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BY

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PREFACE.

THIS little book is the second number of the MOTT SERIES, and it is hoped will prove of value to the community at large, considering as it does such important subjects as "THE AIR WE BREATHE" and "VENTILATION," which, from a hygienic standpoint, should attract the attention of the tenant, the physician, and the architect more than most any other subject.

The Aspirating system of ventilation has been presented to the exclusion of other systems which have been proposed, for the reason that the writer considers the principle on which that system is founded to be correct.

To cure a disease, while palliatives are of value, something must be given that will remove the cause before the cure can be effectual.

Applying this principle to ventilation, it is evident that while diluting the contaminated air of a room improves the same, the correct way is to remove the foul air and not trust to dilution to produce an atmosphere fit to breathe.

Remove, then, the foul air and, *broadly* speaking, the fresh air will take care of itself.

AUTHOR.

APRIL 10, 1883.

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THE recent estimation, that at least forty per cent. of all fatal cases are due indirectly to impure air, should be sufficiently convincing that far more serious consideration should be paid toward the introduction of such a system of ventilation as will substitute for the foul and contaminated air of the bedroom, the school-room, the theatre, etc., a continuous supply of fresh air in such quantities as circumstances may require, so that at all times the atmosphere of our buildings can be maintained in a condition of freshness.

Numerous experiments have been conducted and devices applied to accomplish this most desired result, most of them, however, have proved worthless from the fact that a draught is produced which is not only objectionable but very injurious.

In the course of this little book the subject of ventilation will be fully considered, but before approaching the consideration of this subject it will be best to study briefly the nature of the "air we breathe," by which means we will not only become convinced of the necessity of adopting some efficient system of ventilation, but at the same time will be made familiar with the nature and origin of impure air, and of the conditions which have to be contended with by any system of ventilation to be adopted.

The Atmosphere.

If the earth we inhabit were represented by a globe one foot in diameter, the atmosphere which envelopes the same would be represented by a film one-tenth of an inch in thickness; that is to say, that the height to which the atmosphere extends above the surface of the earth is from forty to forty-five miles. At the equator the height of the atmosphere is about three hundred and two feet greater than at the poles, the difference being caused by the earth's attraction at the two places, and also by centrifugal force.

If the air were an incompressible fluid, instead of being an elastic one, and if it had throughout the density which it possesses at the sea's level, the height of the atmosphere would be 8,360 metres or 5.204 miles. As, however, the air is elastic, it diminishes as the distance from the earth's level increases; thus, at a height of 5,528 metres, the air expands to twice its volume; whilst at a height of twice 5,528 metres the density is only one-third of that which it possesses at the sea level. At a height of 3.522 geographical miles it expands to sixty-four times its volume.

According to the investigation of Lasch, the weight of dry, pure air at 0° C. (32° F.), and under the pressure of 760 mm. (29.922 inches) pressure is 1.293635 gramme, or almost exactly $\frac{1}{773}$ of the weight of water. The normal barometric pressure is the weight of the air at the sea level in our latitude and is equal to a column of mercury at 0° C. (32° F.) having a height of 760 mm. (29.922 inches).

The pressure exerted by the atmosphere on one square centimetre (0.1549 sq. in.) of surface at the sea's level is 1033.3 grammes (2.28 lbs.) which is equal to 14.707 pounds on every square inch, and is generally taken as fifteen pounds. As the pressure of the atmosphere is exerted in all directions equally, and affects all bodies as well as the human frame, it is not noticeable. If, however, the pressure is released in one direction, as when the hand is placed over the open end of a cylinder when the air is being exhausted, then the pressure of the atmosphere forcibly exhibits itself. Our bodies would collapse, but for the fact that our lungs and all of the cavities of the body are filled with air. The weight of the whole atmosphere produces the elastic force of the lower portions by compressing them, and the elastic force of the lower portion exerts the pressure. It is therefore better to regard the pressure of fifteen pounds on every square inch of the surface of the earth as a consequence of the elastic force of the lower portions of air, rather than direct effect of the weight of the whole air.

The entire weight of the air on our globe is equal to that of a sphere of lead 100 kilometers (62.13 miles) in diameter, and weighs, according to Sir John Herschel, $11\frac{2}{3}$ trillions of pounds.

The body of a man of medium size, exposes a surface of about fifteen square feet, and he must consequently sustain a pressure of more than thirty thousand pounds, or about fifteen tons.

At 2.7 miles above the earth, the pressure would be reduced about one-half.

The extreme range of the barometer between the highest altitudes reached in balloons and the greatest depth beneath the level of the sea, is from thirty-three to thirty-four inches; and as the variation of one inch produces a change of pressure upon the body of a man, of one thousand pounds, the variation of pressure experienced in these cases amounts to thirty-three or thirty-four thousand pounds (Pynchon).

If the atmosphere had a uniform density throughout, in such a case the air would extend only to the height of about five miles, as already stated. Its greatest quantity of watery vapor, if condensed, would form a stratum of water about five inches deep; the carbonic acid in a layer would be about thirteen feet deep; that of oxygen about one mile, and that of nitrogen about four miles in depth.

COMPOSITION OF THE ATMOSPHERE.

Air is a mechanical mixture, principally of oxygen and nitrogen. It contains, however, some carbonic acid, watery vapor, ammonia, organic matter, etc.

The following analysis will show the composition of the air we breathe.

Average Composition of the Atmosphere.

(In 100 parts by volume.)

20.964	Oxygen.................	20.61	(20.964 when N. is only considered.)
79.036	Nitrogen	77.95	
100.000			
	Ozone.....	$\frac{1}{7000000}$	of its Bulk.
	Carbonic Acid	0.04	(0.029 combined Oxygen).
	Aqueous Vapor.........	1.40	(1.24 combined Oxygen).
	Ammonia	1 volume in 28,000,000.	
	Organic Matter...	1 grain in 200,000 cu. in.	
	Nitric Acid....	traces.	
	Carburetted Hydrogen...	traces.	
In Towns	Sulphuretted Hydrogen..	traces.	
In Towns	Sulphurous Acid........	traces.	
		100.00	

According to Bunsen the air contains:

	By volume.	By weight (round numbers).
Nitrogen............................	79.036	77.0
Oxygen............................	20.964	23.0
(Other elements not considered.)	———	———
	100.000	100.0

Air contains, then, about twenty-one per cent. by volume of oxygen, and according to Dr. Smith, when the oxygen diminishes to 20.6 per cent. it becomes very bad.

Air taken at great heights, such as eighteen thousand feet, has been analyzed and shown to contain less oxygen than near the level of the sea. This, as has been shown, was to be expected, in accordance with Dalton's and Mariotti's law, and has been sustained on theoretical grounds by Hann.

A mixture of oxygen, in the proportions given by Bunsen, 20.964 per cent. by volume with 79.036 per cent. by volume of nitrogen, furnishes the air we breathe, less, of course, the other constituents. When this mixture is made there is no development of either light, heat, or electricity, such as usually attends the formation of chemical compounds, and the specific gravity, magnetism, and refractive power of the mixture are such as calculation would directly deduce from the numbers expressing these properties for the two constituents, showing that no chemical combination has taken place.

The density of oxygen is 15.96, its specific gravity being 1.10563; the density of nitrogen is 14.01, its specific gravity being 0.9713. While the density of oxygen and nitrogen differ, owing to the law of diffusion, they thoroughly intermix; this, however, would not be the case if the difference had been great, the tendency of the two gases would have been toward separation. It is owing to the constitution of the atmosphere that there exists a permanency of the pitch of sound; any tone once generated remains the tone until it dies away. Its degree of loudness alters in proportion to the distance of the listener from the place where it originated, but its pitch—never. If the specific gravity of oxygen and nitrogen had, however, been widely dissimilar, there would have been a difference. No permanency of tone could then have been depended on, and the pitch of every original note would have varied continually. "All the studied arrangements of defined notes which constitutes the art of music, would have been lost to us forever, had we been enveloped in such an atmosphere."

Oxygen is strikingly magnetic; nitrogen is singularly the reverse; and the atmosphere, a mixture of both, is nearly neutral, as respects magnetism, in all its relations to matter.

The office of the nitrogen is to dilute the oxygen, so that combustion or oxidation will not go on too rapidly; if the proportion of nitrogen were diminished, the functions of life would be called into such rapid action as to soon exhaust the powers of the system. If the atmosphere were to consist wholly of nitrogen, life could never have been possible; were it to consist wholly of oxygen, other conditions remaining as they are, the world would run through its career with fearful rapidity; combustion once excited would proceed with ungovernable violence; animals would live with hundredfold intensity, and perish in a few hours.

The nitrogen, then, is a most valuable element, for it is more or less an indifferent substance and is not poisonous.

According to Professor Moultrie, it is probable that the nitrogen of the air discharges an important office in respiration, by preserving the volume and tension of the cells and extreme tubes of the lungs.

The air dissolved in water is much richer in oxygen than ordinary air, a condition which could not exist if air were a chemical combination of nitrogen and oxygen. When water is saturated with air at any temperature below 30°, the following is the proportion of oxygen and nitrogen in the dissolved and undissolved air:

	Air dissolved in water.	Air undissolved in water.
Oxygen	34.92	20.96
Nitrogen	65.08	79.04
	100.00	100.00

Another proof that air is a mechanical mixture, is the fact that, by a simple process called dialysis, the oxygen can be separated from the nitrogen. It consists in drawing air through membranes, the oxygen passing through in larger quantities than the nitrogen. In a process invented by M. P. Margis, of Paris, the air is forced through bags of taffeta, which have been soaked in a solution of fifty parts, by weight, of caoutchouc, dissolved in four hundred parts of carbon disulphide, twenty parts of alcohol, and ten parts of ether. The gas from the first dialysis shows forty per cent. oxygen, and is suitable for some illuminating and metallurgical purposes. The second dialysis yields gas with sixty per cent., the third eighty per cent., and the fourth gives gas with ninety-five per cent. of oxygen.

Oxygen.

Until the year 1877, Oxygen was considered a permanent gas. In vain did Faraday, Natterer, and Andrews endeavor to liquefy this element. Strange as it may seem, simultaneously, by different methods, Pictet and Cailletet succeed in doing so.

Pictet evolved the gas in a wrought-iron vessel strong enough to withstand an enormous tension, and made use of the rapid evaporation of liquid carbon dioxide to obtain a constant low temperature of 130° C. (266° F.). Cailletet brought about the pressure by means of a hydraulic press, and then suddenly diminished the pressure of the compressed gas. Pictet found that 45.467 grains of liquid oxygen occupied a volume of 46.25 cbc. (2.82 cu. in.).

On opening the tube containing the oxygen, a lustrous jet of liquid oxygen issued with great violence, whilst around was a haze of particles of solid oxygen.

Oxygen remained liquid at a temperature of —29° C. (—20.2° F.), under a pressure of 300 atmospheres.

Sufficient has been said to prove that the air is a mechanical mixture of oxygen and nitrogen, as we have already shown how water is capable of separating and dissolving greater quantities of oxygen than of nitrogen, and also, by the simple process of dialysis, how oxygen of 95 per cent. purity can be produced from the air. It is unnecessary in a work of this nature to describe methods for the production of oxygen, it is more appropriate to describe more elaborately the office oxygen performs in supporting life; and this will be considered farther on. We might, however, state that oxygen is the great supporter of combustion, and that anything which burns brightly in the air, burns with far greater brightness and brilliancy and much more rapidly in oxygen. Ignited pieces of wood or a burning taper when plunged into oxygen gas burn with great rapidity, and emit a far greater light. Finely divided pieces of iron ignite and burn, emitting light when thrown through the air, or with greater effect in pure oxygen. Slow oxidation is continually going on in nature, as the rusting of metals, the decay of wood and organic bodies continually show.

With most bodies, in order for them to take fire and be rapidly consumed they must be brought to a certain temperature. This is not, however, the case with liquid, phosphuretted hydrogen or zinc ethyl, for the minute they are exposed to the air at the ordinary temperature they ignite.

It is to the rapid absorption of oxygen in the case of oiled rags, that a certain temperature is produced and spontaneous combustion results, which is the cause of so many fires.

In the pores and on the surface of finely divided metallic particles oxygen is absorbed, and slow or imperfect combustion frequently results. The slow combustion of phosphorus, producing a glowing light called phosphorescence, begins at 10° C. (50° F.); but when the heat gets up to 60° C. (140° F.) it begins to burn brightly and enter into quick combustion.

All the supposed cases of spontaneous combustion in the human body have been shown by Liebig to be mistaken conceptions.

We cannot help but admire the wisdom in selecting a mixture of oxygen and nitrogen as the most appropriate constituents of the air, for the highest known temperature of the electric spark is necessary to form a combination between these elements. Once formed, death would be sure to result.

Whilst Priestley discovered oxygen, Lavoisier was the first to give the composition of the atmosphere and explain the changes produced in the blood by respiration. Spallanzani showed that the consumption of oxygen was in direct ratio to the muscular activity of the animal. For instance, he found that the chrysalis consumed an exceedingly small amount, the caterpillar a much larger proportion, while the active imago demanded a very large quantity for its support. These researches led to the fact that this element was the only one necessary for the continuance of life for quite a long time, at a sacrifice, of course, however, of the body. Food and drink could be withheld *for days*, and even the nitrogen of the air could be excluded for *many minutes*, and yet no serious injury would result. But if the oxygen is excluded life is immediately extinguished, as no other element holds such an affinity to life. It was therefore reasonably deduced that, in the case of disease, an additional supply of oxygen to the patient than can be obtained from the atmosphere would prove of value, and so a system of oxygen treatment was established by Caillens, which was elaborated by Professor Beddoes, and has since been more or less resorted to to the present day. The oxygen combines with the extra amount of carbon in the blood, and forms carbonic acid, which is exhaled, leaving the blood in a pure state and free to circulate. If the blood gets clogged so that it cannot circulate freely, death is sure to result.

According to Faraday 6,000,000,000 pounds of oxygen are daily consumed by the animal kingdom, and the daily consumption for all purposes reaches the enormous sum of 7,142,857 tons, and the amount of oxygen in the atmosphere is about 1,178,158,000,000,000 tons, capable of supplying the world's enormous demand for 480,000 years; or, if it were separated from the air, would form a layer on the earth's surface one mile in depth. The amount of oxygen in the air, according to twenty-eight examinations of air at Heidelberg by Bunsen, ranged between 20.970 and 20.840 per cent. by volume, which gives a mean of 20.924 per cent. According to one hundred examinations by Regnault, 20.96 per cent. by volume was found. These figures relate to the volume of oxygen present in pure air deprived of moisture, carbonic acid, and ammonia.

According to Dr. R. Angus Smith, the air from the seashore contains 20.999 per cent. of oxygen. In the free air of towns, and especially in foggy weather, it may sink to 20.82 per cent.

Analysis from Dwelling-rooms (Smith).

Before the door of a house in Manchester	20.96
In the sitting-room, not very close	20.89
In a very small room, with a petroleum lamp burning; a good deal of draught	20.84
After six hours	20.83

According to Lewy, in inhabited rooms and crowded theatres the percentage of oxygen may sink sometimes to 20.28, while, according to three hundred and thirty-nine analyses by Smith, the percentage of oxygen in mines does not average more than 20.26. Out-of-door air should contain 20.96 percent. of oxygen by volume, and when it is reduced to 20.6 it must be considered very bad. Whilst the percentage of oxygen does seem to fluctuate somewhat in pure air, still it is safe to say it should always be between 20.9 to 21 per cent. by volume, which shows that its composition is pretty nearly the same.

Wehrle states that "in an atmosphere poor in oxygen there is felt—not so much as a consequence of the presence of nitrogen, as of the absence of oxygen—contraction of the chest, tickling of the eyes, fatigue, weakness, and anxiety; we breathe more heavily and frequently, and are compelled to make more exertion at work, while perspiration and thirst ensue."

Ozone.

Ozone is oxygen intensified; it is an allotropic condition of oxygen.

The greatest amount of ozone in the atmosphere, according to Houzeau, is $\frac{1}{700000}$ of its bulk, and sometimes is wholly wanting. In a gaseous condition ozone is colorless, but when liquefied forms a beautiful blue liquid. The presence of ozone in the atmosphere has been shown by Carius to account for the presence of hydrogen dioxide, nitrate and nitrite of ammonia, which have been found in snow and rain.

The odor of ozone resembles weak chlorine or phosphorus, and is recognized during the passage of an electric spark.

It is one of the most powerful oxidizing agents known, attacking and at once destroying organic substances, such as caoutchouc, paper, etc. It dissolves in water to the extent of 4.5 volumes and imparts its odor and oxidizing properties, and consequently can be used to purify water, by destroying its excess of organic matter.

Ozone is produced in nature from various causes. During a thunder-storm the flash of lightning condenses some of the oxygen and ozone results. Mr. Wise, the late celebrated aëronaut, stated that when, on one occasion during an ascension, he became enveloped in a thunder-cloud, he found the surrounding air impregnated with the peculiar odor of ozone.

Ozone is produced by the beating of the waves against the sands of the coast. Air passing over a surface of water contains much ozone.

The action of light on growing plants has been shown by De Lucca to produce ozone; it is produced by aromatic plants and flowers (Mantegazza); it is also produced by contact with the juices of fungi (Schönbein, Phipson); and during all processes of fermentation, putrefaction, or decay (Phipson).

Its chief source is atmospheric electricity, and as minor sources, the action of aromatic plants and flowers, etc.

More ozone, according to Tidy, is found during the night, most of all at daybreak, more in winter and least in autumn, more at high levels, more on the sea-coast, when wind is blowing over the sea, more in the country than in towns, more after a thunder-storm than any other time, and least of all on damp and foggy days. It is hardly, if ever, present in inhabited rooms.

Ozone is the most perfect disinfectant known. Air containing $\frac{1}{6000}$ of ozone will purify five hundred and forty volumes of putrid air (Barker). Compounds of ammonia, phosphorus, and sulphur, which are so offensive in animal decomposition, are instantly destroyed by the action of ozone. Mould is completely destroyed when exposed to an atmosphere containing ozone (H. Corey Lea); it is therefore reasonable to suppose that it may act as a germ-destroyer, as it destroys simple vegetable substances.

According to Redfern, oxygen containing $\frac{1}{240}$ of its volume of ozone is rapidly fatal to all animals. Dewar and McKendrick state that air highly charged lessens the number of respirations and the strength of the cardiac pulse, and lowers the temperature 5° to 8° F., the blood after death being found venous.

Nitrogen.

Pure nitrogen, at the ordinary temperature, is a colorless, tasteless, inodorous gas, having inactive properties. It does not burn or support combustion. The density of nitrogen is 14.01, its specific gravity being 0.9713; it is therefore lighter than the mechanical mixture of oxygen and nitrogen composing the atmosphere.

During thunder-storms nitrogen is converted by the action of ozone into nitric acid. On the Island of Paderborn a gas spring furnishes ninety-seven per cent. of nitrogen and three per cent. of carbonic acid.

Nitrogen is a diluent or vehicle for the oxygen in the air; not supporting combustion, it cannot sustain life, and death results from suffocation. As in the case of oxygen, nitrogen has been condensed to a liquid. At a temperature of $-13°$ C. ($-8.6°$ F.), and under a pressure of two hundred atmospheres, nitrogen formed a thick mist, which condensed and formed small drops of nitrogen.

Few would have believed before these remarkable experiments of Pictet and Cailletet, that we would ever be able to pour the invisible air in which we move and are supported by from one vessel to another in a liquid form, as we are able to do in the case of water.

Nitrogen is one of the most widely diffused elements, and yet alone it is almost inactive. Still it forms the essential constituent of a large number of organic substances. It is the characteristic ingredient of ammonia, it also constitutes an essential part of many of the most potent and valuable medicines and poisons, such as quinine, morphine, prussic acid, strychnine, etc. It also enters into the composition of many animal tissues. In many places gases rich in nitrogen flow from clefts in rocks, the exact seat of which is hard to find. When it forms eighty-four per cent. of the air, lamps go out; at eighty-nine per cent. respiration ceases and death with convulsions rapidly follows. These gases, according to Lincoln, occur most frequently in long-disused shafts.

Water.

Water in a gaseous condition is always present in the air. It is composed of hydrogen and oxygen, having the formula H_2O. Its vapor density is 8.98. It is, when pure, a clear, tasteless liquid, colorless in small quantities and bluish-green when viewed in bulk. Water evaporates at all temperatures. The amount of moisture in the atmosphere varies with the temperature. When the air contains all the moisture it can hold, it is said to be saturated, and any lowering of the temperature condenses it in the form of clouds, mist, fogs, dews, etc. The degree of temperature at which the moisture is condensed is called the dew-point.

If the temperature of the air has to fall but a few degrees before moisture is deposited, the dew-point is said to be high, and there is much moisture in the air; while if the temperature must fall far, the dew-point is low, and the air contains less moisture. It is obvious, therefore, that by finding these two points of temperature, the amount of atmospheric humidity can be obtained. Hygrometers are instruments designed for this object.

The amount of moisture in the air of our artificially heated rooms is a matter of great importance to health, and the hygrometer is very valuable for ascertaining this factor.

The atmosphere is estimated to contain 50,000,000,000,000 tons of water in the form of vapor, but in a state of constant transition to rain or fog, snow or hail.

The amount of precipitation annually is estimated at

188,450,000,000 tons, of which the chief part falls upon the earth and furnishes the supply of rivers (Lincoln). The annual amount of rainfall is greatest at the equator, and diminishes with some regularity toward the poles. The amount of rainfall is very far from being an index of the moisture of the atmosphere. In fact, these two are often found in inverse ratio to each other. A showery climate is a disadvantage when it keeps people in the house.

The importance however of sufficient moisture in the atmosphere cannot be overrated to persons accustomed to live in an atmosphere containing moisture. While it has its disadvantages in favoring decomposition and putrefaction, still all vital operations depend in a high degree on this factor. At least three-fourths of plants and animals consist of water, and they are absorbing and exhaling it all the time. If the atmosphere were perfectly dry, the evaporation from leaves of plants would proceed faster than supply from the roots, and the plant would quickly wither and die. A man weighing 154 lbs. contains 116 lbs. of water. In an absolutely dry air, he would quickly exhale this from skin and lungs, exhaust the tissue of their fluids, and shrivel to a mummy (Youmans). According to Palgrave it would appear that the presence of moisture in the atmosphere is not so important. He speaks of the climate of the Arabian deserts, where one is exposed to a very dry, pure air with abundance of light, the effect being very stimulating. The parching influence of the air prevents a carcase from being offensive, putrefaction being thus effectually anticipated. He also refers to the dry air of the Rocky Mountains and of some portions of California as being known to have a very exhilarating action on the nervous system. After living in a very dry atmosphere a moist and warm climate is felt as very depressing. If the air is free from malarial germs the inhabitants are, however, found to be very healthy. Temperature and humidity of the air are the conditions suitable for decomposition of all kinds, and the air swarms with disease-germs, the effluvia from an impure soil, and the putrescent changes going on in it being greatly aggravated. It becomes necessary under these conditions to resort to sanitary precautions. In the north the cold prevents, to a large degree, such conditions, but in the south, as the West Indies and in tropical India, the heat aggravates them. In the zone from 12° north to 12° south latitude the heat is never oppressive, and the large amount of moisture in the atmosphere is as congenial to the health of man as it favorable to the growth and development of vegetation.

As the temperature of the atmosphere rises the amount of vapor which is capable of retaining the gaseous state increases very rapidly, and consequently any sudden reduction in the temperature, even of a few degrees, causes precipitation of water, which accounts for the great copiousness of the rains which characterize the season of changeable weather in the tropics.

One cubic foot of air saturated with moisture (Barom. 30 in.) at 60° F. contains 5.77 grains of aqueous vapor, while at 30° F. it only contains 1.97 grain, and at 90° F. it contains 14.85 grains.

Carbonic Acid.

This gas was first distinguished from ordinary air by Van Helmont, who termed it *gas* sylvestre. Dr. Black, in 1757, called it *fixed air*, as he found it contained in limestone. Under ordinary conditions carbonic acid is a colorless, transparent gas, with a faintly acidulous smell and taste. At 0° C. (32° F.) it requires a pressure of 38.5 atmospheres to retain it in a liquid form. It is found liquid in some crystals, topaz, sapphire, etc.

The density of carbonic acid gas is 21.945, having a specific gravity of 1.5241, being more than half again as heavy as air. The correct name for this gas is carbon dioxide, but as it is better known as carbonic acid we will continue to call it so. This gas is not inflammable, neither will it support combustion, and in fact extinguishes burning bodies.

Carbonic acid is widely distributed in nature and forms a constant and essential constituent of the atmosphere, although existing in small quantities. It originates from many sources.

Respiration in man and animals is always attended with the formation of this gas. The air expired contains between four to five per cent. of this gas, and its presence may be demonstrated by breathing through a tube inserted in lime-water, when it will become turbid by precipitation of carbonate of lime (calcic carbonate).

An adult man gives off when breathing 0.6 to 0.7 of a cubic foot of carbonic acid gas in an hour while awake, and 0.5 to 0.6 when asleep. The amount given off is more than one hundred times as much as the air contains.

The air is polluted in large manufacturing towns with carbonic acid gas arising from the burning of coal, wood, etc.

This gas is also formed from decaying and decomposing organic bodies. It originates from the combustion of illuminating gas in dwellings. One cubic foot of gas yields 0.9 of a cubic foot of carbonic acid, nearly one-third more than a man gives off in an hour.

The carbonic acid in the atmosphere is as necessary for the plant as is oxygen for the animal. In the presence of sunlight, plants have the power, through their leaves, of decomposing carbonic acid, taking up the carbon to form their tissue and eliminating oxygen, and it is for this reason that the amount of carbonic acid in the air is about constant.

"Without plants animals could not live; without animals, plants had no need to be." Animals derive all the material of their structure from plants—they destroy these substances, and by respiration while living, and putrefaction after death, restore them again in a gaseous form for the plants to reduce by the aid of sunlight to a solid form once more, thus maintaining its equilibrium and permanence. Immense amounts of carbonic acid are produced by the combustion of fuel. It is estimated by Smith that 15,066 tons are daily poured into the air of Manchester. In comparison with 330 tons from respiration the latter is insignificant.

The amount of carbonic acid in the air normally, whilst it fluctuates slightly, reaches about four volumes in ten thousand of air. The following table gives the

CARBONIC ACID IN AIR FROM CONFINED PLACES.

(Parts in 10,000.)

PLACE.	Time.	Observer.	Parts.
Strand Theatre, boxes	10.3 P.M.	Smith.	11.1
Strand Theatre (same evening)	12 P.M.	Smith.	21.8
City of London Theatre, pit	11.15 P.M.	Smith.	25.2
Standard Theatre, pit	11 P.M.	Smith.	32.0
Public schools of Philadelphia in 1875 (average of 10 grades)	....	E. Thomson.	13.15
Public schools of Boston (average of 25 primary and 15 grammar) in 1870	....	Storer and Pearson.	14.5

Carbonic Acid in Air from Confined Places.—*Continued.*

(Parts in 10,000.)

Place.	Time.	Observer.	Parts.
Public schools of Michigan (average of 11 high and normal).....	....	Kedzie.	24.0
Annaberg, five schools...........	....	O. Krause.	39.9
Schoolroom after two hours	....	Pettenkofer.	72.0
A school in March	....	Oertel.	56.7
Same in July	....	Oertel.	41.0
A Sunday-school, 80–100 children, before opening	....	W. R. Nichols.	7.21
Same an hour later	....	W. R. Nichols.	29.51
Same half an hour later still	....	W. R. Nichols.	31.96
A Sunday-school, 350 persons	....	W. R. Nichols.	26.34
Same room, evening, 200 people, and 10–12 gas-burners	....	W. R. Nichols.	21.58
Highest amount found in an United States naval vessel	....	Th. G. Turner.	39.1
Smoking cars, 15 analyses, ranging from 9.8–36.9 (1874)	....	W. R. Nichols.	22.8
Passenger cars (range from 15.9–36.7).........................	....	W. R. Nichols	23.2
Portsmouth City Prison, cells of 614 cu. ft., always occupied....	....	Wilson	7.20
Same, cells 210 cu. ft., occupied only at night	....	Wilson.	10.44
English mines examination, 339 examinations (average)........	....	Smith.	78.5
Chancery Court, closed doors, 7 feet from ground	....	Smith.	19.3
3 feet from ground	....	Smith.	20.3

By shifting the decimals two places to the left we have the percentages in the above table.

According to Pettenkofer, who is authority, there should not be allowed more than seven parts in ten thousand, .07 per cent., in the air of dwellings. These figures relate to the carbonic acid generated by respiration, while all carbonic acid is the same; yet, as it is taken as an index of purity, it is but right to state that associated with this gas in the air exhaled from the lungs are other deleterious substances, which will be alluded to farther on.

There is a vast difference when carbonic acid originates in the breath. Smith, for instance, after making the experiment, says: "It seems to me impossible to endure four per cent. for any length of time."

Air containing four per cent. of carbonic acid extinguishes a candle flame, and if 2.2 per cent. of carbonic acid replaces a corresponding amount of oxygen the candle will also go out.

Carbonic Oxide.

Carbonic oxide gas is transparent and colorless and possesses a faint oppressive odor. It has recently been condensed to a liquid. The gas does not support combustion any more than hydrogen gas, but burns itself with a pale blue light, becoming oxidized and forming carbonic acid gas. It is produced in large quantities in stoves and furnaces. Carbonic acid gas is formed at the bottom of the grate, but on traversing up through the column of fuel takes up additional carbon, forming carbonic oxide. It shows itself by the flickering blue flame playing over the burning fuel.

Carbonic oxide, then, is only half-burnt carbon. It is a deadly poison to inhale, even when diluted largely with air, producing a peculiar sensation of oppression and tightness of the head. It combines with the hæmoglobin of the blood. The whole dissolved oxygen is expelled, the blood acquiring a light, purple-red color, numerous experiments have been conducted from time to time on various animals, by different scientists to study this peculiar action, as the subject is important.

Small animals die almost instantly when placed in the gas. According to Rosco, "the accidents, as well as suicides which occur from burning charcoal in a chauffer in a small room, are due to the inhalation of this gas, formed by incomplete combustion, and deaths occurring from sleeping upon lime-kilns and brick-kilns are probably also produced by this gas."

The density of this gas is 13.94, its specific gravity being 0.9678 (Cruikshank).

The chemist, Chenot, having accidentally inhaled a single breath of this gas, fell on his back to the ground, as if struck by lightning; his eyes were rolled in their sockets, and his extremities drawn up. In a quarter of an hour, external sensation returned, with a feeling of cold and suffocation. A heavy sweat covered his whole body; while a peculiar hyperæsthesia of the brain existed.

According to Eulenberg, the first effects of inhaling carbonic oxide is to produce stupefaction, then convulsion, and finally asphyxia.

Carbonic oxide is known to be present in small quantities in inhabited rooms, originating from imperfect combustion of the fuel in furnaces and stoves and escaping into the room through crevices in such apparatus. It is also produced by the imperfect combustion of illuminating gas, as also in the smoke from a glowing candle-wick and from a cigar.

Many people are affected particularly by the quantities originating from such causes, and complain of giddiness, headache, and prostration of strength.

The presence of carbonic oxide gas can be detected in the atmosphere of a room by means of Vogel's spectroscopic test.

Böttcher saturates a piece of linen or cotton cloth with a solution of chloride of palladium, and then superficially dries between blotting-paper; when cloth thus prepared is exposed to the air, if carbonic oxide is present a black color will appear in a few minutes. Gottschalk prefers passing the air by aspiration through a solution of sodio-chloride of palladium, when the black color is produced.

Ammonia.

Ammonia is present in the atmosphere in minute quantities. In a gaseous condition it is colorless and possesses a very pungent odor, inducing a copious flow of tears; it has an acrid taste. If breathed in large quantities in a concentrated condition it produces irritation of the lungs and proves fatal, while if breathed in a diluted form it partakes of the nature of a valuable stimulant. It is composed of hydrogen and nitrogen, its formula being NH_3. Its density is 8.505, being 0.586 times as light as air. This gas was liquefied by Faraday; a reduction of the temperature to —50° C. (—58° F.) will produce the change. If the temperature is reduced below —75° C. (—103° F.) in a bath of solid carbonic acid, and ether placed in vacuo, a mass of white translucent crystals of solid ammonia is obtained. In this condition it possesses only a faint smell. It has the power of changing red litmus paper blue and of neutralizing acids.

During the processes of decay and putrefaction of the nitrogenous constituents of plants and animals, ammonia gas is evolved and given off to the atmosphere.

Ammonia is abundant in barn-yards, privies, and foul places.

Smith, speaking of ammonia, says: "It has very bad relations and keeps very bad company, and if it increases so as to be perceptible to the senses, it becomes unpleasant, and, of course, unwholesome."

"Albuminoid ammonia" is that which is obtained from organic substances, either alive or dead, and in decay. An excess in air is a suspicious circumstance, to just what its presence is due cannot always be told.

The following table by Smith gives the analysis of air from places differing widely in character. The figures are only relative, showing the amount present, as measured by reference to that contained in pure air from Innellan on the Firth of Clyde, taken at 100:

LOCATION.	Total ammonia.	Not albuminoid.	Albuminoid.
Innellan	100	100	100
London	112	117	109
A bedroom	179	194	173
Glasgow	202	150	221
Inside and outside of office	205	235	193
Underground Railway (Metropolitan)	234	138	271
A midden	395	643	301

According to Ville, one million kilogrammes of air contained on the average in the year 1849, 24.7 grains of ammonia, and in 1850, 21.1 grains. This amounts to about one volume of ammonia in 28 million volumes of air, or 0.35 c.c. of the gas in 1 cubic metre of air. Other experimenters give higher results. Muntz and Auber found the amount of ammonia in the air on the top of Pic du Midi, 2,877 metres above the level of the sea, to be—1.35 milligramme in 100 cubic metres. Ammonia is chiefly present in the atmosphere as carbonate and sulphide.

Impurities in the Air.

We have considered the normal constituents of the atmosphere, and it now becomes necessary to consider the nature of the impurities which we are subjected to under various conditions.

Sulphur Compounds.

From the decomposition of animal matter, which generally contains sulphur, sulphuretted hydrogen and sulphide of ammonium are evolved. Sulphuretted hydrogen also results from the burning of coal. Its action on this system is the same as carbonic oxide. Exposed to the air it is oxidized to sulphuric acid. The sulphide becomes sulphate, which, coming in contact with chloride of sodium (common salt) produces sulphate of sodium and chloride of ammonium, the sulphates being present in soft-coal burning districts.

Bisulphide of carbon is also present in the air at times. Nitric and nitrous acid are present in the air at times, and are produced by the oxidation of ammonia or organic substances, as also, during a thunder-storm, by the oxidation of nitrogen by the ozone produced by lightning. Plants are sometimes withered by its action. In excessive quantities these acids would be very dangerous, but such conditions never arise.

The air sometimes contains phosphuretted hydrogen and hydrochloric acid; the latter being produced from alkali works.

Sewer-Gas.

Sewer-gas is a combination of various gases, which contains germs of disease, and is to be dreaded more than most any other impurity. Marsh-gas, sulphuretted hydrogen, sulphide and carbonate of ammonium, carbonic oxide and acid, and various compounds of carbon and ammonia are present in *sewer-gas.* Some of these gases have produced death, being active poisons. As these gases arise from the putrefaction of the matter in the sewers, a rapid discharge and a perfect ventilation should be kept up in the sewers to prevent such decomposition as much as possible.

By the odor of sewer-gas its presence can in most cases be detected, but the absence of odor is no positive proof that sewer-gas is not gradually finding its entrance into our buildings.

No mechanical system of sanitation can totally prevent the admission of sewer-gas into buildings. Numerous traps filled with water can be employed, but as soon as the water in the traps is saturated by absorption of the gas, it passes directly through, carrying with it the germs of disease. This has been demonstrated by actual experiment.

The sewer-gas generated in the soil-pipes of a house by the decomposition of excreta before it reaches the main sewer possesses, only in a less degree, the properties of street sewer-gas. We cannot, then, afford to overlook the gas arising from this source. It is owing to bends, angles, rough surfaces, etc., of house-drains that accumulation of fermenting matter always exists, which is not dislodged by the flow of water through the drain. These internal sources of gas generation, added to the source existing outside of the house, confer upon the question of the suppression of sewer-gas more complexity than is usually recognized.

E. J. Mallett, Jr., after thoroughly studying the subject of domestic sanitation, invented the germicide system, which has for its object the prevention of any decomposition in the soil-pipes of the house, and this is accomplished in a very simple manner by supplying to the bowl of the basin in the closets of our house a continuous supply of an antiseptic solution drop by drop, the solution being composed of chloride of zinc. The combination of the germicide system with the best mechanical devices for the prevention of street sewer-gas from entering our houses, furnishes us with all that could be desired.

Solid Impurities.

Tyndall was the first to show that when a given volume of air in an enclosed box was allowed to remain at rest for a few days, that all the suspended matter would be precipitated, and if a ray of light were allowed to pass through the box, the direction of the ray could be seen entering and leaving the box, but total darkness would prevail within the same, proving that it is the suspended impurities in the air which makes a ray or beam of light visible. What, then, is the solid suspended matter in the air?

Careful examination has shown them to be the débris of vegetation, animal and vegetable organisms, as also suspended inorganic matter. The wind takes up from the soil in the form of dust these various substances, and transports them through the upper strata of air miles and miles. African organisms have been detected in the air of Berlin.

In workshops the air is always found to contain dust of the various substances manipulated, which gives rise to special diseases.

Animal and vegetable organisms exist in the air in great quantities. Ehrenberg has discovered individuals of the rhizopods, tardigrades, and anguillulæ, which, when dried, retain their vitality for months and years; and in dust-showers he has found some hundreds of forms, classed as polygastrica, phytolithariæ, etc.

Bacteria, vibriones, and monads are found very frequently.

The vegetable kingdom furnishes to the air the seeds and débris of vegetation—pollen, cuticular scales, vegetable fibres and hairs, seed capsules, globular cells, etc.

It is from the presence of these minute organisms that Tyndall and others have been able to establish the germ theory of disease.

The germs in the atmosphere have been shown by Ehrenberg to exist in masses or clouds. So that, in a room containing infection, a portion of the air may be loaded, while other portions are nearly free, which would explain anomalous cases of escape from septic or zymotic influences.

The animal exhalations in the air of crowded rooms, when condensed on cold glass and on the furniture, will, on drying, form a glutinous coating, and if this be examined under the microscope, it is seen to be a closely matted, confervoid growth, or, in other words, the organic matter is converted into conferva. Between the stalks of these confervæ are to be seen a number of greenish globules constantly moving about, various species of volvox accompanied also by monads many times smaller.

Before this occurs, the odor of perspiration may be distinctly perceived, especially if the vessel containing the liquid be placed in boiling water (Lincoln).

After the air has become saturated with the effete matter and organic vapors of perspiration and breathing, the excess is precipitated on the walls, floor, windows, etc., of the room, which in turn becomes putrid in a warm atmosphere. *Cleanliness* of the person is a most important factor in maintaining the purity of the air in a room, for with the most perfect system of ventilation, the air will be contaminated from uncleanly people.

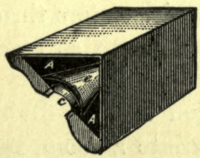
In dry and healthy localities but few germs are found in the atmosphere, while in low, damp places, crowded houses, unhealthy cities, houses in which the drainage is poor, the number of disease-germs increase with marvellous rapidity. One germ, under favorable conditions, will, by growth and division, multiply into millions in a short time.

It is to the microzymes we are indebted for catarrh, to ozæna for hay fever, etc.; to the bacillus for consumption, etc.

The presence of these germs in the air in rooms occupied by sufferers with such affections shows the necessity of keeping them well ventilated, so as to change the air as often as possible.

In robust health the purifying action of the liver and excretory organs soon expel from the blood the germs which gain entrance, and which would remain if the glands were not active and produce serious disease.

Weak persons, or persons not given to out-door exercise, cannot withstand the influence of these germs, they cannot expel them from the system, and the result is disease. Even the most robust and active man cannot be subjected too often to such conditions without breaking down.



VENTILATION.

Having considered the nature and properties of the "Air we Breathe," we can pass on to the consideration of the subject of ventilation better able to appreciate the many difficulties to be contended with. Ventilation is either natural or artificial. Natural ventilation is limited to the supply of air which enters through passages not intended for the purpose, such as cracks and pores in the walls, doors, windows, etc.

Artificial ventilation can be divided into two heads: those which force air into a room, and those which draw air out of the room.

There is one thing very certain, that the correct principle is to withdraw the foul air out of a room as soon after it is formed as possible, and not to trust to diluting the foul air so that it can be breathed. It is necessary, of course, that the air admitted to replace the foul air aspirated out should be pure.

How few housekeepers stop to think that the foul air from their damp and mouldy cellar is continually rising and polluting the atmosphere of their houses. It is most important to keep this part of the house perfectly clean, for the air receives but little if any sunlight, and does not circulate freely, and is polluted in many cases by the decomposition of vegetables and other organic matters in the ash-heap. It would be far better to spend the time required to dust the ornaments in the parlor in cleaning the cellar every day, if we wish to enjoy breathing a pure atmosphere.

The atmosphere of the cellar is sure to enter through seams into the duct which supplies the furnace with air, and through unintended openings in the hot-air box of the furnace, and this mixed air is distributed throughout the house.

The subject, then, of heating and ventilating are almost linked to one another, for no system of heating can be recommended that introduces impure air into our houses, or simply heats the contaminated air present in the house, without making the requisite provisions for supplying by ventilation the necessary amount of fresh air required to support life under the most favorable circumstances.

Forster has shown that currents of air are continually passing into our dwelling-rooms from the soil on which we live; in fact, we are in continual and direct communication with the soil beneath us through the medium of the air. The necessity of cleanliness in our cellars cannot, therefore, be elaborated upon too much.

The opening of the flue for supplying fresh air to the furnace should be as high above the level of the ground as possible. In many cases it is quite the reverse, and the air, instead of being pure, is fouled by dust or by exhalations from gutters, cesspools, or streets.

Houses situated on high sites and exposed to fresh winds, are certain to be supplied with pure air. But in closely built places where the wind has not its full sway, the amount of fresh air entering a house is diminished. In cities toward the centre, the air is very apt to be stagnant, or contaminated, unless open squares are frequent, and the vegetable kingdom undertakes to purify the air. The air admitted through the flue to furnaces should be screened, for in cities few sources of fresh air are so free from dust, spores, or carbon-flakes as to render this precaution needless.

A hot-air furnace is practically an encased stove, which is usually placed in the cellar. They act indirectly by heating the air supplied to them by the ducts, which is distributed into the various rooms. A good chimney-draft is necessary, and must always exceed the draught-power of the hot-air pipes; from the defect of this requirement a leakage of coal-gas into the house is occasioned.

If the combustion in the furnace is controlled by the admission of air through the grate rather than by a damper in the smoke-pipe this will rarely, if ever, occur.

As much has been said respecting open grate fires as a means of ventilation, it is best to consider them as we pass on. Open grate fires, when used in rooms heated by other means, are unquestionably of value. They partake, however, of the nature of an expensive luxury if used alone, and subject persons in the room to draughts. Only twelve to fourteen per cent. of the heat produced by the fuel in an open grate is rendered available; the rest goes up the chimney, and in doing so draws air out of the room. To supply this loss fresh air must come in through the doors and windows; this being cold is scarcely heated before it has to escape, a draught is thus occasioned which is very objectionable, to say the least. If the room is heated by a furnace, then, of course, the draught of cold air is avoided, and the open fire is a delightful source of additional heat, the luminous rays also produce a genial effect striking directly on the person, and the large amount of air aspirated up the chimney keeps the atmosphere of the room much purer.

Ventilating fireplaces and stoves, which are now so well known, combine the fireplace and the furnace. The "Fire on the Hearth" is a double-cased stove, the space between the two cases is open at the bottom, and forms a channel through which the air of the room, or fresh air from out of doors, can circulate and become heated, after which it issues into the room through a perforated top.

Close stoves do not assist essentially in promoting ventilation in a room, for the amount of air they take from the room is only sufficient for combustion, and according to Moirin amounts to less than one hundred and twenty cubic feet of air for every pound of coal consumed.

Steam has gradually grown into favor for heating, as it is a most convenient means of conveying heat for any considerable distance. A heater in which steam circulates may be placed in the rooms to be heated, or a large heater may be placed in the cellar and used to heat fresh air admitted from out of doors, which is then conducted to the various rooms.

It is safe to estimate that in a cold climate the steam required for one horse-power will warm about 12,000 cubic feet of space to 70° by direct radiation, which will allow for a complete change of air every hour by natural ventilation. One square foot of radiating surface heated by steam at one pound gauge pressure will be required for one hundred and fifty cubic feet of space in the rooms. When low-pressure steam is used for warming dwellings by indirect heaters, it is customary to provide one square foot of heating surface for every forty cubic feet of space in the house (Richards). Air from a furnace can only be distributed over a radius of about forty feet, while steam can transfer heat most any desired distance in a horizontal direction. Without some suitable system of ventilation it is objectionable to heat rooms by steam coils placed directly in the rooms—for the coil can only heat the air in the room without furnishing any fresh air.

Lincoln suggests that a proper arrangement would be to enclose each coil in a box, forming an arrangement like a system of stove-flues, each box having an inlet for fresh air and an outlet or register to discharge it into the room. Such a box could be placed under the window without occupying much space. (See Gouge's system.)

Requirements for Good Ventilation.

No system of ventilation can keep the air of rooms as pure as out-of-door air, for, as Herter says, an infinite amount of air would have to be introduced to accomplish this object. By a system invented by John F. Cameron, which will be described presently, the foul air of the room is continually passing out and other air substituted, so that the atmosphere, or the air which is breathed, is always in a condition of freshness.

From the amount of carbonic acid exhaled, the amount of fresh air required by an adult can be estimated, and the amount of air necessary to dilute the exhaled air to the conventional standard of purity for houses, can be ascertained, if this system is to be adopted.

It has already been stated that an adult man gives off in breathing six-tenths to seven-tenths of a cubic foot of carbonic acid in an hour while awake, and from five-tenths to six-tenths of a cubic foot when asleep.

Women give off less, and children and old people also give off a smaller amount.

A man inhales at least twenty cubic inches of air at each breath, which at twenty respirations per minute, gives fourteen cubic feet as the quantity passed through the lungs in one hour.

The air exhaled contains from four to five per cent. of carbonic acid, or more than one hundred times the normal proportion in pure air, and saturated with moisture, no matter how dry it may have been when taken into the lungs. The vapor given off by the lungs is accompanied by from one-twelfth to one-sixth of a pound of vapor emanating from the skin each hour, and is diffused through the surrounding air.

The vapor, says Richards, which escapes from even the healthy human system contains volatile substances and effete matter, which it is one of the functions of breathing and perspiration to remove from the body as injurious, and which it is evident should not be again taken into the system. These last impurities, when present in comparatively small quantities, render air unfit to support life, and when habitually breathed are insidious, and often unsuspected causes of gradual deterioration of vigor and health.

To estimate, then, the amount of air required by each person hourly, carbonic acid is taken as the index, and the deduction will be as follows: Since the amount of carbonic acid excreted by the lungs in twenty-four hours is assumed to be one and three-fourths cubic foot, which corresponds to forty cubic feet expired air, containing 4.334 per cent. (Vierrordt) of carbonic acid.

If the expired air is diluted with two hundred times its volume of atmospheric air containing the usual four parts per ten thousand (or .04 per cent.) of carbonic acid, the total amount of carbonic acid which will be present will be an allowable amount.

The amount of air, therefore, required daily will be about 89,000 cubic feet, and hourly about 3,300 cubic feet.

Morin from his investigations has formulated the following table, which is generally accepted as correct, the difference in the amount of air allowed for children, as Lincoln says, is too great, as the amount of carbonic acid gas eliminated from their lungs is not so much less than from adults:

Volumes of Fresh Air Required for Ventilation.

	Cubic feet per hour.
Hospitals for ordinary sickness	2,400
" " wounded	3,600
" " epidemics	5,000
Prisons	1,800
Workshops for ordinary trades	2,100
" " unhealthy trades	3,600
Halls for long meetings	2,000
" " short meetings	1,000
Barracks at night	1,600
Schools for children	500
" " youths	1,000

According to Billings, a man should have one cubic foot of fresh air per second, and this should be the minimum amount, which would equal 3,600 cubic feet per hour.

When we consider the volume of air actually breathed, these figures may seem large, but they are insignificant when compared with the quantity of air which comes in contact with the body, when in the open air, for the motion of the atmosphere on a nearly calm day is rarely less than two miles an hour, and with this velocity over the ten square feet presented by the body, the ventilation amounts to the enormous figure of 100,000 cubic feet per hour, of perfectly pure air (Richards).

The great problem is—how to ventilate a room so as to replace the foul atmosphere with the necessary amount of fresh air required to sustain life under the most favorable conditions.

Cameron System of Ventilation.

The principle of the *Cameron System of Ventilation* is to draw or aspirate out of a room, the carbonic acid and effete matter from the breath, almost as soon as the lungs throws it out, not giving it time to precipitate and intermingle with the air which it is necessary to breathe. All the air admitted into the room then by natural ventilation through cracks and pores in the walls, doors, windows, etc., to replace the air aspirated out, is not called upon to dilute impure air, but affords an atmosphere which can be immediately breathed without performing any other office.

Advantage is taken in this system of the fact that the gases exhaled from the lungs, although at the ordinary temperature heavier than the air, when given out are much warmer, consequently more expanded and lighter, and therefore rise to the top of the room, until they become reduced in temperature and precipitate toward the floor, intermingling with and contaminating whatever fresh air finds entrance into the room from natural causes.

This is unquestionably the correct principle, and to carry it into effect a hollow cornice, with orifices opening in the room, is connected at one end with a pipe, up which a current of warm air is rising, by which means a suction is produced and the air is drawn out of the cornice, the foul air of the room filling up the vacated space, which in turn is drawn out, the process continuing indefinitely.

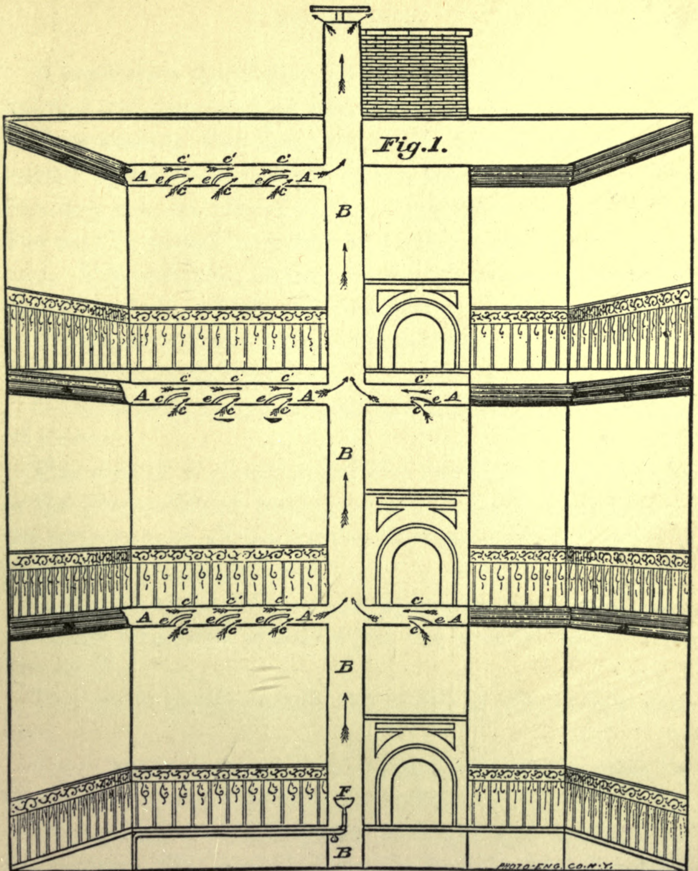
To properly apply the system to buildings, a perpendicular tube, opening into the cellar and extending through the roof, is first introduced into the house; this tube may be placed in the chimney, up which heat is going, or as an abutment to such a chimney. A gas-jet is placed in the bottom of the tube, to be used when there is no heat in the chimney. The fire during the day and the gas-jet at night is sufficient to produce the necessary suction.

The orifices in the cornice are covered over with a guide spout just behind them, so as to prevent the air that is drawn into it from escaping into other rooms of a different temperature, and also to secure an unbroken current outward through the perpendicular flue. These guide-spouts are one of the principal features of the Cameron system and are very efficient in their working.

In hotels and in public institutions, such as jails, courts, etc., the hollow cornice is affixed in the corridor, and an opening in the wall of each room is connected with it, the cornice in turn being connected with a perpendicular flue having a gas-jet at the bottom, placed at the end of each corridor or any other convenient location.

This system is applicable to the cellar and every floor of the house.

Plate I. illustrates the system.



CORNICE VENTILATION.

A represents the hollow cornice, which of course can be painted and decorated as usual, or more so.

B represents the flue up which heated air ascends, caused by being in contact with a heated chimney. The flue may also be placed in the chimney or the air in the flue may be heated by means of a gas-jet placed at the bottom. It is well, also, to place an Archimedean screw at the top of the tube, which will be actuated by the wind.

C represents the orifices in the cornice.

D represents the chimney.

E represents the guide-spouts, which are in the shape of a cone.

The area of B should equal the combined area of AA, or the perpendicular suction-pipe must be of same area as the aggregate of all the cornice tubings in a house at their mean width, measured at C′.

A should equal CC, or the aggregate size of all the openings on a floor should equal the area of hollow cornice at C′.

The guide-spouts reduce the width of the hollow cornice.

From two to three orifices on each side of the room in the hollow cornice will be quite sufficient.

The operation of this system is simple and is shown by the arrows. The foul air from the breath, the odor from cooking, and the smoke of cigars rises to the ceiling of the room and is drawn into the hollow cornice, whence it is conveyed by suction to the perpendicular flue, and escapes up it into the air above the roof of the house.

In kitchens a perforated false ceiling is connected with the cornice, which is in turn connected with the flue in or next to the chimney, and by this means all the odors arising from cooking are immediately drawn out of the room and escape into the atmosphere.

With respect to the rising of carbonic acid, smoke, odors, etc., in a room to the ceiling, this is a well-established fact, as when carbonic acid is exhaled from the lungs it is much warmer than the atmosphere of the average room (which should be between 65° and 70° F.), it is, therefore, more expanded and lighter. If, however, cool air were admitted through a window or otherwise at the top of the room, the carbonic acid would be reduced in temperature, and being much heavier than air at the same temperature, would at once precipitate to the ground and intermingle with the air we breathe. It is for this reason that it is most important to remove the carbonic acid, etc., by suction from the room as soon as it reaches the ceiling.

With respect to the aspiration produced by a gas-jet, Morin has shown that 7 cubic feet of gas burnt per hour in a flue 11 inches square and 66 feet high, draw 13,300 cubic feet of air per hour from the room. When this amount of ventilation is taken in connection with that produced by natural causes, as pure an atmosphere as could be desired is produced.

In order to determine the extent to which "natural" ventilation affects the air of a dwelling-room, Pettenkofer applied the reaction for carbonic acid. He found that in a room with brick walls, containing 75 cubic metres of air, or about 2,700 cubic feet, the air contained was completely changed once in an hour, when the temperature outside stood 32.2° F., and inside 64.4° F., a difference of 34.2°. At the same temperature, a brisk fire being made in the stove, and all the valves and doors opened to the chimney, the hourly change amounted to 94 cubic metres, or nearly 25 per cent. increase. But when all the cracks in the doors and windows, and even the keyholes were closed with strong paper and paste, the change of air still equalled 54 cubic metres in an hour, which is only twenty-eight per cent. less than the first result. This effect was, it is true, very much dependent on the difference of temperature between the outer and the inner air, as is shown by the fact that when these equalled respectively 64.4° and 71.6° F., the average change of air was only 22 cubic metres per hour, and even the opening of a window, with a space of 8 square feet, increased the change of air only 42 cubic metres per hour (Lincoln).

In winter in this vicinity there are such great, and even greater, differences of temperature as 34.2° and 64.4° F., between the air of the house and that of out of doors. It will therefore be seen that natural ventilation under favorable conditions is not so insignificant as one would suppose.

Railroad Cars.

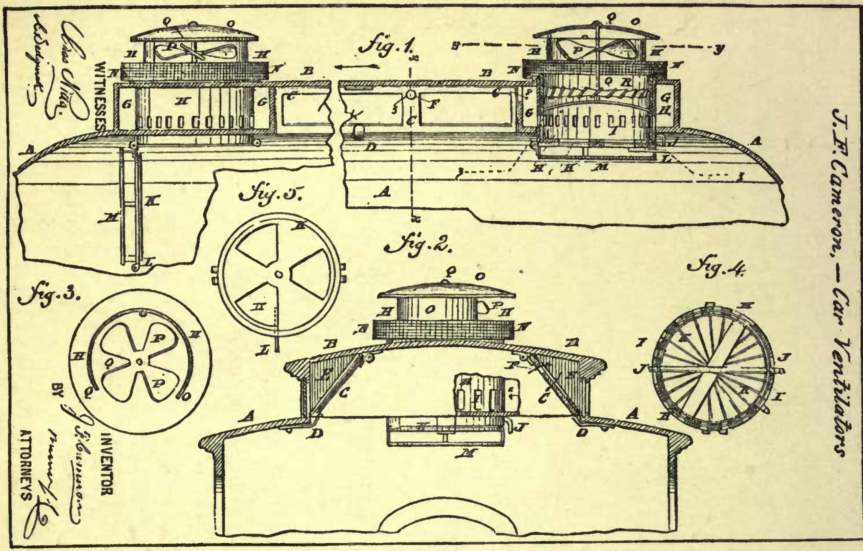
The Cameron system of ventilation for railroad cars possesses some novelty, if not merit, and will therefore be illustrated and detailed at length. Before doing so, it will be well to look into the amount of carbonic acid usually found in cars.

In the report of Fisher and Nichols the results of a large number of analyses for carbonic acid are given. The averages of these are as follows (in parts per 10,000):

Series.	Place.	Average.	Maximum.	Minimum.
1	Smoking cars..................	22.8	36.9	9.8
2	Passenger cars.................	23.2	36.7	15.9

If figures are necessary to establish the fact of the importance of ventilation, the above table will furnish them, but it is pretty generally conceded, that above all places, the ventilation in a railroad car is by far the worst of all.

If a window is opened at the top of the car, cold air pours down on the top of the head of a passenger sitting



CAR VENTILATION.

below, bringing with it the carbonic acid, which should by some means be removed, instead of being allowed to remain and pollute the air.

To ventilate a car so as not to produce a perceptible draft, has been a most difficult problem; the apparatus illustrated on Plate II. is designed to accomplish it.

Figure 1 is a side elevation, partly in section, and shown as applied to a car.

Figure 2 is a sectional end elevation of the same, taken through the line X X, Figure 1, and part being broken away.

Figure 3 is a sectional plan view of a part of the same taken through the line Y Y, Figure 1.

Figure 4 is a sectional under side view of a part of the same taken through the line Z Z, Figure 1.

Figure 5 is a plan view of the lower or circular register.

The object is to facilitate the ventilating of cars and promote convenience in controlling the ventilators.

The invention consists in a car ventilator, constructed with perforated pipes at the sides of the upward extension of the car-roof, and connected at their ends with air, chambers, in which are placed rotating turrets, having gauze covered openings at their tops above the air-chambers, annular registers in their sides within the air-chambers, and circular registers at their lower ends, below the air-chambers, and provided with wind-wheels and fan-wheels, whereby the impure air can be withdrawn and pure air forced into the car.

The wind-wheels at the tops of the turrets are covered with hoods open at one side, whereby the movement of the air caused by the forward movement of the car can be made to turn the wind-wheels in either direction.

Beneath the circular register is suspended a plate to receive and distribute the entering air.

A represents the top or roof of a car, in the middle part of which is formed a rise or upward extension, B.

In the vertical sides of the rise B are set glass plates to admit light to the car.

To the roof of the rise B, at a little distance from the vertical sides of the rise, are hinged the upper edges of partitions, C, which in the illustration given are formed of frames provided with glass plates, and are secured at their lower edges to the lower parts of the vertical sides of the rise by spring catches, D, or other suitable means, so that the partitions can be readily swung inward to allow the glass plates to be conveniently cleaned.

The partitions C thus form pipes or passages, E, into which air from the car enters through openings, F, formed in the partitions C.

The ends of the pipes, E, open into air-chambers, G, formed in the end parts of the roof of a car.

In the top and bottom of the air-chambers G are formed circular openings in which are secured rotating turrets, H. In the sides of the turrets H, within the air-chambers G, are formed openings which are covered and uncovered by the movements of bands, I, having corresponding openings, and operated by rods, J, attached to them, and passing through short slots in the sides of the said turrets, thus forming annular registers through which air can pass from the pipes or passages E into the turrets H.

The lower ends of the turrets H are closed by circular registers, K, which are opened and closed by the handles, L, attached to the movable parts of the registers.

The circular registers K are hinged at one side to lower edge of the turrets H, and are secured at the other side by eyes and pins or other suitable fastenings, so that they can be readily swung down as shown in the left hand part of Figure 1, for convenience in cleaning them and the interior of the turrets.

M are circular plates placed below and at a little distance from the circular registers K, and connected with the registers by short studs, to receive and distribute the cold air as it enters the car through the register, and prevent it from passing directly downward upon the heads of the passengers.

In the walls of the turrets H above the air-chambers G, are formed suitable openings, N, for the passage of air, and which are covered by wire gauze to exclude dust.

To the tops of the turrets H are attached hoods, O, which are open upon one side, as shown in Figures 1 and 2, and within which are placed wind-wheels, P. The wind-wheels P are attached to vertical shafts, Q, which revolve in bearings in the hoods O in the tops of the turrets H, and in cross-bars attached to the turrets, and to which, within the said turrets H, are attached fan-wheels, R, constructed to force air downward through the turrets when turned in one direction, and to draw air upward through the said turrets when turned in the opposite direction.

In using the improvement the turrets H are adjusted in such positions that the movement of the air caused by the forward movement of the car will rotate the wheel P R of the forward turret in such a direction as to force air downward through the turret, and will rotate the wheels P R of the rear turret in such a direction as will force air upward through the said turret.

In the forward turret H the annular register I is closed to prevent the air from entering the air-chamber G, and the circular register K is opened to allow the air to be forced into and discharged through the car.

In the rear turret H the circular register K is closed and the annular register I is opened, so that the action of the wheels P R will draw the impure air that enters the air-pipes E through the openings F into the turret, and force it out through the gauze-covered openings, N, in the upper part of the turret.

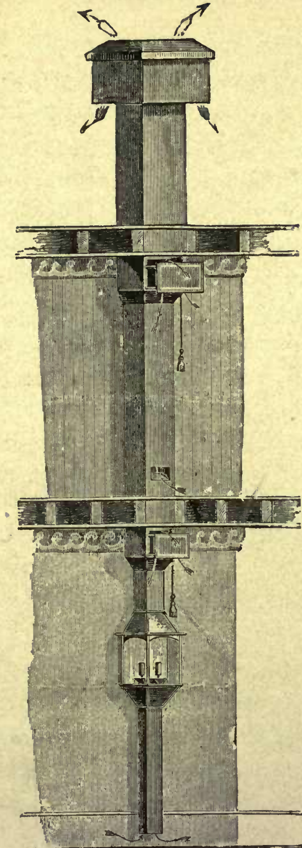


PLATE III.

The propeller fan can be actuated by a rod attached to the axis of the car, or the suction fan can be set directly in motion by such a rod by a system of cog-wheels. Then the velocity of the fan will be sufficiently great to cause a strong suction.

GOUGE'S SYSTEM OF VENTILATION.

The artificial induction of air up a vertical shaft, as represented in Plate III., is the essential motive power of "Gouge's Atmospheric Ventilator." Through this induction powerful up-moving currents of air are obtained. But little heat is required for the purpose, which may be furnished by a gas jet, kerosene lamp, or other equivalent.

Referring to Plate III., at bottom of shaft curved arrows indicate the entrance of draft to supply the ventilating flame in the lantern immediately above. Above the lantern the flue is contracted to concentrate the current or draft of air, and then expands at the orifice for induction of foul air near the ceiling, indicated by arrows, with curtain or shield in front, and valve-cord for regulating the discharge. In the second story are shown two induction orifices, a small one near the floor and a large one—with second enlargement of flue—near the ceiling.

At each of these openings an active suction is maintained at all times by the ascending current initiated in the lantern.

Above the roof is a final expansion of flue, with patent weather-cap, insuring free discharge in all conditions of the atmosphere. The successive enlarged portions of the flue correspond accurately in cross section to the total area of the draft and induction orifices beneath them, insuring equal velocity in the ascending current at all points.

Gouge's Inlet for Fresh Warm Air.

Plates IV. and V. illustrate this apparatus. Plate IV. shows a cross section, and the inlet passage is clearly shown, entering horizontally beneath the window-seat, then bending downward nearly to the floor as the course of the arrows indicate, where the air enters an enclosure containing the steam or other radiator for heating.

Rising around and between the radiating surfaces the air becomes at once warm and diffused at the top, where it is stopped and thrown downward into the room by a projecting deflector. Thus no cold air can strike and chill the interior atmosphere, nor can persons be subjected to drafts or currents of air.

Plate V. shows a front view of the air-warming enclosure, with valves, and the projecting and overhanging top,

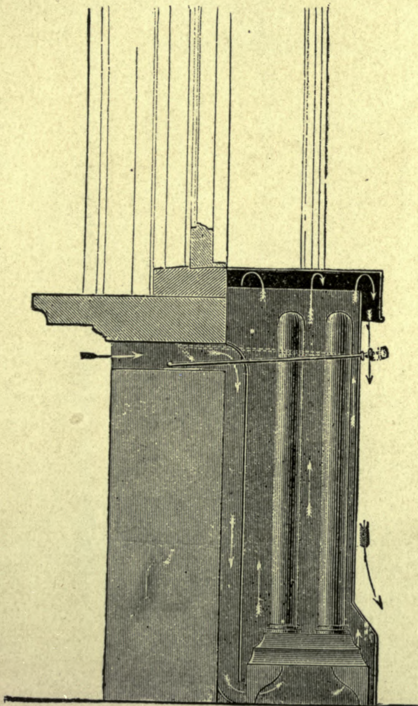


PLATE IV.

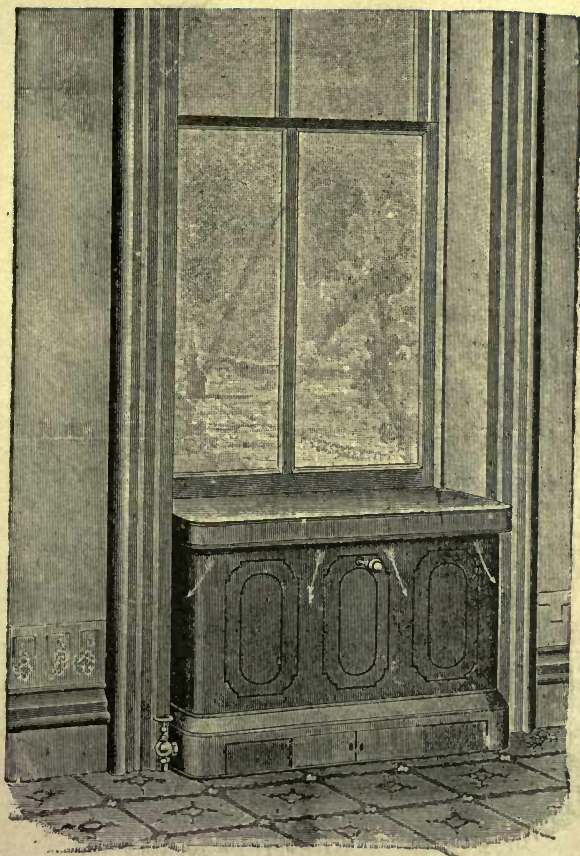


Plate V.

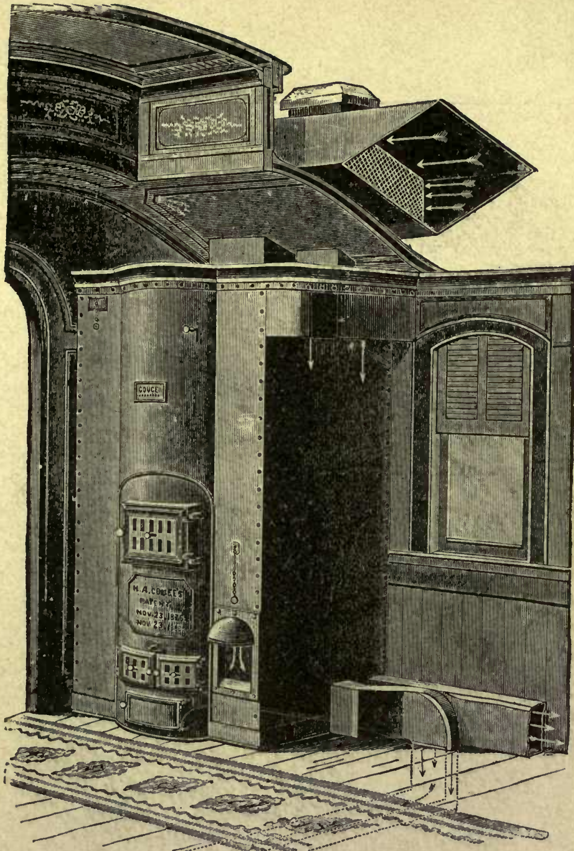


PLATE VI.

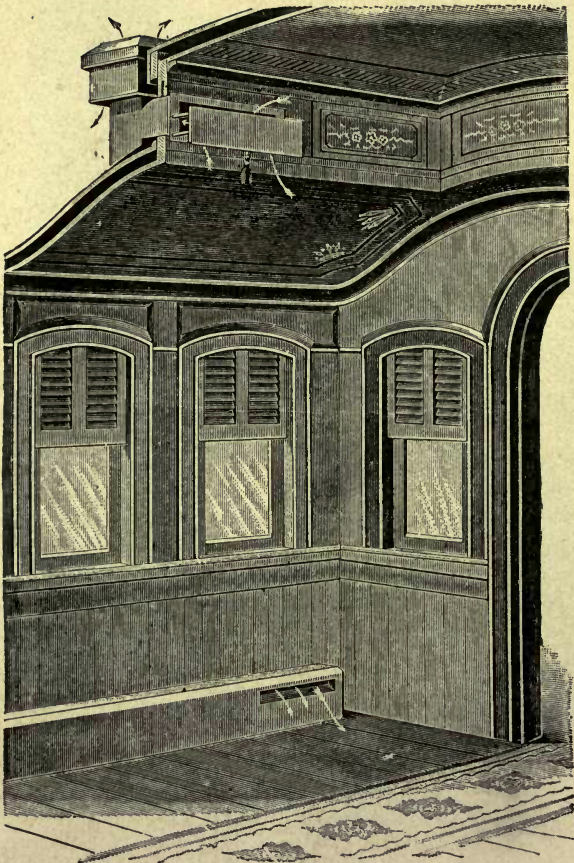


PLATE VII.

from under which the warmed air is diffused downward into the room.

Gouge's Warming and Ventilating Apparatus for Passenger Cars.

Plate VI. shows a corner of passenger car with apparatus. The inlet hood is seen above the roof, with arrows indicating the current of fresh air as forced into the heater by motion of train, alike from either direction. Near the floor are seen (1) in front of the heater an outlet, with arrows, supplying *warmed* air to the same end of the car; (2) at the side, the tubes which convey air *very much hotter* along both sides and near the feet of passengers, radiating its heat until they reach the further end, and there discharging the air into the car at the same temperature with that discharged at the fire end. But when the car is at rest and without pressure, the front outlet becomes an inlet, draws the air from the bottom of the car into the heating passages, and discharges it at the top, where the arrows beneath the projecting deflector indicate a free discharge of warm air downward. On moving, the pressure instantly closes this place of discharge, and starts again the forcible injection of warmed fresh air near the floor, at both ends.

Plate VII. shows a corner of the car at the opposite end from the heater, with termination of hot air pipe on one side, and deflecting orifices for the fresh air; also one of the exhaust pipes and weather-caps at top for the removal of vitiated air.

The Blackman Exhaust Fan.

As this fan possesses great merit it will be considered in detail. Plate VIII. illustrates the fan, and it will be seen that the wheel is constructed on an entirely new principle as applied to air. It is a disc fan, provided with a series of gain-scrolled wings, so shaped as to give an equal pressure of air on each square inch of blade (or rather bucket), thereby insuring the removal of all the air it comes in contact with. In motion it strikes the air edgewise, sculling itself through it, and, as a natural consequence, takes but a fraction of the power to run required by others, and runs noiselessly. Practically it creates a vacuum by withdrawing the foul air and allowing it to be replaced by fresh.

This wheel takes about two-horse power, and should be run at from 500 to 600 revolutions a minute. At this rate of speed, one 48-inch wheel will force out 30,000 cubic feet of air per minute. It should always be placed as near as practicable to the point where gas, steam, or offensive air is generated, to avoid drawing it through the room.

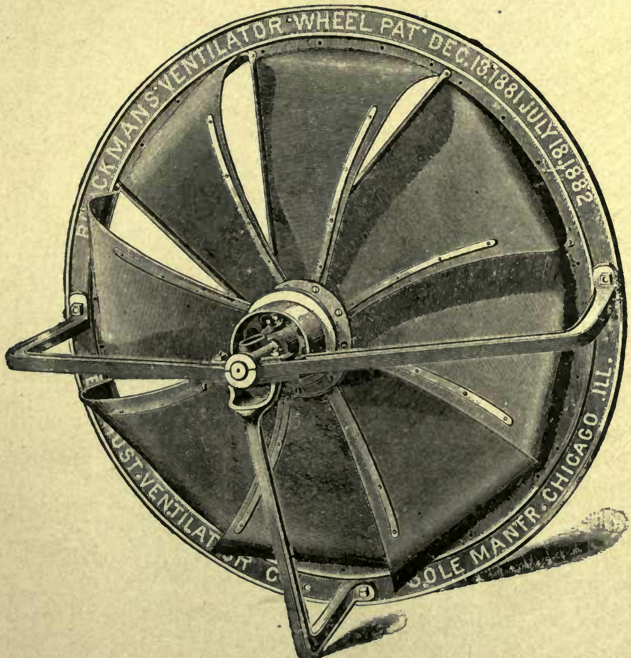

VENTILATOR WHEEL PAT. DEC. 13.1881 JULY 18.1882
SOLE MANFR. CHICAGO ILL.

PLATE VIII.

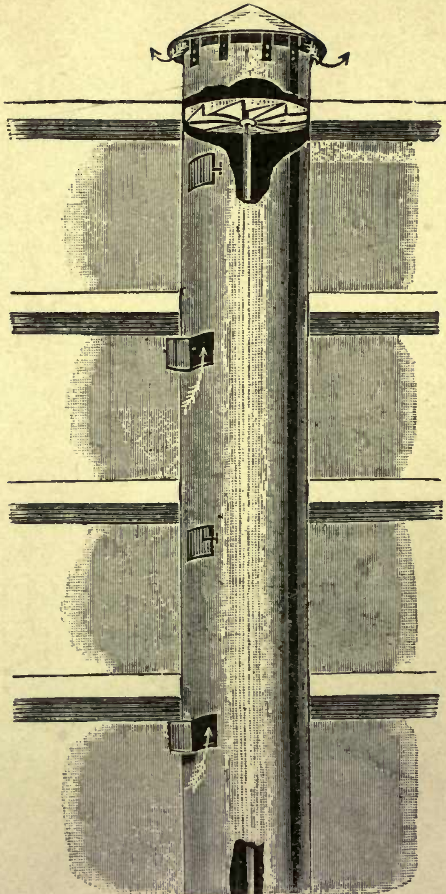


PLATE IX.

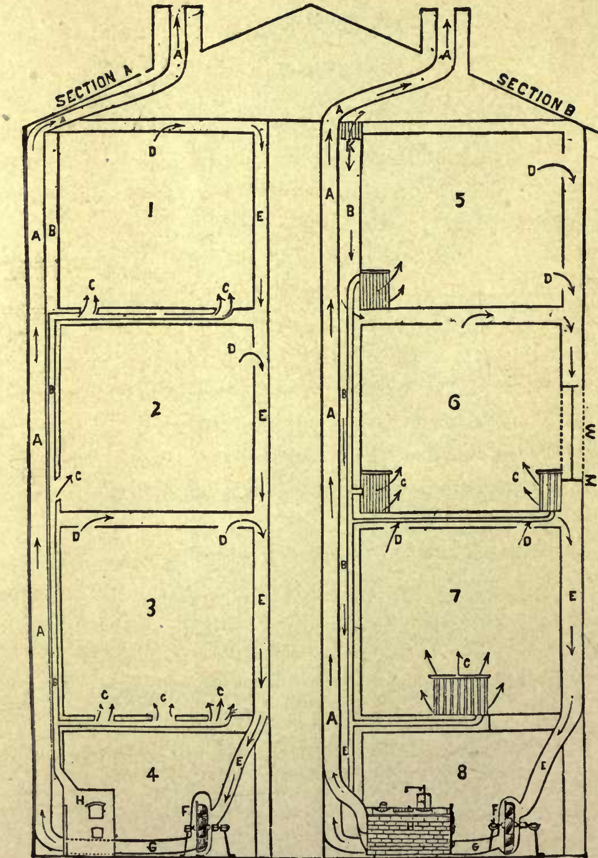


PLATE X.

The fan is especially adapted to public halls, theatres, vessels, factories, hotels, and any place where it is desirable to remove foul, hot, or objectionable air, smoke, steam, gas, etc.

Plate IX. shows how the fan can be placed to ventilate two or more floors of a building. It should be just above the highest adjustable opening, or at top of the air-shaft. By means of these adjustable openings placed near the ceiling, each floor can be ventilated at one time and by one wheel. If the rooms are far removed from air-shaft, they can be connected by air-ducts along the ceiling.

Plate X. illustrates the application of the fan for the ventilation of public buildings, apartment houses, etc., where sufficient power can be furnished in basement or cellar.

Sections A and B illustrate several methods of application.

A, in both sections, the chimney flue.

B, in section A, flue for conveying heated air to rooms.

B, in section B, fresh air flue containing also the steam-pipes.

C, registers or radiators.

D, escape registers or apertures connected with E.

E, main exhaust flue and branches for removing vitiated air.

F, the Blackman wheel, encased and revolving by the application of power.

G, pipe from wheel connecting with chimney flue A.

H, Furnace or heating apparatus, connected with flue A, and in section A furnished with cold air box.

K, in section B, screened aperture placed near the cornice for admission of pure air.

W, in section B, window illustrating use of window ventilation by tube connecting with aperture M, and carried back of radiator.

Both of the plans, as drawn, will reveal at a glance the saving of heat.

In section A the supply of pure air drawn through air-box of furnace H is delivered heated to each room. By action of exhaust wheel F, the vitiated air is drawn through apertures D and ducts E, creating sufficient vacuum to compel the steady and full action of hot air flues. This removes the objection to hot air furnaces, because whatever the direction and force of the wind, the exhaust impulse given by the wheel will regulate the force of the hot air current.

The heated impure air passing through the ducts E imparts heat to the walls, thus preventing the waste. The air current forced by fan through pipe G, which may be connected with chimney flue, furnishes sufficient draught at all times. If not needed, by a damper the current may be removed through another exit.

Summer ventilation may be secured—1st, by connecting air-box of furnace directly with flues B, the movement of the air being secured by exhaust of fan; or, 2d, by connecting fan with flues B and reversing the direction of current, the current passing through air-box, flues E joined, and entering the room through apertures D, while the exhaust pipe, being connected with flue B, draws the air through apertures C, thence through fan to chimney.

In section B, the pure air drawn through aperture K, placed at some point near or within cornice, is drawn through flue B, is heated to some extent by contact with steam-pipes, and enters the rooms back of or beneath the radiators C. The impure air rising is removed through apertures D and flue E, connected with fan F, thence carried through pipe G to flue A, or through aperture to outside air.

Room 6 illustrates one method of securing fresh air by duct opening beneath the window, which conveys the air beneath the radiator, thence into the room.

The position of aperture K, in section B, tends to furnish purer air than if placed near the ground.

Ventilation of Theatres.

The ventilation of a theatre is a most difficult problem. A theatre consists not of a single apartment permanently enclosed like other assembly rooms, nor of several distinct and permanently separated rooms like a school, but of three large open parts—auditorium, stage, and corridors—at one time separated and distinct, at another joined as one. To this difficulty must be added others of even greater force, the constant shifting of scenery, the movement among the audience, the varying number present, the influence of the lighting, and the acoustic requirements.

Our first-class theatres should be more popular resorts in summer than in winter. On the contrary, it is with extreme difficulty that a summer management can be made to pay. If the temperature within the auditorium could be maintained at a lower point than the temperature without, and at the same time fresh air be furnished in abundance without causing unpleasant draughts, the popular objections would immediately cease.

Plate XI. illustrates the application of the Blackman Exhaust Wheel for the ventilation of the Academy of Music in Chicago, Ill.

Two wheels were placed upon sides of the dome as illustrated. Two wheels were also placed in the upper gallery; one is represented at C, exhausting directly across the upper section, near the centre, thoroughly ventilating both galleries. The admission of fresh air is regulated by registers properly located.

The arrows show the direction the foul air takes in finding its exit.

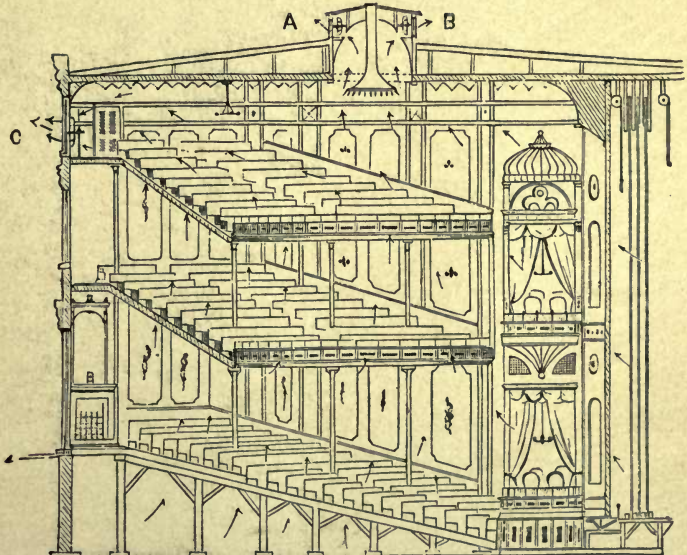


PLATE XI.

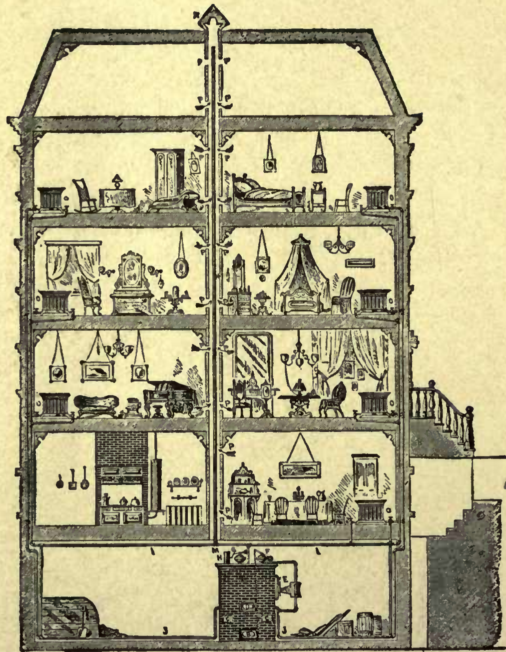


PLATE XII.

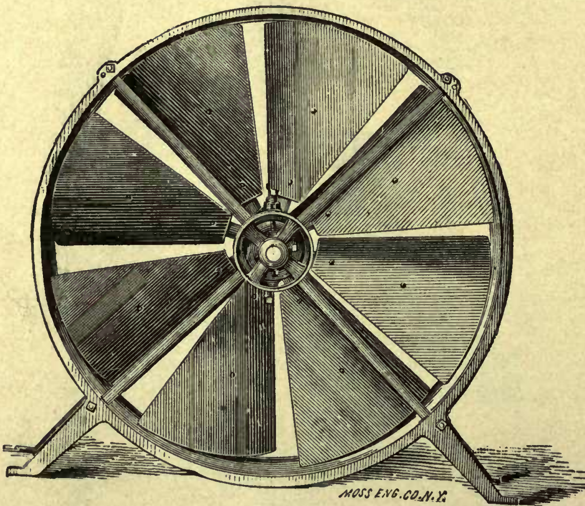


PLATE XIII.

The air in the Academy is pure, and no unpleasant draughts are produced. This certainly is a great step in advance.

Gillis and Geoghegan System of Ventilation by Means of Steam.

Plate XII. represents a section of a private dwelling. Through the middle walls of the house runs a large flue between the rooms, in which is placed a steam pipe (M) which extends to the top of flue at R; this heats the air in the flue around it, and causes an upward draft, which is very strong on account of the length and straightness of the flue.

Each room has two registers communicating with this flue, one near the floor and another near the ceiling, by which means either the lower or upper strata of air in the room can be drawn into the flue and carried off over the roof of the house.

The Johnson Fan.

The Johnson Fan is shown on Plate XIII., and has proved to be very effective as well as economical as regards power necessary to propel it.

The Wing Disk Fan.

Plate XIV. illustrates the Wing Disk Fan. The blades in this fan are curved and have an expanding pitch, which tends to increase its power. A 48-inch fan can be run by a two-horse power "Otto" gas-engine and will exhaust about 1,000,000 cubic feet of air per hour. The amount of friction is very small. The entire arc of the fan being active for the air to pass through, the current is much slower than in the usual form of fans or blowers, hence the unpleasant buzzing sound caused by the air passing rapidly through small pipes or openings is avoided.

If a rapid current is desired, it is obtained by reducing the diameter of the pipes. It can be put at either end or in the centre of a pipe, in a wall, window, or door, as it can run horizontally or perpendicularly, as circumstances may require. Plate XV. illustrates a transverse section of a building where this fan is successfully applied.

A contains the Wing Disk Fan.

B, B, ventilating pipe, enlarged, on each floor.

C, C, C, pipes for ventilating water-closets.

D, D, D, D, openings with slide-doors for ventilating each floor.

E, branch pipe to office.

Air Meter, or Anemometer.

Plate XVI. illustrates the Anemometer, used for measuring the velocity of air-currents. The principle upon which it works is similar to that applied to water or gas meters.

By the use of this delicate instrument it is possible to determine accurately the amount of air moving in or out of the place being ventilated. A pipe one foot square is the unit used in calculation. Thus a pipe eight inches square with a Wing Fan Ventilator on top, showing on the meter to have a current of 300 feet per minute, would readily be moving about 8,000 cubic feet of air per hour, the pipe being smaller than one foot square. A large pipe would be computed the same way; thus a pipe four feet square with a Wing Disk Fan exhausting or forcing air through, and showing a current of say 1,500 feet per minute, would really be moving $1{,}500 \times 16 = 24{,}000$ cubic feet of air per minute, or 1,440,000 cubic feet per hour.

The Willson Propeller, or Circulating Fan.

Plate XVII. shows a rotating or circulating fan, which is used in restaurants, kitchens, offices, etc., to produce cooling currents of air. The blades or fans are made with an expanding pitch adjustable for the work to be done, which increases their efficiency over convex blades. They are fastened in hubs with wrought-iron arms and jam-nuts, making them very strong.

The Spaulding System of Ventilation.

The object of this system of ventilation is to produce a thorough and uniform ventilation of large rooms, such as public halls, school-rooms, churches, factories, and railroad cars, as also a uniform distribution of heated air from registers or other sources of supply. To effect this, floor-registers connecting by passages with a ventilating shaft are used, such passages being so arranged that they are of uniform length between the shaft and registers, wheresoever the registers are placed, so that instead of the exit of air being entirely at the registers nearest to the shaft, there will be a uniform action at every register.

Plate XVIII., Fig. 1, shows a perspective view of a floor. Fig. 2. is a plain view, showing the passages as arranged in relation to the ventilator shaft, and Fig. 3, on Plate XIX., is a vertical section at the point of the connection between the main passage and shaft. Similar letters indicate corresponding parts.

The ventilating shaft A, Figs. 2 and 3, is placed at the

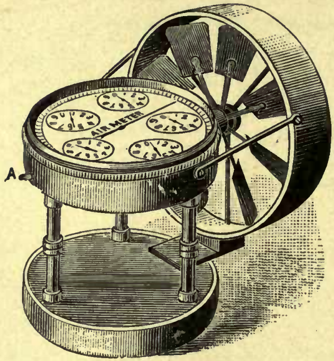


PLATE XVI.

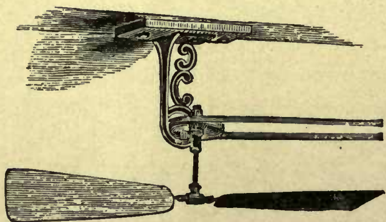


PLATE XVII.

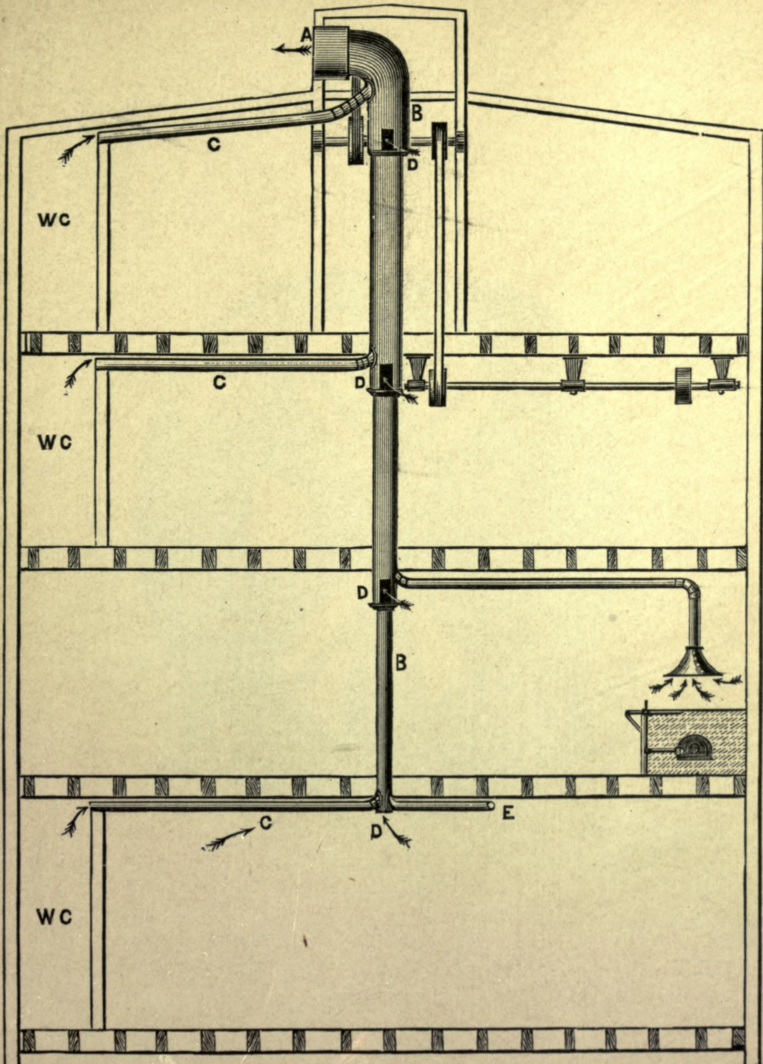


Plate XV.

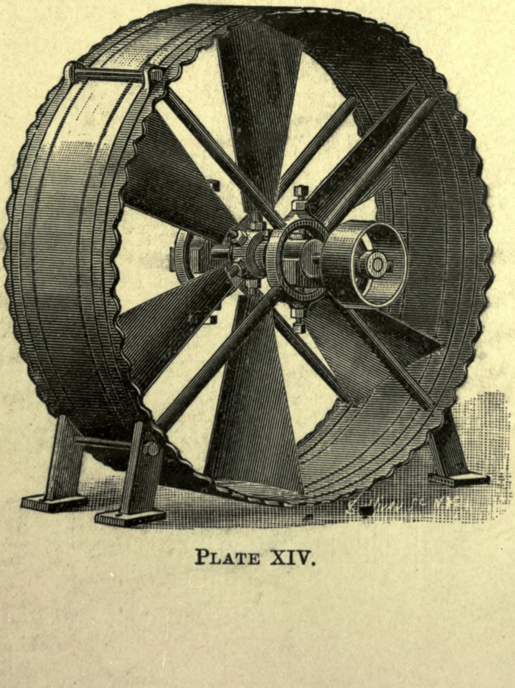


Plate XIV.

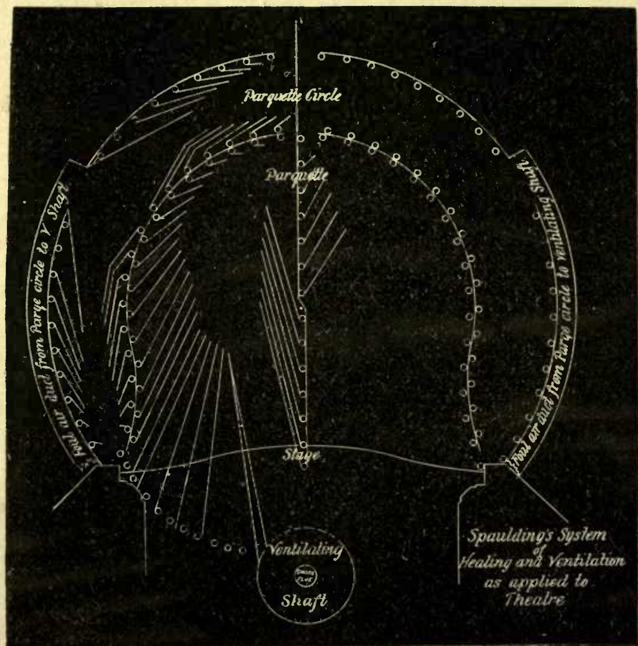

Parquette Circle
Parquette
Foul air duct from Parqe circle to V Shaft
Foul air duct from Parqe circle to ventilating Shaft
Stage
Ventilating
Shaft
Spaulding's System
of
Heating and Ventilation
as applied to
Theatre

PLATE XX.

end, side, or corner of the room, as most convenient; or in case of a long and narrow hall, or in a railroad car, it may be at the middle. Usually the shaft A will contain the smoke flue, as shown at B, so as to utilize the heat in obtaining an artificial draught.

The hot-air inlets or registers, shown at C, may also be placed as most convenient, and the ventilation outlets or registers, D, will be fitted in the floor next to the side and end walls, equidistant from each other, or otherwise, as most convenient.

Beneath the floor are the passages, *a*, from the registers, D, to shaft, A, such passages being arranged so that the air passing out is compelled to travel an equal distance, or nearly so, to the shaft.

The construction of the floor for obtaining the passages is shown in Figs. 1 and 3. *b b* are the joints of the floor-beams, on which is laid a floor, *c*. Upon this floor *c* furring strips, *d d*, are secured, and upon the strips *d* is the floor *e*, of matched boards. There is thus a space obtained between the floors *c*, *e*, which space is divided by furring strips to form the ventilating passages *a*. For the registers at the end of the room, or most distant from the shaft A, the furring strips are laid to form straight passages that run together near the shaft, as shown in Fig. 2. For the side registers the strips *d* are laid to form V-shaped passages, each of equal length. A simple method is, as shown, to utilize the passage from the corner-registers as a main for all the side inclined passages.

When the ventilating shaft A is at the centre the arrangement will be similar at each end of the room. In the case of a church, where the registers are in the aisles, the strips will be arranged accordingly, and other modifications, to conform to the shape of the room and location of the shaft, will be readily understood.

At the opening into the shaft A is a hinged flap or valve, *f*, fitted for being raised to close the opening more or less, and thus wholly or partially arrest the exit of air at all the registers at once. This method of controlling the exit of air insures uniform ventilation and heating. The cold air lying next to the floor will pass by the registers to the ventilating passages, and they being of equal length, the amount of air escaping will be equal at every register. The heated air will consequently be drawn down uniformly in every part of the room. The natural tendency of the air to escape by the registers nearest to the shaft and by the shortest passages is thus overcome, and the work of the ventilating shaft distributed equally.

Mr. Spaulding claims that the vitiated air and fetid gases exhaled by the inmates of a room, instead of rising, fall at once to the floor and are exhausted from the room by means of the converging passages of uniform length leading from each ventilating register to a ventilating

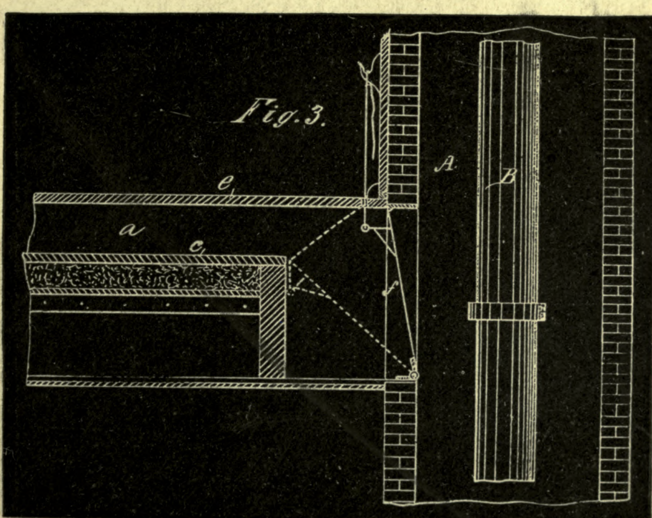
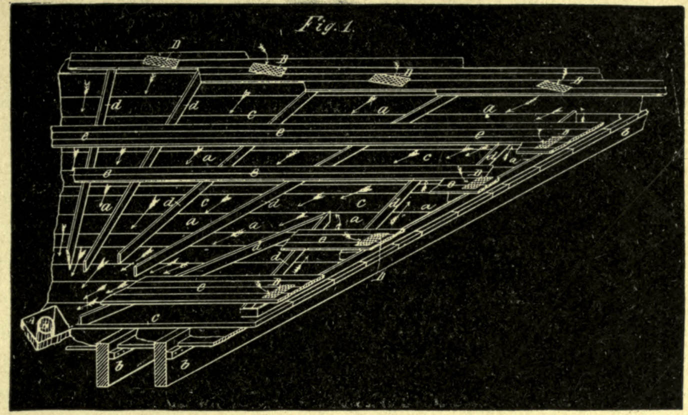


PLATE XIX.



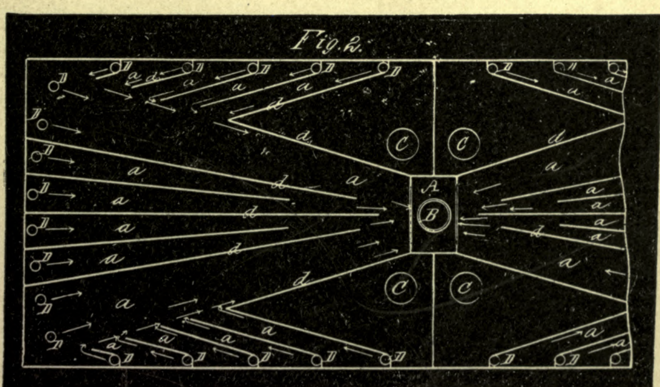


PLATE XVIII.

shaft or outlet. When the aspiration is not sufficiently strong to produce this by utilizing the heat in a chimney, an exhaust fan is used.

It is evident that if the gases which are exhaled were not immediately drawn down, but ascended, they would finally descend and would have to be inhaled again, so that an inmate would never get pure air to breathe. It is also very questionable if a sufficiently strong suction were produced at the register to induce the exhaled air to immediately fall, whether such a current would not be produced as would be objectionable.

The registers for introducing heated air would naturally have to be at the top of the room near the ceiling, for if near the floor considerable heat would be aspirated out without producing any effect. Cold air is naturally drawn out of the room, as owing to its specific gravity in this condition it would keep near the floor. An equal temperature in the room is undoubtedly obtained, as the hot air from the inlets at the ceiling is drawn down to the floor, and at the same time the floor is kept warm, which is most desirable in a sick-room or hospital. Plate XX. illustrates this system applied to the ventilation of a theatre.

The ventilating registers are located at any desired points in the floor of the parquette, and are then connected by means of equidistant passages leading to one common outlet directly in front of the stage; then from this outlet there is an air-tight duct to the ventilating shaft. The parquette circle is divided into two sections, taking the impure air out at the centre on each side, and from thence conveying it by means of ducts to the main outlet or ventilating shaft. In like manner the dress circle is arranged, and the balcony, the balcony circle, and the family circle. By this means each floor and circle becomes connected with one main outlet or ventilating shaft, and as all ventilating registers are at an equal distance from it, the same action will take place at every ventilating opening throughout the entire house. If an exhaust fan or blower be connected with the main shaft, its force will be distributed equally at each opening, and all impure air, vaporous exhalations and gases, it is claimed, will be removed in a rapid and systematic manner. Or, in cases where so desired, the action of the fan or blower may be reversed and the pure air from outside be drawn in, carried into contact with the radiators, or other heated surfaces, and then by means of the converging passages of uniform length will be distributed. For summer cooling and ventilation this system cannot be excelled. If desired, the main shaft or outlet may be located in the front portion of the building instead of at the rear. Then all ducts leading to it may be carried on the same pitch as the floors of each respective circle. Each ventilating duct terminates in four openings or ventilating registers. This method

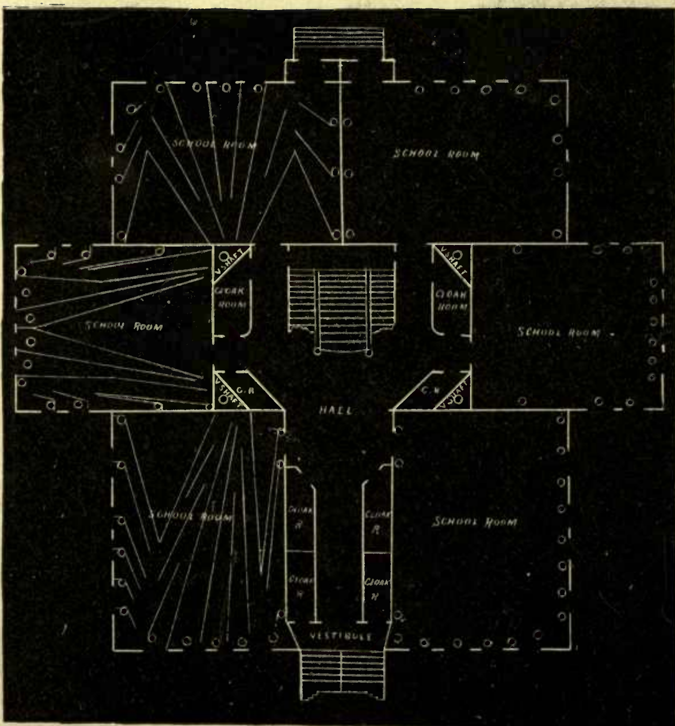

SCHOOL ROOM
SCHOOL ROOM
SCHOOL ROOM
SCHOOL ROOM
SCHOOL ROOM
SCHOOL ROOM
V. SHAFT
V. SHAFT
V. SHAFT
V. SHAFT
CLOAK ROOM
CLOAK ROOM
C.R.
C.R.
HALL
CLOAK R.
CLOAK R.
CLOAK R.
CLOAK R.
VESTIBULE

PLATE XXI.

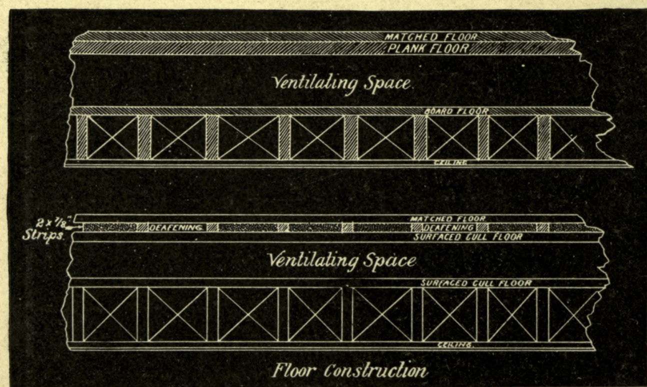

MATCHED FLOOR
PLANK FLOOR
Ventilating Space
BOARD FLOOR
CEILING
2 x 7/8"
Strips
MATCHED FLOOR
DEAFENING
DEAFENING
SURFACED CULL FLOOR
Ventilating Space
SURFACED CULL FLOOR
CEILING
Floor Construction

PLATE XXII.

gives a great amount of register surface. The equidistant passages are formed with hollow tiles, and are designed to be used in fire-proof construction.

When the rapid diffusion of gases through the air is taken into consideration, it is difficult to see how this system can be successful in a theatre. While it might possibly, with a sufficiently strong downward current, keep the air of a single floor more or less pure, when two, three or more floors are taken into consideration, as in a theatre, the atmosphere of the parquette must be anything but desirable.

Unquestionably in this case the suction should be upward and not downward.

Plate XXI. is the plan of a school-room, so constructed as to furnish a ventilating register for each pupil. The floor space is divided into four equal parts. Each section is connected with a separate ventilating shaft. In order to prevent dust and water from entering at the floor, galvanized iron pipes are fitted into these ventilating openings and carried up to any required height under the seat of each pupil. A school-room is fitted up in this manner at Capac, Mich. And this system is recommended for hospital wards. Plate XXII. shows the floor construction.

VENTILATORS.

Two ventilators will be illustrated, the Angle Ventilator and VanNoorden's Ventilator, both of which are used extensively at present.

The Angle Ventilator.

This ventilator, shown on Plate XXIII., is intended for buildings, bulk windows, and railroad cars. An upward draught is produced, while at the same time it is storm-proof.

VanNoorden's Ventilator.

This ventilator, shown on Plate XXIV., is an improvement on the Emerson Ventilator, and consists of a flue and flaring flange, with an inverted cone over the top of the flue, which is supported by means of posts, the vertex pointing downward into the flue and quite near its surface.

When the wind blows, it enters the flaring opening presented on all sides by means of the inverted cone above and the flaring flange beneath, and, blowing toward the centre of the flue, increases in force as the passage becomes narrower. The downward slope of the inverted cone presses the air close to the surface of the flue, so that by its tendency to

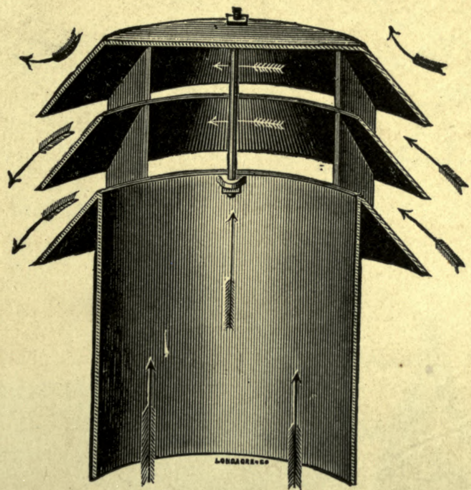


PLATE XXIII.

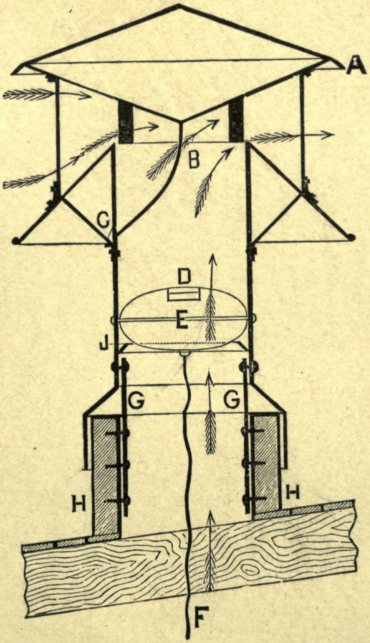


Fig. 1.

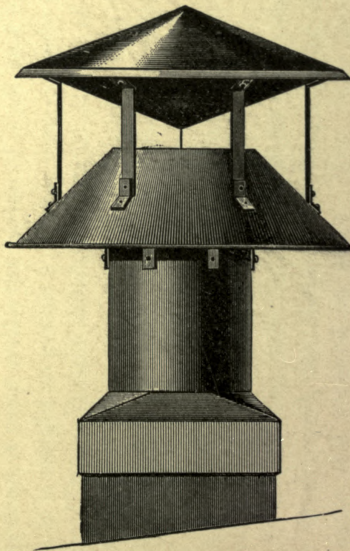


Fig. 2.

Plate XXIV.

produce a vacuum, it catches the air in the flue and draws it swiftly out, creating a strong draught.

Figs. 1 and 2, on Plate XXIV., are sectional view and elevation of ventilator complete, with base, damper, etc., ready to attach to roof.

The drip A, Fig. 1, prevents rain which strikes top cover from falling down inverted cone and dropping off at apex. From apex we run the conducting wire, B, C. Its object is to carry off water which may collect on inverted cone during a driving rain storm. It has its outlet at point C, where it runs through a hole in shaft, emptying the water outside of shaft. The hole is protected by a small cap or shield, as shown.

Should any rain drive in between top of shaft and inverted cone, it must strike the inside of shaft, and running down, it is caught in gutter J, which runs entirely around inside. Thence it runs through holes to outside of shaft. We claim that no water can run down into room below, and our experience with these ventilators confirms our claim.

E is a valve or damper, worked by means of cord, F, and weight, D, attached thereto.

H, H is a wooden curb built in roof, to which the ventilator is attached, the sheet metal flange being slipped over same and screwed to wood. The four band-iron braces, G, G, are nailed or screwed to inside of curb.

Wing Fan Ventilator.

Plate XXV. shows the Wing Fan Ventilator. The figure explains the operation of the fan, so no description is necessary. The upper bearing is kept continuously lubricated by capillary attraction, the oil-cells requiring refilling only once a year. It is, comparatively speaking, noiseless, and by its mechanical operation causes an exhaust in addition to all natural currents. When properly placed on buildings it is a protection against down draughts and storms.

This ventilator, if placed over or connected with skylights, produces good ventilation.

Eureka Ventilator.

Plate XXVI. shows the Eureka Ventilator, or, better, "Outside Wall Register," which affords a practical means of introducing fresh air in such an upward cast as to prevent draughts.

In connection with the Wing Disk Fan or Fan Ventilator, fresh air is supplied to take the place of the foul air exhausted.

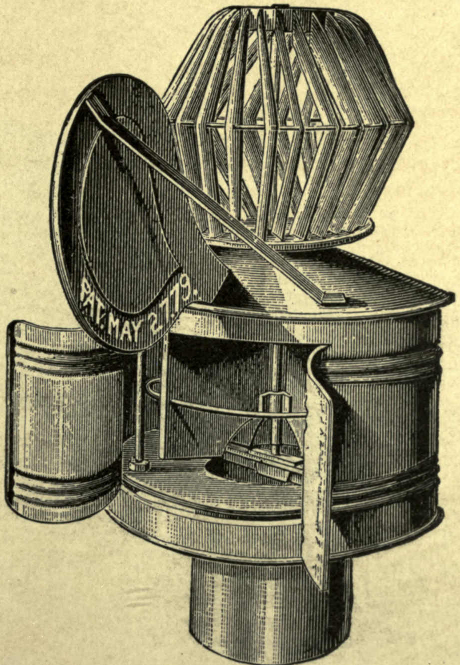


PLATE XXV.

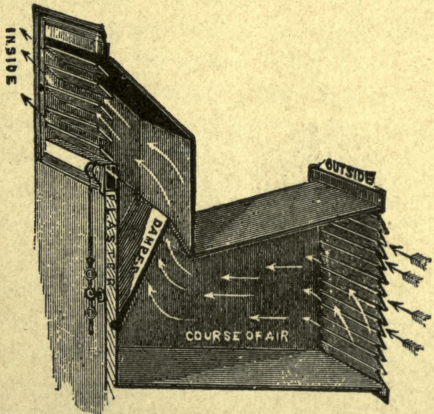


PLATE XXVI.

CONCLUSIONS.

Other systems of ventilation might be presented, but the foregoing illustrate the very best systems in use.

The Cameron system, as also the Gouge system for private dwellings, is all that can be desired ; while the application of the Blackman, Wing Disk, and Johnson Fan, where there is power in a building, certainly accomplishes the removal of the foul air in a very expeditious manner.

Theoretically it is only necessary to remove from a room just that amount of contaminated air that is given out by the breath, or that arises from some particular source, but unfortunately the foul air diffuses itself to a great extent through the atmosphere, especially that nearest the ceiling at first, so a much larger amount of air must be removed and supplied by fresh air to keep the atmosphere pure. Most systems, however, provide for the removal of more air than is actually necessary. The amount of air necessary to dilute foul air so that it can be safely breathed has misled many in their calculation of the amount necessary when the Aspirating System is adopted.

In whatever system adopted provision must of course be made for the admission of pure air with the chill taken off; this has been alluded to before, so will not be elaborated upon here.