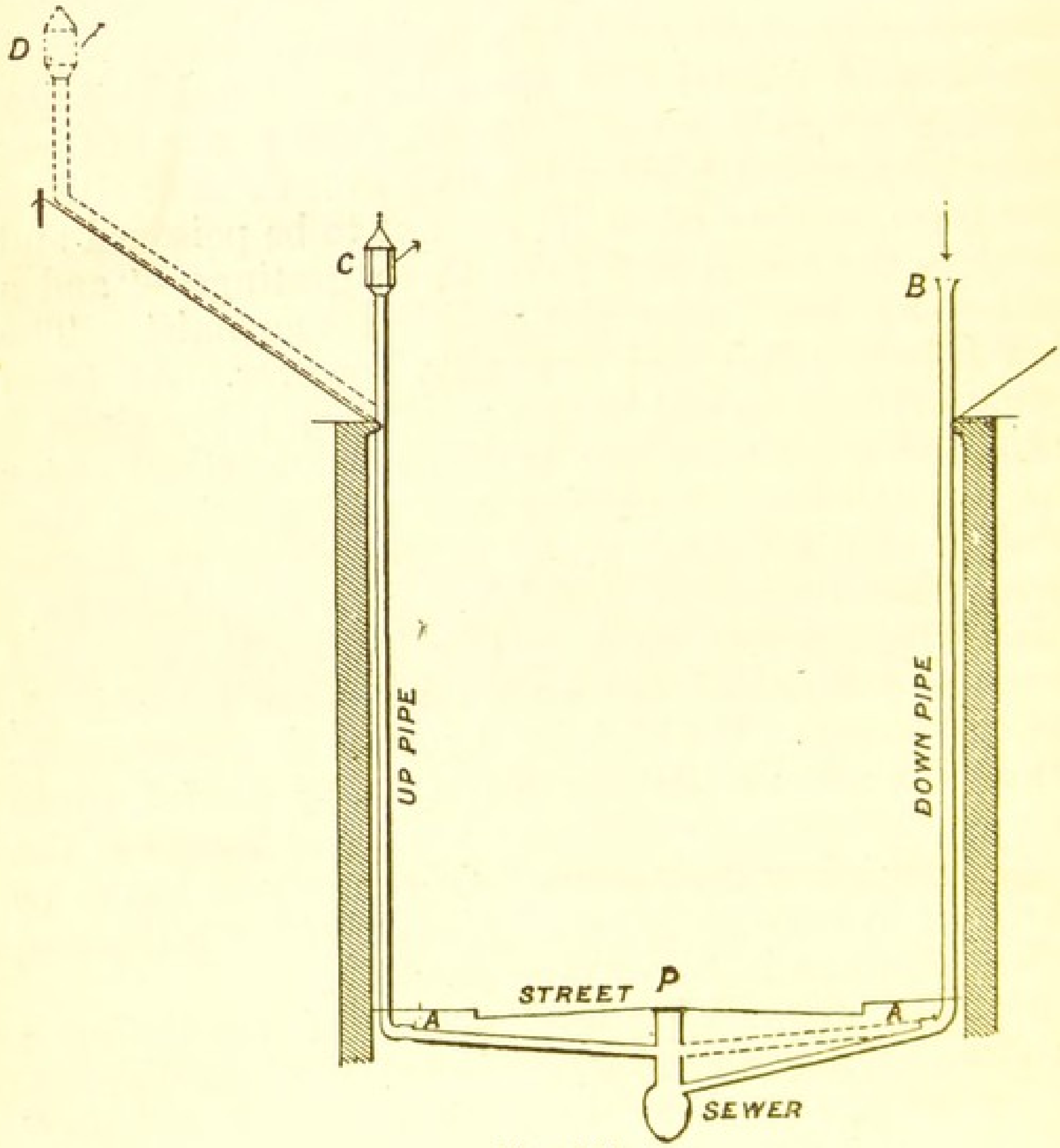


Fig. 161.

current go from the house. A A indicate two access-openings, covered with iron lids, for access to bottom of upright pipes, if wished, without disturbing them. The principle may be carried out in a variety of ways, the outlet being made to look as an ornament or finial, &c.

Fig. 163 shows how to make a levelling-rule for laying drains with. Take a piece of planed wood $\frac{1}{2}$ in.

thick, $2\frac{1}{2}$ in. broad, and either 3 ft. long, as per L, or 3 ft. 9 in. long, as L + C in sketch. Suppose the drain-pipes are in yard lengths, exclusive of the faucet, and it is intended to give each pipe a fall of $\frac{1}{2}$ in. or 1 in 72, then a small piece of iron, brass, lead, or wood $\frac{1}{8}$ in. thick, is fixed on at H, then at other end a piece of wood, or its equivalent, is fixed on at R, $\frac{5}{8}$ in. thick. When the pipe Q is put into the pipe P, and the spirit-level, S, is applied, as per A or B, it will easily be understood that when the air bulb stands at A or B, the faucet end of the pipe Q is $\frac{1}{2}$ in. higher than the faucet end of the pipe P. Some tradesmen level their pipes on the top outside, but that does not secure such correctness of level as levelling on the bottom inside of the pipes, because the pipes are not always exactly round. If it is wanted to give a fall of 1 in 36, then, with the

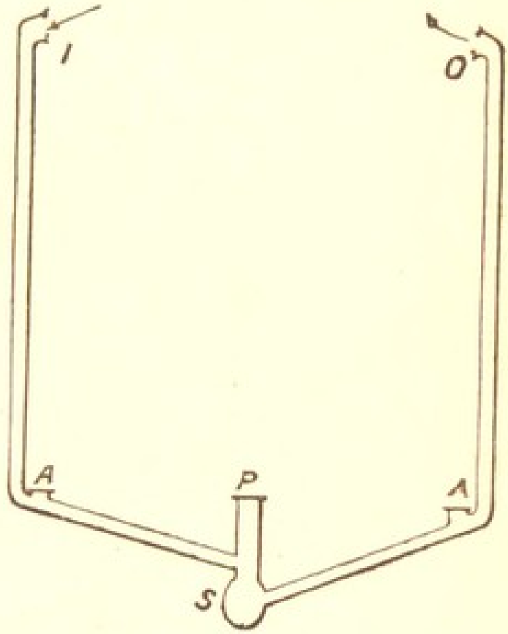


Fig. 162.

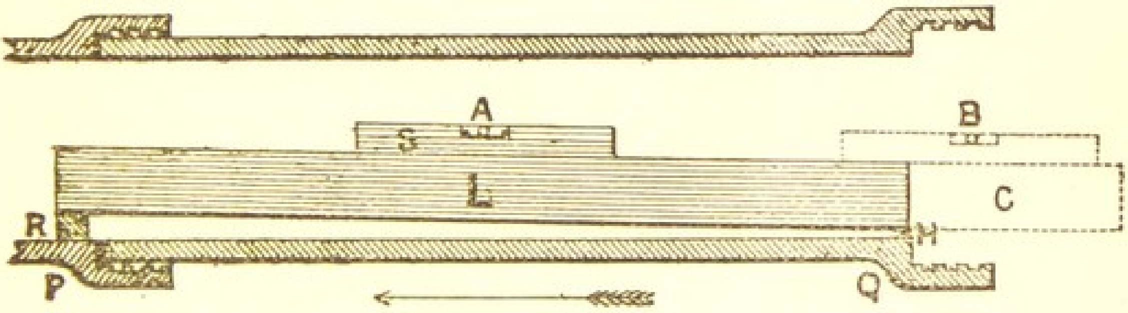


Fig. 163.

levelling-rule at H raised $\frac{1}{8}$ in., a piece of wood or a pin, to project $1\frac{1}{8}$ in., is put on at R.

When jointing the pipes care has to be taken, while making them tight, not to leave any of the cement sticking up inside the pipes, at the joints. Of course the use of the access pipes, Figs. 145, 153, and 154, tends to safeguard that.

Fig. 164 illustrates the new "Adjustable Gradient Indicator," lately invented by Mr. T. J. Moss Flower, sanitary engineer, Bristol. The Indicator is shown as laid upon the top of a drain-pipe, D E, having a fall of 2 in. to a foot. A is the brass plate with the various gradients engraved on it, such as 1 in 6, 1 in 36, or 1 in. to the yard, 1 in 54, or $\frac{3}{4}$ in. to the yard, and so on. B C is the limb carrying the spirit tube. It works about the pivot at C. H is a tangent screw put on upon the finer instruments where very exact adjustments are necessary. An ordinary length of the instrument is 10 in., but it may be had any length. Further particulars may be had from the patentee.

Iron oxidises readily, and galvanised iron is soon spoilt in a manufacturing district where there is much acid

Fig. 164.

rain. If well painted, however, both cast iron and galvanised iron last very much longer. Cast-iron pipes for rain and for ventilating sewers and drains should be painted with red-lead paint *inside* in addition to the outside painting. If not well painted inside, the iron ventilating pipes of soil and waste pipes rust much sooner from the vapour and air than the pipes below, which get a coating of grease from the the waste water. Metal exhaust ventilators on buildings might be painted every four years or so.

Instead of painting iron pipes many prefer to dip them in boiling tar or "Smith's solution." Iron pipes intended to be exposed *and painted* had better not be tarred, as the paint does not adhere well to the tar.

CHAPTER XVIII.

Ventilation of Bath-Rooms.

The number of deaths that have been caused by the use of gas-heated hot-water appliances, or artificial geysers, in bath-rooms calls for some special remarks regarding their ventilation.

On page 20 it is stated that 1 part carbonic oxide gas in 1,000 of ordinary air rapidly destroys life. Now, as the cubic capacity of many bath-rooms is only about 500 to 750 cubic ft.,* it follows that when so small an

* Why should bath-rooms be such miserably small and dingy appurtenances as they so often are? Many are only about 7 ft. by 4 ft., and with a water-closet, too, in that, so that it is virtually doing penance to bathe or wash in some of them, not to speak of the danger of skinning one's elbows against the narrow walls. Even in highly-rented houses the bath-rooms are small, and a good-sized one with a fireplace in it a *rara avis.* They are often badly placed between two bedrooms, or between the drawing-room and a bedroom, and so are often a nuisance to persons in either the drawing-room or bedroom, especially if there be a fire on in either of the latter to draw the air from the bath-room to it. In the writer's house when he got it the bath-room—10 ft. 8 in. by 7 ft. 8 in., containing bath, closet, and wash-basin—was in the first flat, between the drawing-room and best bedroom, and the soil-pipe going down inside the house and the drain right through it. This did not suit the writer's ideas, and all were cleared out, the bath-room—12 ft. by 10 ft.—being put on the ground flat, with a fireplace in it, and ventilated as shown in Fig. 23, the drains being all put out of the house, and bath and basins, closets, sink, wash-house, and rain-pipes discharging into separate disconnecting traps. The whole surface of the ground in the empty space—several feet down from the wooden flooring—was asphalted, and a hidden wall built below the ground, about 6 in. out from the front and two gables of the house, all to keep out damp air from the interior of the house. After eight years' experience of this the writer considers that prevention is better and cheaper in the long run than cure, it being with sanitation as with some other useful things, the gain coming not from merely talking about it, but by practising it.

amount as one-half or three-quarters of a cubic foot of carbonic oxide is generated in a bath-room by a gas-heated hot-water apparatus, and no ventilation provided, the person in the bath-room may be very quickly and quietly killed by the poisonous gas.

We read in the newspapers just now of the sad death of the son of Admiral Croft, a young man of nineteen, so killed. He went into the bath-room to take a hot bath before dinner, the water being warmed by a gas-heated geyser, but failing to come out again, his parents got alarmed and broke open the door, when he was found dead in the empty bath, poisoned by the carbonic oxide produced by the gas when so used.*

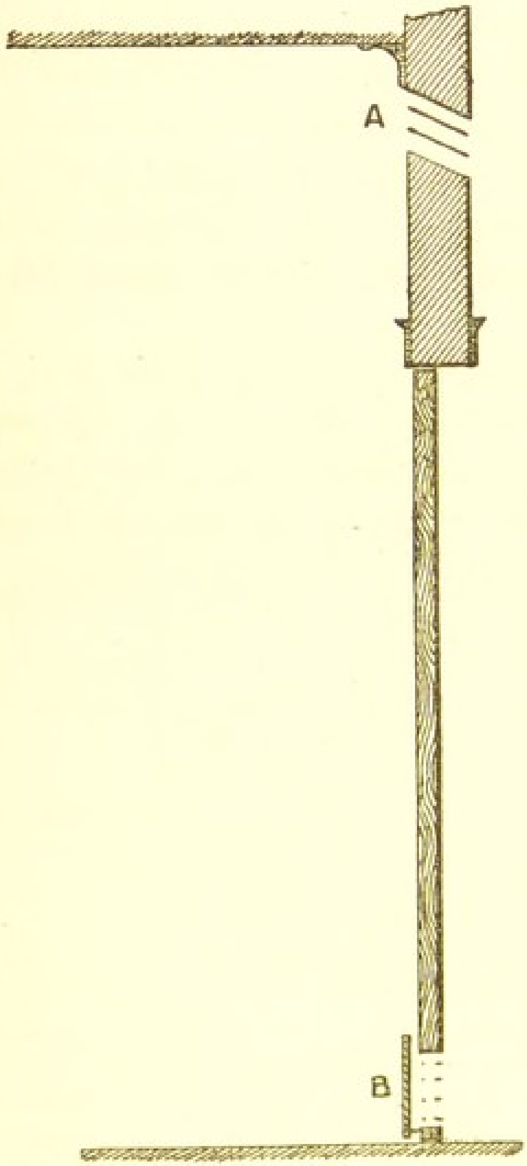


Fig. 165.

The room was not ventilated. Bath-rooms should be ventilated by the window, as per F, G, Fig. 23, for inlet, and for outlet either a 4-in. or larger ventilating pipe put in, as per Fig. 88, or its equivalent, as suitable in the circumstances; and where geysers are used, in addition to a ventilating pipe properly put in for the geyser or gas-heating water apparatus—which in some cases is troublesome—a ventilating opening might be made into the lobby near the ceiling, say 18 in. by 6 in., with a couple of

* Gas burned in many heating appliances has a much more pernicious effect upon the atmosphere than when burned openly, as used for lighting.

louvre boards in it, as per A, Fig. 165, and another opening in the door at its bottom, about 14 in. by 5 in., or so, with an iron grating in its face, and inside the door a board about 18 in. long by 7 in. broad, or so, fixed on at B about 1½ in. out from the door, so as to allow air to get freely in at the top of the board, and also at the bottom or ends, and at same time prevent the bath-room being seen into through the grating. Had a wooden board been fixed up inside the top of the window, as at G, Fig. 23, and the fresh air allowed to come in at F, Fig. 23, while the heated, poisonous gases got exit up a tube, A, off the ceiling, as in Fig. 88, or into the lobby through opening, as at A, Fig. 165, then a number of persons, now dead, might still have been living.

The object of this short chapter will be served if it causes occupiers of houses, &c., to take extra precautions in the ventilating way in bath-rooms, or other places where gas is used for heating geysers or other hot-water appliances, or for other heating purposes.

CHAPTER XIX.

METHODS OF EXAMINING THE AIR OF BUILDINGS.

(1.) *Testing for CO_2.*

THE important impurities present in an atmosphere vitiated by the products of respiration and exhalations from the skin, &c., are, broadly speaking, of two kinds, or if we include the low forms of life, or micro-organisms which generally flourish in such an atmosphere, of three kinds—one, a well-defined compound which can be readily estimated, namely, carbon dioxide or carbonic acid gas, the other an ill-defined organic substance or substances containing nitrogen, which probably are very unstable, readily undergo putrefaction, but for which there is as yet no very satisfactory method of measurement. The number of micro-organisms, on the other hand, can be determined with great exactness.

Although a knowledge of both qualitative and quantitative chemical analysis is essential in order to understand and carry out the processes thoroughly, the which may be obtained from works on the subject, yet we shall deal with the methods in some detail, as we venture to think that in these days of abundance of scientific education and technical instruction, many readers will be able to follow the text intelligently.

The methods about to be described are those by which Professor Carnelley carried out his classical experiments on air (Carnelley, Haldane and Anderson, Phil. Trans. Roy. Soc., Vol. 178, 1887, B., p. 62) and subsequent papers, and are the methods now generally adopted, because they are easily carried out, and the results obtained can always be strictly comparable with those of the above-mentioned investigators.

(1.) Carbonic Acid. There are two methods of determining CO_2 in air, both depending on the fact that carbon dioxide combines with the alkaline hydrates to form carbonates, the two methods differing in detail and mode of carrying out. In the one case the increase in weight indicates directly the amount of CO_2, in the other the amount of alkali neutralised indicates the amount of CO_2 which has combined to form a neutral carbonate. This last is known as Pettenkoffer's method, and is the one we shall describe.

Most persons will have observed that when a bottle of lime-water has been left standing for any length of time uncorked, a thin scum or crust has formed on the surface of the liquid. This scum is really carbonate of lime, which has been formed by the combination of the CO_2 in the air with the lime dissolved in the water, and it is not difficult to see that if we know beforehand how much hydrate of lime we had to begin with, and find out how much is left, we can tell with absolute certainty how much has been used up, so to speak, by the CO_2, and from that the CO_2 itself. This is precisely what is done, only baryta-water is used instead of lime-water.

So much for the principle of the process: let us now see what apparatus and chemicals we require for the complete operation. For collecting the sample a wide-mouthed glass-stoppered jar or bottle is best. It must be from four to six litres capacity (about a gallon), and this must be measured correctly to a cubic centimetre, so as to know exactly what volume of air is being dealt with. Of course this only requires to be done once, and the volume scratched on the bottle and stopper with a diamond. The bottle is then washed chemically clean and dried, and is then ready for a sample. Some sort of bellows is required with which to change the air in the bottle for the air to be examined. Ordinary bellows have been used, but it is preferable to suck out the air and allow the sample to flow in round the tube. A capital bellows can be easily manufactured from an old concertina by substituting for the reeds wooden ends, with proper valves and spout. This latter should be at least 1 inch in diameter, and long enough to reach within an inch of the bottom of the bottle, and at the same time leave 3 or 4 inches out to get hold of with one hand comfortably, whilst the other works the

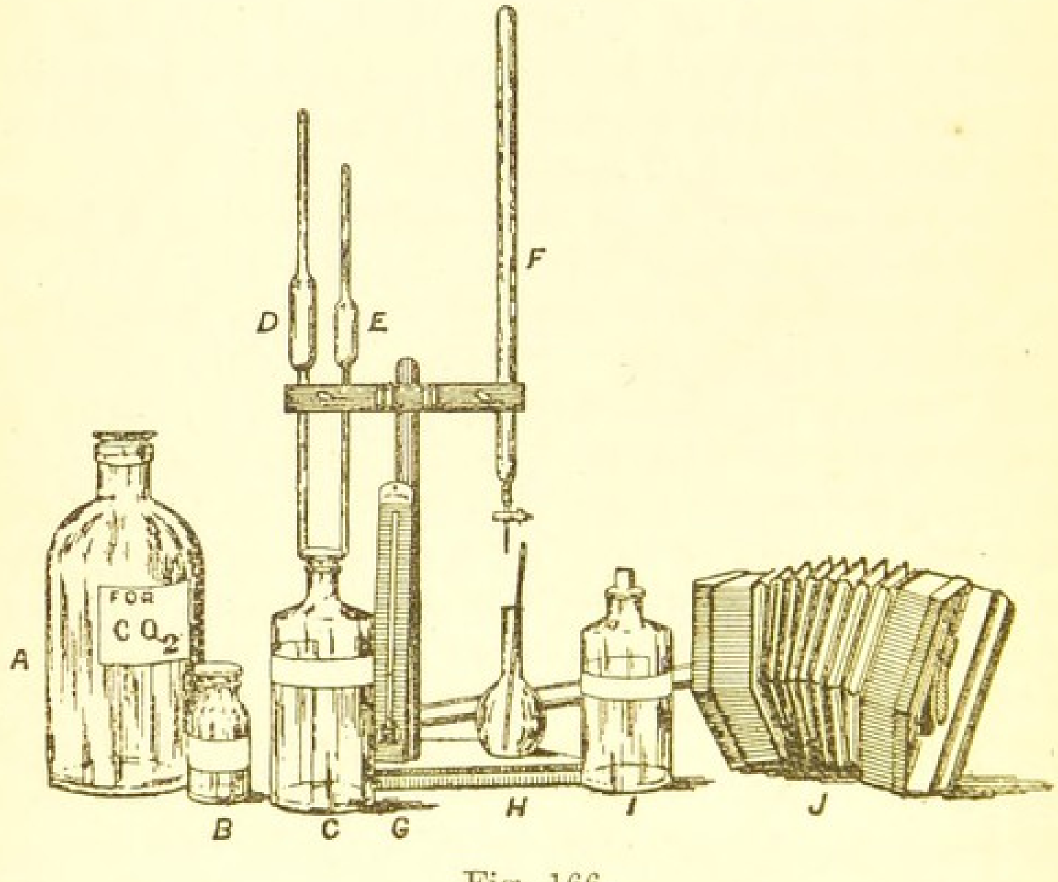


Fig. 166.

Apparatus for CO_2.

A, jar for sample. B, strips of turmeric paper. C, standard solution of oxalic acid. D, 50 cc. pipette to measure baryta into jar. E, 25 cc. pipette to withdraw solution for testing from jar. F, burette to measure oxalic used. G, thermometer. H, flask to titrate. I, baryta water. J, bellows.

bellows. Besides these, we require a burette, a 50 cc. and 25 cc. pipette, burette stand, four-ounce flask, stirrer, and turmeric paper. The first standard solution we require is oxalic acid. This is obtained by dissolving 2·8636 grams of pure crystallised oxalic acid in a litre of distilled water: each cubic centimetre is then equivalent to ·001 gram CO_2 The baryta solution is made as follows: 100 cc. of a saturated solution of barium hydrate is diluted with five or six times its volume of distilled water, well shaken and then standarised by means of our previously prepared standard oxalic acid. To do this 25 cc. of the baryta-water is run into the four-ounce flask, and the burette is filled up to the mark with standard oxalic acid. The oxalic is run into the flask containing the baryta a few cubic centimetres at a time, and the flask well shaken, keeping the neck of the flask closed with the thumb. This operation is continued until a drop of the solution taken out with the stirrer no longer leaves a red mark on turmeric paper, or until the red mark just disappears. Several trials are necessary, as it is essential that the exact point be accurately obtained.

We next read off on the burette the amount of oxalic acid used, and this gives us the exact strength of the baryta solution. Let us, for the sake of example, suppose that we have finished the preceding operation, and we find that 25 cc. of baryta-water are exactly neutralised by the addition of 20 cc. of our standard oxalic acid. If, then, on shaking up a known volume of air, with 25 cc. of baryta-water, we find on pouring out the 25 cc. into the flask and treating it cautiously with our oxalic acid, that it no longer requires 20 cc. of oxalic, but 19 cc. to just hit the point on the turmeric paper, we know that the place of 1 cc. of oxalic acid has been taken up by carbonic acid, and as we made our oxalic solution of such a strength that 1 cc. of it was equivalent to ·001 gram CO_2, it therefore follows that this is the weight of CO_2 which was contained in the known volume of air taken. It only remains, therefore, to convert this weight of CO_2 into volume, and then a sum in simple proportion will give us the result in volumes per 10,000, which is the customary expression for this gas. We shall now describe the method of taking a sample and work out an actual analysis. Suppose we make a determination of outside air. The bottle should be dry, and placed about three feet from the ground. The stopper is removed, the bellows inserted, and thirty to forty strokes given, which should ensure complete change of the air in the bottle for the air to be examined. On withdrawing the bellows 50 cc. of baryta-water is run in with a pipette, the stopper inserted, and the temperature noted. The bottle is then removed to the laboratary or room where the analysis is to be made and shaken up repeatedly in order to bring the baryta in contact with the whole of the air, so that complete absorption of the CO_2 may take place. The bottle should then be allowed to stand for several minutes to allow the precipitated barium carbonate to subside. When this has taken place the stopper is removed, and 25 cc. or half of the solution is withdrawn by means of a pipette and run into a clean four-ounce flask. This is then treated or titrated with standard oxalic acid until the red stain on the turmeric paper just disappears, the volume of oxalic used is then read off and the analysis is completed. Suppose, then, our bottle to have had a capacity of 5·050 litres, the temperature to have been

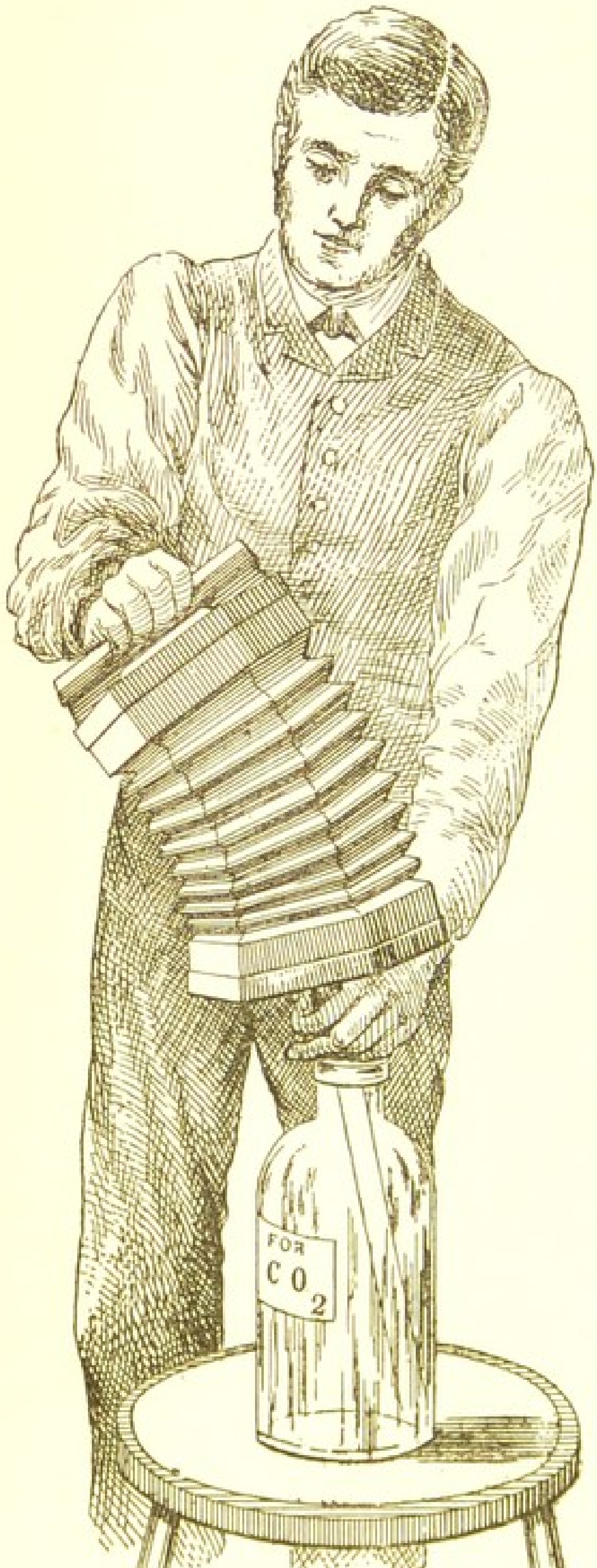


Fig. 167.
METHOD OF TAKING A SAMPLE.

10° C., the amount of oxalic acid required 18 cc., and 25 cc. of our baryta-water equal to 20 of oxalic acid. As 50 cc. of the capacity will be taken up by the 50 cc. of the liquid introduced this must be deducted, making the available capacity 5·000 litres. Again, we found that 18 cc. of oxalic acid were required instead of 20. This shows that 2 cc. is equal to half the CO_2 in the sample, as we titrated one half only of the baryta; so that altogether we have 4 cc. neutralised, and these we have seen are equal to ·004 grm. CO_2. We have, therefore, 5 litres of air at a temperature of 10° C. containing ·004 grm. CO_2. Now, one litre of CO_2 weighs 1·9712 grm., therefore ·004 grm. CO_2 is $= \frac{\cdot 004}{1\cdot 9712} \cdot 002029$ litre at a temperature of 0° C., but at 10° C. the volume will be (correcting for temp.) $\frac{\cdot 002029 \times (273 + 10)}{273}$ $= \cdot 002103$ litre of CO_2 in 5·000 litres of air at 10° C.; how many litres will there be in 10,000 of air? simply $\frac{002103 \times 10{,}000}{5} = 4\cdot 20$ parts or volumes per 10,000.*

This description may seem a little difficult to follow at first sight, but it is in reality very easy. Of course in actual practice a series of constants are calculated for each bottle, for each degree centigrade from 0° to 20°, so that one has only to multiply the constant for the temperature in question by the number of cc. of oxalic acid equivalent to the CO_2 in the sample. Suburban and country air generally contains from three to four volumes per 10,000, so that the solutions might be roughly verified by the analysis of a sample taken from either.

(2.) *Testing for Organic Matter.*

As has already been pointed out, this is an impurity which does not admit of very accurate measurement.

* Here we have not taken into account the correction for atmospheric pressure. For example, the amount of CO_2 here determined would be 4·35 vols. if the barometer stood at 29 inches instead of 30. The difference is, however, so slight that in ordinary cases it may be neglected.

This may be due to either its not being of constant composition or its unstable nature, as one can easily imagine that a reagent which may be affected by it in the nascent condition may not be so affected after it has undergone decomposition. As it contains nitrogen, one method proposed, and indeed carried out to some extent, notably by Dr. Angus Smith in his classical experiments, is that known as the ammonia process for water analysis. Mr. Foggie, F.C.S., recently made quite a number of determinations by this method in the air of schools, but it is not a method which will ever come into general use, as it is a tedious process; the reagents require to be very specially prepared, and to be specially looked after when they are prepared. Besides, there is another source of error which can hardly be avoided, and this lies in the fact that as a considerable volume of air has to be operated upon, and there is of course a limit to the size of the jar used to collect the sample, it requires to be filled by means of the bellows several times. In order to be certain that the residual air is removed each time, a number of strokes in excess of what would fill the jar are necessary. Now it is just possible that the organic matter from the air in these few bellowsful may be absorbed by the water in the jar, and thus indicate a greater amount than the total calculated volume of the jar. The method, however, may be used as a comparative test by always taking the same number of jars-full of air and giving the same number of strokes of the bellows in re-filling. It may be of interest, having said so much, to give a *resumé* of the process. A quantity (250 c.c.) of specially-purified water, free from ammonia, is shaken up with a known volume of air. This water partly dissolves and partly takes up in suspension the various impurities present. This water is then subjected to the process for estimation of ammonia, as in an ordinary drinking water; that is, it is distilled from a retort, first with a little carbonate of soda, when the free ammonia comes over in the distillate, and is estimated colorimetrically by means of the brown tint which Nessler's reagent gives with ammonia, a standard solution of ammonium chloride giving the comparative coloration. Next, to the remainder in the retort is added a strongly alkaline solution of permanganate of potash, which converts part of the nitrogen of substances like albumen into ammonia, which again comes over on distillation, this being termed the albuminoid ammonia. The results are stated either in parts per million or in milligrammes per cubic metre of air.

The method now generally adopted for organic matter is a modification of that employed by Angus Smith. (Dr. Carnelley and Mr. Mackie, "Proc. Roy. Soc.," vol. xli., p. 238.)

The principle of this process depends on the fact that when organic matter is brought into contact with a solution of permanganate of potash it is readily oxidised, the pink colour of the permanganate at the same time undergoing a bleaching action, which may be said to be proportional to the amount of oxidation which has taken place. The mode of operation is as follows:—A known volume of air is shaken up in a convenient jar or bottle, such as has already been described for determination of carbonic acid, with 50 cubic centimetres of a standard solution of permanganate of potash. After agitating the jar for six or eight minutes, half of the solution is withdrawn by means of a pipette, and run into one of a pair of exactly similar glass cylinders, 6 or 8 inches high by about 1½ inch wide, with glass stirring-rods, standing on a white tile. Into the other cylinder are run 25 cubic centimetres of the standard solution; to both is added an equal bulk of pure distilled water, and the liquids stirred. The cylinder containing the sample will be more or less decolorised according to the amount of organic matter present in the sample. What now remains to be done is to add from a burette just sufficient of the standard solution of permanganate to bring the tint up to what it was originally, *i.e.* to the colour of the second cylinder. When this has been done the number of c.c. used is read off on the burette, and as each cubic centimetre is equivalent to ·000008 gram of oxygen, and we know the exact capacity of the jar, we can easily arrive by a suitable calculation as to how much oxygen is required to oxidise the organic matter in 1,000,000 volumes of air.

The standard solution of potassium permanganate is obtained by dissolving 3·156 grams of $K MnO_4$ in a litre of water, taking 10 c.c. of this and diluting it to one litre, along with a little dilute sulphuric acid. In exact

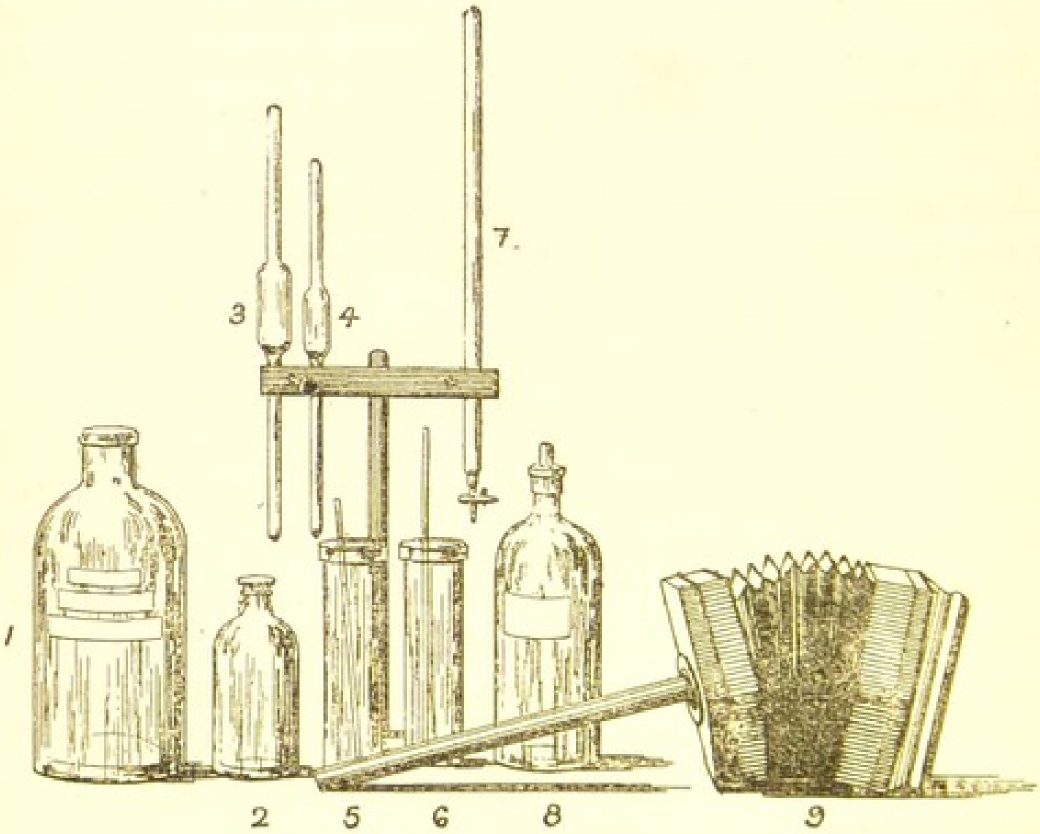


Fig. 168.

Appliances for Organic Matter.

1, sample jar. 2, standard solution of potassium permanganate. 3, a 50 cc. pipette to measure liquid from 2. 4, a 25 cc. pipette to withdraw potassium permanganate from jar after shaking. 5 and 6, glass cylinders to do color estimation in. 7, burette to measure potassium permanganate in doing titration. 8, distilled water to add to both jars and for washing. 9, bellows.

experiment it is necessary to standardise this solution against a standard solution of a ferrous salt, but that process need not be detailed here.

In this, as in the ammonia method, the strictest attention to cleanliness is essential in order to obtain anything like accurate results. The jar must be rinsed out with the solution, and neither the pipettes nor the stopper allowed to come in contact with the fingers where they are likely to touch the permanganate afterwards.

Unfortunately there are several substances which also have a bleaching action on the permanganate, as, for example, sulphur dioxide and sulphuretted hydrogen. These gases, however, are not generally met with under ordinary conditions, unless, perhaps, traces in rooms where coal gas is escaping or being consumed. Nevertheless they are impurities in every sense of the term. For all practical purposes, the permanganate method is considered to give reliable indications as to probable amount of deleterious organic matter, and is more easily carried out than the ammonia method.

(3.) *Testing for Micro-organisms.*

In the classical researches already referred to (Drs. Carnelley, Haldane, and Anderson,) the method adopted for the determination of the number of micro-organisms in air, was that proposed by Dr. Hesse, of Darmstadt. It consists in slowly aspirating a known volume of air through a wide glass tube which is coated internally with a highly nutrient jelly. As the air passes through it deposits all solid particles on the side of the tube, and the living matter finding itself in good soil, multiplies rapidly, giving rise to clumps, or colonies as they are termed, visible to the eye, the number of these colonies indicating the number of microbes present in the amount of air taken. The method is very fully described in their communication, "Phil. Trans. Royal Society," vol. 278, 1887B, p. 62, to which those interested are referred. It may be useful, however, to give a general outline of the details of the process.

The Hesse tube, Fig. 169, is about 2 to $2\frac{1}{2}$ ft. long, and $1\frac{1}{2}$ to 2 in. in diameter. One end is fitted with an india-rubber stopper A, through which passes a piece of glass tubing, B, of about $\frac{3}{16}$th of an in. in diameter, the other end being closed by means of a piece of india-rubber cloth. This is perforated with a $\frac{1}{4}$ in. round hole, C, and is kept on the end of the tube by means of a rubber ring. Outside of this is placed another piece of

Fig. 169.

the same cloth, D, to close the aperture, this also being secured by rubber rings. The small tube, B, Fig. 169, is plugged with cotton wool.

The nutrient medium used is that known as Koch's, and consists of meat juice, gelatine, and peptone, in form of a clear and transparent jelly, care being taken to ensure its perfect sterility. A quantity of this is introduced into the tube, which is again sterilised by heating for some time in a steam bath. It is then allowed to cool, being turned round as it does so with the result that a thin film of jelly coats the inside of the tube. After it has thoroughly solidified it is ready for use. In examining a sample of air the tube is placed horizontally on a convenient support about three feet from the floor, an aspirator is connected by a piece of rubber tubing to the small glass tube, the outside cap is carefully removed and the aspirator started, the flow of water being carefully regulated so as not to draw the air through too rapidly. When the exact amount of air has been drawn through, the aspirator is stopped, the cap replaced, and the tube left at rest in a temperature of about 20° C. In the course of a few days colonies begin to appear, and must be counted daily until no further increase in number takes place. The number of colonies gives the number of micro-organisms in the volume of air aspirated, which will grow on that particular medium. There are several objections to the Hesse tube, and various modifications have been proposed, amongst which may be mentioned that of Dr. Percy Frankland, "Roy. Soc. Proc." vol. xli., p. 443, and Dr. Carnelley and Mr. T. Wilson, vol. xliv., p. 45, for the description of which the reader is referred to the original papers.

The quantity of air aspirated above will vary according to its purity, a litre being about the average, and the results are stated as so many micro-organisms per litre, moulds being counted separately.

Fig. 170 shows the appliances used in testing for micro-organisms.

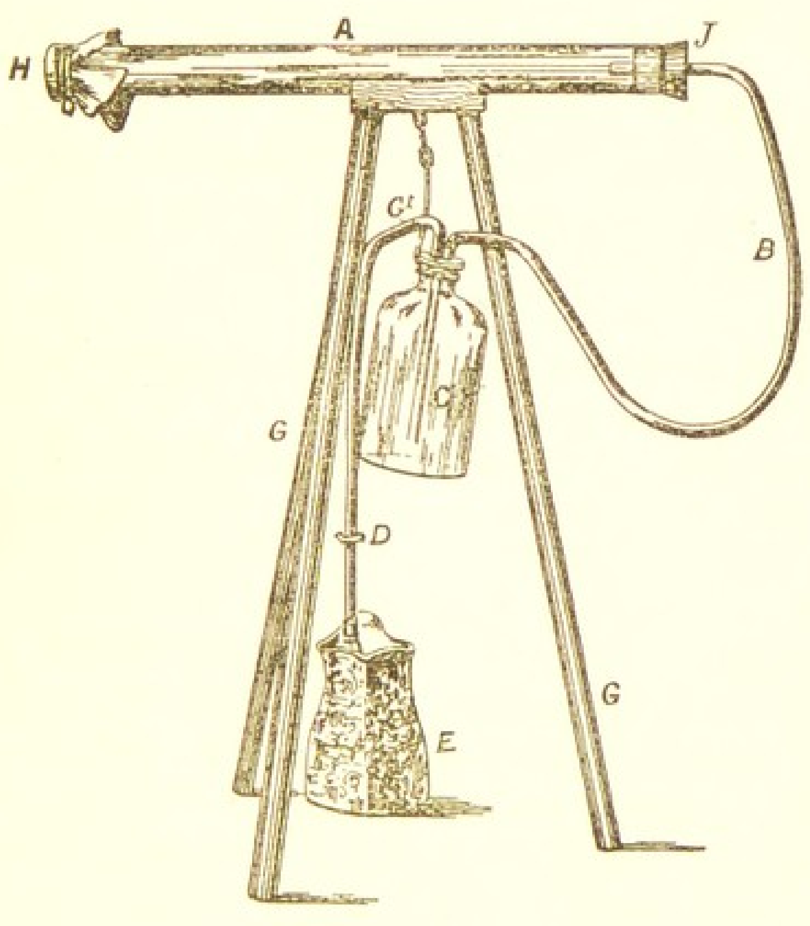


Fig. 170.

HESSE TUBE, TAKING SAMPLE.

A, Hesse tube. B, indiarubber tubing connected to exit tube and to aspirator, C. C, aspirator working by siphoning out a known volume of water which runs through tube C[1] into E, jug placed to receive it. D, a pinchcock to regulate the flow. E, jug. G, tripod. H, rubber caps, one of which is removed when taking sample, the inside one having a hole in it through which the air to be examined enters. J, india-rubber stopper with small glass tube in centre.

Having thus far described the mode of determining the various impurities, it may be well to indicate the average amounts of each normally present in the atmosphere; the averages for the air of (1) dwelling-houses, and (2) schools; and lastly, the standards of purity suggested by consideration of these results.

CARNELLEY, HALDANE, AND ANDERSON. *Dec.—Mar.*, 1885-86.

	CO_2 in 10,000.	Organic matter. Vols. Ox. per million of air.	Micro-organisms per litre.	
			Bacteria.	Moulds.
Country air*	3·1	2·8	0	·35
Town air: Dundee and Perth	3·9	8·9	6	2·0
One and two-roomed houses	10·0	12·4	50	1·5
Four-roomed and upwards .	7·7	4·5	8·5	0·4
Dundee schools: Mech. vent.	12·3	10·1	16	0·6
,, ,, Nat. vent.	18·6	16·2	151·0	1·1

The standards of purity proposed by these investigators are as follows:—

The air of a dwelling-house or school must be considered bad if the following limits be exceeded:—

	Total.	Excess over outside air.
Carbonic acid — For dwel.-houses	10 vols. per 10,000	6 vols. per 10,000
Carbonic acid — For schools .	13 ,, ,,	9 ,, ,,
Organic matter . .	Ditto.	2 vols. oxygen per million of air.
Total micro-organisms .	Ditto.	20 per litre

The following table of averages from the writer's note-book may not be without interest, in so far as it shows how close results by different persons may agree. The two tables, however, are not strictly comparable, as the first was obtained from determinations made during the winter, whilst the second was almost entirely confined to the later spring and earlier summer months.

* Suburbs of Perth and Dundee.

FOGGIE. 1887-88.

	No. of cases.	CO_2 in 10,000.	Organic matter.	Micro-organisms per litre.		Free ammonia milligr. per cub. metre.
				Bacteria.	Moulds.	
Country air (north of Fife) . . .	12	3·1	1·5	—	—	0·1
Town air (Dundee) .	22	3·97	4·0	—	—	0·23
Four-roomed house .	11	9·2	—	9	1	0·35
Dundee schools nat. vent. . { March, June }	35	15·5	10·3	69	—	0·93
*Country schools nat. vent. (Fife) { March, June }	26	19·8	9·0	82	7·7	—

* Carnelley & Foggie.

TABLES FOR CONVERTING FRENCH MEASURES INTO ENGLISH.

LINEAL MEASURE.

1 millimetre	=	·03937079 inch, or about $\frac{1}{25}$ of an inch.
1 centimetre	=	·3937079 inch.
1 decimetre	=	3·937079 inches.
1 metre	=	39·37079 inches.
1 kilometre	=	39370·79 inches, or 1093·6 yards nearly.

SQUARE MEASURE.

1 square millimetre	=	·00155006 square inch.
1 square centimetre	=	·155006 square inch.
1 square decimetre	=	15·5006 square inches.
1 square metre	=	1550·06 square inches, or 10·7643 sq. feet.

CUBIC MEASURE.

1 cubic centimetre	=	·0610271 cubic inch.
1 cubic decimetre	=	61·0271 cubic inches.
1 cubic metre	=	61027·1 cubic inches, or 35·3166 cubic feet.

The litre—for liquids—is similar to the cubic decimetre. It is equal to ·220215 of an imperial gallon.

MEASURES OF WEIGHT.

1 milligramme	=	·015432349 grain.
1 centigramme	=	·15432349 grain.
1 decigramme	=	1·5432349 grain.
1 gramme	=	15·432349 grains.
1 kilogramme	=	15432·349 grains, or 2·20462125 lbs. avoir.

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THE END.

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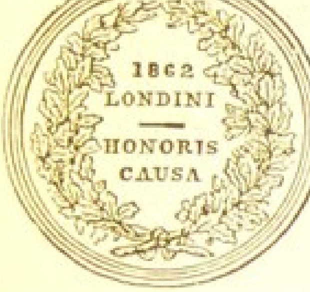

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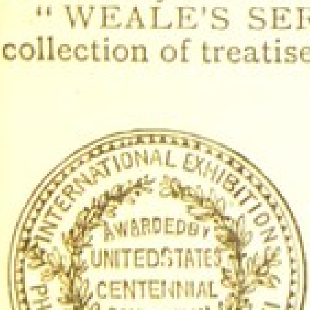

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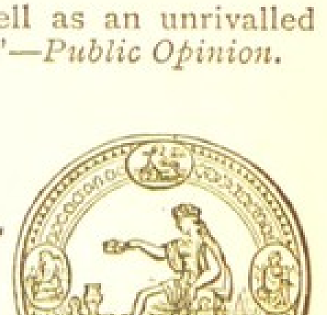

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