VENTILATION AND HEAT

EDWARDS.

THE VENTILATION

of

DWELLING HOUSES

AND THE

UTILIZATION OF WASTE HEAT FROM OPEN FIRE-PLACES,

INCLUDING

Chapters on London Smoke & Fog, Modern Fire-Places, &c.

BY

FREDERICK EDWARDS, JUNIOR,

Author of "Our Domestic Fire-places," "A Treatise on Smoky Chimneys," &c.

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CONTENTS.

CHAPTER I.

CHAPTER II.

CHAPTER III.

CHAPTER IV.

CHAPTER V.

TO THE PRESS.

A new edition of this book has been often asked for and promised. At last it appears. That it has not appeared before is due to a very simple cause, the explanation of which may not be devoid of utility. When the previous edition appeared, the publisher followed the usual course and sent about sixty copies to the press for review. A few notices appeared, sometimes very short, and after a long period, showing that some writers did not care to spend much time or thought on the subject. As he had comparatively little assistance from the proprietors and editors of newspapers the author had to depend for a sale of his book on the issue of advertisements, which cost him a very considerable sum. There is, however, a necessary limit to such a state of things. It is not very satisfactory to labour in the public interest, and to pay heavily for it in time, money and disappointment. The author, therefore, delayed the issue of a new edition till the time appeared opportune. He hopes that is now the case, and will simply add that as long as the proprietors of newspapers do not take a higher sense of public duty, as long as there is not a systematic examination of books sent for review, so long will many writers on public subjects have grounds for grievous complaint. Some papers have however given him generous support, and to these he returns heartfelt thanks.

On the present occasion, instead of sending out a large number of copies for review, some of which may never be reviewed, the author decides to issue the book chiefly to those editors who have a desire to review it. Such papers as the *Times* and the *Saturday Review* must have had a host of his books and have received a large sum for advertisements, but have never given him the slightest support.

He will now say a few words about the express purpose of this book. This is to offer sound practical advice on the ventilation of dwelling houses, so far as it relates to the admission of fresh air, the withdrawal of impure air, the economical warming of dwellings, and the prevention of smoke. An exhaustive consideration of the subject of ventilation would entail an enquiry into every cause of impurity, and open up the entire subject of sewage and drainage. This the author does not attempt. The subject of Healthy Dwellings has been recently discussed by Captain Douglas Galton and Mr. Eassie. But so wide is the range of subjects that Capt. Galton, in a volume of much greater extent than the present, is compelled to refer his readers to a number of authorities on matters of practical detail.

Since the publication of the previous edition, the Tobin system of ventilation has been introduced, has been found to possess no novelty and not to solve the question of ventilation. The Moule system of earth closets has been introduced and so largely advertized that we must conclude it is extensively used in country districts and abroad, though it appears to be utterly ignored where drainage and sewage exist; the Moule system of burning chalk and coal has been laid before the world through the influence of the *Times*, but appears to be an utter failure as nothing seems now to be heard of it. Lastly the Country Parson's Grate, or more properly speaking the late Mr. Leslie's grate, has been brought forward but appears in the estimation of the manufacturers to be a practical failure, as the contrivance they sell as a Country Parson's Grate is something in which the principle of that grate is widely departed from. All these schemes have been brought into notice through the influence of the *Times*, which has never given the author of this book any support whatever, which has rejected his letters, while it has readily accepted those from people who have done little or nothing to enlighten the public on such matters. Whether such a course contributes to the pecuniary success of the paper, he will not say, but he has a very strong opinion that it is not the way in which a public duty should be performed.

However the writer has some reason to suppose that his labours have not been without public benefit, even though they may have been of little benefit to himself. In most modern grates, the principle of slow combustion, which he has been recommending for twenty-five years past, has been introduced in some form or other. In one case, that of the Coalbrookdale Company, the principle of controlled combustion has been recently adopted on the method introduced by the author seventeen years ago but though he has urgently represented to that Company that, as a matter of courtesy and honour, they should describe their grates as constructed on the principle introduced in 1863 by himself, he has utterly failed to persuade the managers to comply with a just and reasonable demand. The principle of heating a large number of houses from a single powerful furnace, which the author discussed in the previous edition of this book, has not been introduced in this country, but has been introduced in America, where his volumes have circulated.

The system of utilizing waste heat has not been used to his knowledge, but he hopes that the modified system of utilizing the waste heat which passes from the fire, up the chimney simply to the height of the ceiling, will have a better chance of becoming adopted.

The writer will now only allude to the amendments of the Building Acts, which a rather lengthened experience has shewn him to be absolutely required. He has shewn that by some of our chimneys we discharge as much as from twenty to sixty thousand cubic feet of air per hour. This air does not come entirely from our houses or we should die from inanition. It comes from our doors and windows, occasioning draughts of cold air. It comes up from the basement of a house, bringing with it smells of cooking and other impurities. It descends unused chimneys, bringing with it a smell of soot, and causing them to smoke when a fire is lighted. It comes down the short chimneys of our attics and small back rooms, built outside the main structure of a house, rendering them cold, uncomfortable, and the chimneys the most incorrigibly smoky ones, with which the builder has to deal, and it comes from even worse sources. It comes up the numerous escape pipes which communicate with our drains and sewers, bringing with it abominable contamination. If the air does not come in, in sufficient quantity to replace what passes away, what do we get? We get a close atmosphere, sluggish currents in our chimneys, and an occasional return of offensive products of combustion. All these evils are to be effectually dealt with, in additions to the Building Acts by two necessary provisions.

The first is that the discharge of air by our chimneys should in all cases be effectually checked by means of the properly constructed register door recommended by Dr. Reid, Dr. Neil Arnott and by the writer, which any person may open more or less without injuring or soiling his hands. The second addition is that a supply of fresh air from an external source should be compulsorily admitted in connection with every fire-place to replace the minimum quantity which passes away by the chimneys, so that we may not depend on a mere chance supply by doors and windows. We may admit the air warm or cold as we please. It is far better to admit the air warm than cold, either at the upper part of the grate or near the ceiling, as we get air at 100 or 110 degrees instead of from 30 to 50, and we greatly economise our coal. By these two important improvements we gain the following advantages—

1. Economy in fuel.
2. An absence of draughts.
3. An absence of closeness.
4. An absence of smoky chimneys.
5. No rush of air from the basement with smell of cooking, &c.
6. Attic floors and small rooms with short chimneys easily warmed and perfectly habitable.
7. The chance of the entrance of foul air by escape pipes reduced to a minimum.

The value of the principle contained in these propositions is so evident and may be so easily ascertained and corroborated by experienced men that the value attaching to them should undoubtedly receive as early as possible the sanction of the Legislature. The matter is not one that ought to be left to individual caprice, because we have the inexperience of architects, the inexperience of the public, and the inexperience or selfishness of builders to take into consideration. But for the public apathy of the principle would have become established very many years ago. It was introduced by M. Gauger in France in 1715, by Dr. Désaguliers in this country at the same period, by the Marquis de Chabannes early in the present century, and in more modern days by Mr. Cundy the elder, an architect, by Mr. William Pierce, of Jermyn Street, and has been used by Mr. Robson, for the London School Board, by Mr. Alfred Waterhouse, by the present writer, and by many others, and is undoubtedly the principle which we must adopt if we wish to have our houses economically warmed and ventilated with a freedom from the entrance of smoke.

Copies of the author's publications will be sent to those editors who desire to receive them, on application being made either to Messrs. Longmans', or to himself.

49, Great Marlborough Street,

December 24th, 1880.

ON VENTILATION AND HEAT.

CHAPTER I.

A SHORT ACCOUNT OF THOSE WHO HAVE INTRODUCED ARRANGEMENTS FOR VENTILATING PUBLIC BUILDINGS, &c., AND OF THE SYSTEMS ADOPTED.

A DESCRIPTION of some simple appliances for ventilation, and certain suggestions for the utilization of waste heat in dwelling-houses, may perhaps usefully be preceded by a short account of those who brought the subject of ventilation into prominent notice, and operated with success in its application chiefly to public buildings. Persons of general information are necessarily aware that it is only within about thirty years that the advisability of providing special facilities for changing the air of ordinary apartments has been extensively recognized, but it would be erroneous to infer that indifference to the subject at previous periods is to be attributed solely to a deficiency of knowledge with respect to the conditions necessary for maintaining a healthy existence. It is a fact worthy of remark, that the necessity for ventilation has increased with the demand for it. Fifty years ago or more, when the British fire-place was large and open, the volume of air which passed up the chimney, supplied abundantly from doors and windows, insured a constant renewal in the apartment, though under uncomfortable conditions. Our predecessors, therefore, were probably more often familiar with an excess of ventilation than with an absence of it, and they frequently encountered the evil to which they were accustomed by the use of large screens in winter, which answered the double purpose of protecting the body from cold currents of air, and of arresting and radiating much heat from the fire. It is not therefore surprising that a recognition of the practical necessity for ventilation appliances in dwellings has followed the introduction of contracted fire-places, better fitting doors and windows, and the use of coal gas for lighting, and that previous requirements were confined in a great measure to public buildings such as the Houses of Parliament, theatres, hospitals, &c., where the occasional or constant presence of many persons presented exceptional conditions.

Special arrangements for ventilation appear to have been first found necessary in mines;* certain methods of moving or renewing air having been described by Agricola in his 'De Re Metallica,' several hundred years since, but it was at a much later date that any attempt was made to ventilate a public building. This was at the House of Commons by Sir Christopher Wren. The great architect's arrangements were, as might be supposed, of a very simple nature. He had four large holes made in the ceiling of the chamber, one at each corner, and over each hole he placed a wooden trunk or channel which passed into the room above. As soon as the house became warm

* Bernan. 'History and Art of Warming and Ventilating Houses and Buildings,' 1845, Vol. II. p. 39. These volumes, it appears, were published under a *nom de plume*, and written by Mr. Robert Meikleham, C.E. The writer must express his acknowledgments to these volumes for the intimation they have afforded him of several sources of information with respect to the historical part of the subject, which would perhaps otherwise have escaped his notice.

by the presence of many persons, an interchange took place between the air in the house and that above the ceiling, the warm air of the house rising through the channels and cool air descending. The contrivance amounted practically to nothing more than increasing to a certain extent the area of the house, but it perhaps answered fairly the requirements of a time that was not as familiar as the present with attentive legislators and prolonged debates. A certain amount of inconvenience, however, was found to result from the descent of cold air at the holes in the ceiling on the heads of those situated beneath whenever the house became hot by the presence of many persons, which evil in 1723, Dr. Desaguliers, the distinguished philosopher and mechanician, undertook to remove. Dr. Desaguliers appears to have been the first to make the subject of ventilating buildings a special study, and to have been led to it by a circumstance resulting from his French origin. Brought as a child to this country by protestant parents, after the revocation of the edict of Nantes, he became in mature years vicar of Edgware, chaplain to the Prince of Wales, and, what is more interesting to the student in physical science, the author of the elaborate and valuable 'Course of Experimental Philosophy,' and of many contributions to the Transactions of the Royal Society. In the course of his investigations he became familiar with a book called 'La Mécanique du feu,' by M. Gauger, in which very ingenious contrivances were described for improving the comfort and salubrity of apartments warmed by wood fires. Of this book Dr. Desaguliers published a translation in 1715,* which, he says, led

* 'Fires Improved, or a New Method of Building Chimnies, so as to prevent their smoking, in which a small fire shall warm a room much better than a large one made in the common way. And the method of altering such chimnies as are already built, so that they shall perform the same effects. By Monsieur Gauger; made English from the French original by J. T. Desaguliers, LL.D. and F.R.S.' A second edition,

him "to make experiments on the purifying of air, conveying it from one place to another, and changing it for the advantage of those that breathe it in close places to the detriment of their health." At the House of Commons he endeavoured to perfect Sir Christopher Wren's arrangements by means of fires kept burning over the ceiling of the chamber, which fires were designed to be supplied with air drawn from the body of the house through the air channels in the ceiling, and thus effectually withdraw the air which had come heated and contaminated, the essential principle of which was that fires should be supplied with air from an external source, and that warmed fresh air should be allowed to circulate in the apartment. This important principle will be alluded to in subsequent pages. The reverend doctor did not adopt the simple and effective device of supplying his fires and the chimney draught with air drawn only from the house. What he did was to carry tubes from Sir Christopher Wren's air holes and channels into the chimneys, and to make the tubes pass in contact with the fires, so that an ascending current might be facilitated by the rarefaction of the air within the tubes. Dr. Desaguliers records that when the fires were lighted early in the day, an ascending current was maintained in the tubes and chimneys, and the old inconvenience was removed. He had, however, to do with a certain personage who was not so interested as himself in the success of his scheme, and contrived, by a philosophy of her own, practically to defeat it. Mrs. Smith, the housekeeper, being disturbed in her possession of the rooms by the new-fangled contrivance, offered a passive resistance. She neglected to light the fires till the house became crowded and hot. There was

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'with an appendix containing several further improvements made by the translator and others,' was published in 1736. The book is curious, from its being apparently the earliest publication relating to fire-places.

not time, therefore, for the ventilating tubes to be heated so as to become practically useful, and the results was that descending currents of cold air at the air holes renewed the old inconvenience, to the apparent discredit of the doctor. A little after this, Dr. Desaguliers succeeded in giving the House of Lords relief from cold draughts of air, and a committee being appointed in the House of Commons to consider the question of ventilation led to his being commissioned to make some contrivance for drawing the hot and foul air from the house by the agency of a person who would be more amenable to his control than the slyly-obstructive Mrs. Smith. The doctor accordingly removed his air tubes. He constructed instead a centrifugal or blowing-wheel, and provided a man to turn it, who was called "the ventilator," and who was "to suck out the foul air, or throw in fresh, or to do both at once, according as the Speaker was pleased to command, whose orders 'the ventilator' waited to receive every day of the Session." The blowing-wheel, shown in figs. 1 and 2, consisted of a cylinder with fans radiating from it, both enclosed in a drum seven feet in diameter, which was provided with two air channels, one to convey air propelled by the fans, the other to allow air to enter the drum. The fans were set in motion by the "ventilator" turning a handle, who could propel air into the house or expel air from it, according as he placed the one channel or the other in communication with the house. The blowing-wheel was powerful, for Dr. Desaguliers testified that it could supply air through the aperture seven inches in diameter at the rate of a mile a minute. Some means, therefore, must have been necessary to prevent the old inconvenience of cold draughts, but what those means were is not stated, nor is it clear in what way the machine was made to inject and expel air simultaneously. The old air holes and channels of Sir Christopher Wren were in some way utilized in connection with the blowing-wheel, and so successful was the contrivance considered, that it remained in use, with some alteration, for a subsequent period of eighty years. In 1734, Dr. Desaguliers exhibited a model of it to the Royal Society, and, the attention of the lords of the Admiralty being called to the subject, they witnessed the operation of the wheel over the House of Commons, the result being an order for it to be tried on board a large vessel at Woolwich. At that time the only special means used for removing the air in the confined quarters of vessels was the wind-sail, which consisted simply of a common sail rolled into a tube, and so placed that it could take advantage of a passing breeze, the fresh air sweeping through it from the upper end to the decks below. The wind-sail could never be more than a very rough contrivance in certain states of the weather. In calms, when ventilation was very necessary, it was useless ; and in stormy weather, when the hatches had to be closed and ventilation was most required, it was unbearable, the result being that the amount of sickness, disease and death, always attendant on a long voyage, in consequence of men being in the frequent habit of breathing a very foul atmosphere, was truly appalling, and occasioned great complaints. Permission was given to Dr. Desaguliers to show how he could improve on the wind-sail by his mechanical means, but it is evident from the doctor's interesting narrative that he was not much more fortunate in dealing with a Board of Admiralty than inventors of more recent times. He succeeded in applying his blowing-wheel, and he put down his pipes for conveying fresh air and withdrawing the foul. He showed, to the satisfaction of all present at his experiments, that on charging a room with smoke, he could rapidly expel the smoke, and that his machine would therefore be efficacious in replacing foul air by fresh; but he had a warning of the reception his suggestion was likely to meet with, for an old man, who had been with the vessel to Jamaica, grumbled that though it was the best thing he had ever seen, he was sure it would never be suffered to be put in practice. The old man was right. Dr. Desaguliers soon found that he had to do with some who had no desire to be convinced. Sir Jacob Ackworth, surveyor to the navy, had attended their lordships to witness the action of the blowing-wheel at the House of Commons, and he was requested to report on the experiments at Woolwich. He began by throwing difficulties in the way, and he avoided witnessing an experiment when the doctor was present. When he did attend, he chose a time when plenty of wind was blowing. He had his favourite wind-sails hoisted, and "Now," said he, to the doctor's representative, "I would have you work the engine and see whether that will throw out so much air as our wind-sails you see do." The man protested with astonishment, but in vain. He pointed out that the blowing wheel was to be used when the wind-sails were useless. But Sir Jacob knew with whom he had to deal, and he stuck to his prejudices. He would not stay any longer. He told Dr. Desaguliers afterwards that "he was sorry it succeeded no better, but he thought it might be a very pretty thing in a house;" so that the worthy doctor exclaimed in indignation: "Now let every impartial person judge whether I have not reason to complain, for not one of the lords of the Admiralty, who talked of having many of these machines for the preservation of the health of the persons then going to Jamaica, so much as saw the experiment made. Nay, Sir Jacob himself, who condemned the thing, did not once see it, but made his report from another reporter whom he left behind to give an account. Thus ended my scheme, which I hoped would have been of great benefit to the public." The worldly prosperity of

Dr. Desaguliers appears not to have been assisted by his devotion to science, for he is stated to have died in great distress. The following lines to his memory have been quoted :*

> "How poor neglected Desaguliers fell;
> How he who taught two gracious kings to view
> All Boyle ennobled and all Bacon knew,
> Died in a cell without a friend to save,
> Without a guinea and without a grave."

Contemporaneous with Dr. Desaguliers was another reverend and frequent contributor to the 'Philosophical Transactions of the Royal Society,' and who was equally conspicuous in advocating the use of ventilators for close places. The Reverend Stephen Hales, D.D. and F.R.S., perpetual curate of Teddington and rector of Faringdon, took much interest in matters relating to the moral and physical well-being of his countrymen. "Could I but see," said the doctor, "the immoderate use of spirituous liquors less general, and the benefits of ventilators more generally known and experienced, I might then hope to see mankind better and happier." In 1758, Dr. Hales published a treatise on ventilators,† in which he dwelt

* Ency. Britt., Art. Desaguliers. The lines quoted from the poet Cawthorn. The facts described are taken from the 'Fires Improved,' 1736, and from the 'Course of Experimental Philosophy,' Vol. II., pp. 556-568. Second edition. 1745.

† 'A Treatise on Ventilators, wherein an account is given of the happy effects of many trials that have been made of them; which has occasioned their being received with general approbation and applause, on account of their utility in many ways to the great benefit of mankind, viz. : in refreshing the noxious air of ships, hospitals and mines, to the better preservation of the health and lives of multitudes; in preserving the timbers of ships much the longer from decaying; in easily sweetening cask water, and curing the ill taste of milk from some food of cows; in new methods of distilling plenty of good water at sea; in refreshing the air, and keeping up and regulating the warmth of melon and cucumber-frames and hot green-houses. By Stephen Hales, D.D., Clerk of the Closet to her Royal Highness the Princess of Wales, F.R.S. and Member of the Royal Academies of Sciences at Paris and Bolognia. London, 1758.'

very fully on their utility, and gave complete details of the manner of making and working them, with diagrams of those he had hitherto applied. Dr. Hales, like Dr. Desaguliers, proposed to ventilate a chamber by propelling fresh air into it, or by reversing the process and expelling air, but he was led to the adoption of different mechanical means by observing the action of bellows used for organ performances or at the smith's forge. A simple illustration of his contrivance is given in fig. 3, which represents a large oblong box closed on all sides, with the exception of certain openings protected by valves, two of which opened so as to allow air to enter the box, and two of which opened as to allow air to pass out. Within the box was a division board called the midriff, suspended at one end by leather hinges, and capable of being moved up and down like a flap by means of a handle which passed through the top of the box. A glance at the figure and accompanying explanation will suffice to show that with every movement of the division board or midriff, air both entered the box and was expelled from it, the valves provided at the apertures preventing anyretrogade motion. When the midriff was raised, air entered the box at a lower valve, and air was expelled at an upper one. When the midriff was depressed, air entered the box at an upper valve, and air was expelled at a lower one. To bring the contrivance into practical use, it was necessary that it should be fixed in a position as nearly contiguous as convenient to the place required to be ventilated. The valves opening outwards were then placed in communication with the chamber by means of an air channel of suitable dimensions, and the other valves were left exposed to the external air. With every movement of the handle a considerable quantity of fresh air was thus forced into the room, and if it was preferred to reverse the process and expel air from the room into the external atmosphere, the air channel was made to communicate with the valves opening inwards, and those opening outwards governed the means of exit for the foul air. The valves consisted of wooden flaps suspended by leathern hinges, and readily opened or closed by the pressure of the air. Dr. Hales considered his contrivance to be most simple, and in principle analogous to the means used by nature for propelling air into the lungs of men, viz. by the easy rising and falling of the midriff. He suggested the title of "the lungs of a ship" when recommending his bellows for sailing purposes, and ingeniously argued:

"It ought in reason to convince us of the great importance that plenty of fresh air is to our welfare, when we consider that the great Author of nature has allotted near one half of the trunk of our body for the office of respiration or breathing only; can any one, therefore, be so unreasonable as to grudge the little space these will take up in a ship, or the small labour they will require to furnish great plenty of fresh air? Were an animal to be formed of the size of a large ship, we are well assured, by what we see in other animals, that there would be ample provision made to furnish that animal with a constant supply of fresh air by means of large lungs, which are formed to inspire and breathe out air in the same manner as these ventilators do. Can it, therefore, be an unreasonable or an improper proposal to attempt to furnish ships, gaols, hospitals, &c., in the same manner with the wholesome breath of life, in exchange for the noxious air of confined places, which is rendered unwholesome by the great quantity of rancid vapours which are incessantly exhaling from human bodies, and are the occasion of much sickness and of the death of multitudes."

The learned doctor was familiar with a sad array of facts to give strength to his persistent endeavours. The "Ship-fever," the "Hospital-fever" and the "Gaol-fever," all similar in nature, because proceeding from common causes, recall even worse sanitary conditions than those with which we are now familiar; but, in contriving his remedy, it was more easy for Dr. Hales to draw an ingenious analogy from the subtle processes of nature, than to imitate those processes with success. He might propel fresh air into a place, and he might reverse the process with some little trouble and expel foul air. He might also, by a double set of bellows and air channels, as shown in fig. 4, carry on the two processes together. Such a complicated arrangement, however, as the last was unnecessary. Fresh air propelled into a room would force air to leave it if proper openings were provided, and air expelled from a room would, of course, allow an equivalent supply of fresh air to enter. Practically the ventilating bellows were used sometimes for one purpose and sometimes for another. They were often very large, measuring as much as ten feet long, and were sometimes fixed in the upper part of a building, with a main channel and with branches leading to different parts. To each branch a shutter was provided, so that certain chambers might be ventilated at one time and certain others at another, the pump not being sufficiently large to do the whole simultaneously. Dr. Hales first applied the machine to the county hospital and county goal at Winchester ; then to the Savoy prison, where a great decrease in the annual number of deaths was the consequence; and subsequently to the goal at Newgate, and many other public buildings both in England and abroad.

A constant objection made to the ventilating bellows was the necessity for frequent manual labor to work them, which obliged the doctor to plead incessantly the cause of activity and health against stagnation and disease. He sought to stimulate the men who worked the bellows by the sight of a little twirling windmill, or the sound of a tinkling bell, occasioned by the rapid passage of the air, that they might thereby be amused, and have some evidence of their labor not being in vain. At Newgate, Dr. Hales constructed a windmill on the roof, which was for use instead of amusement, as it frequently sufficed to keep his bellows in motion without manual assistance. In certain vessels on long voyages, there was no objection made on the point of labor; a letter from Captain Ellis, F.R.S., published in the Royal Society's 'Transactions,'* stating that "the bellows were far from inconvenient, and afforded good exercise for the slaves, and a means of preserving the cargo and lives." The treatise on ventilators was translated into French, and it has been stated that in France the advantages were so fully established, that the ventilators were immediately adopted by the French Government, and applied with success in a far greater number of cases than the inventor had ever contemplated.†

Between Dr. Hales and Dr. Desaguliers there was some little rivalry. Dr. Hales, in his early announcements, made no mention of his contemporary's contrivance, though, as Dr. Desaguliers reminded him, he had a little wheel by him at his house at Teddington. Dr. Desaguliers praised the ventilating bellows of his reverend friend, but slyly hinted at a similar contrivance having been in use in Sweden, and made known to Dr. Hales by a visitor to the Royal Society. Dr. Hales retorted, in his complete account of his ventilators published in 1758, by alluding to the blowing-wheel over the House of Commons, only to express a preference for his own arrangement, and slyly hinted that a similar device to that of Dr. Desaguliers had been described by Agricola. Dr. Hales even then avoided mentioning his contemporary's name, but he became punished for his want of due consideration

* 'Philosophical Transactions.' Vol. XLVII. 1750-51.

† In the celebrated 'Encyclopédie' of 1765, Dr. Hales is thus spoken of: "Le célébre M. Hales, un des grands physiciens de ce siècle et l'un des mieux intentionnés pour le bien public, a inventé un ventilateur d'un usage presque universel. M. Demours, médecin de Paris en a traduit en Français la description. Paris in-12, 1744." Article, *Ventilation*.

or candor by another rival for public distinction, who fought his way with no little pugnacity.

Mr. Samuel Sutton, brewer, being informed in the year 1739 that "the sailors on board the fleet at Spithead were so dangerously ill for want of fresh air that they were put ashore to recover their health, and the ships to which they belonged stunk to such a degree that they infected one another," thought himself obliged, as he states, "in compassion to his fellow creatures, to do all that was possible for their relief in such unhappy circumstances." This brought him in contact with a Board of Admiralty, and so curious and entertaining is the account of his experience of naval authorities that the commissioners of patents were advised a few years since to reprint it.*

Mr. Sutton was led to adopt an entirely different system to that of the reverend doctors by observing that when fires were burning in rooms communicating with each other, air would often rush violently down one while it ascended the others. He reflected that if air descended a chimney to support combustion and maintain chimney draught in other chimneys, a common fire might be turned to account to withdraw the air of a place that required ventilation. In fact he proposed to utilize systematically, with respect to ships, the power which has for centuries ventilated our dwellings in cold seasons, viz., the simple use of an open fire. Mr. Sutton did not venture to ask that a fire should be kept burning in a ship for the sole purpose of ventilation, but he ingeniously made use of the ship's coppers. He shut off the ordinary supply of air to the fire and led tubes from the ship's hold and other

* 'An historical account of a new method for extracting the foul air out of ships and with the description and draught of the machines by which it is performed: in two letters to a friend. By Samuel Sutton, the inventor. The second edition. To which are annexed two relations given thereof to the Royal Society by Dr. Mead and Dr. Watson.' London, 1749.

places he desired to ventilate to the ash-pit below the fire. As soon as a fire was lighted, a constant supply of air through the air tubes supported combustion or escaped by the chimney, ensuring a constant entrance of fresh air through the port-holes into the chambers with which the tubes communicated, however calm might be the external atmosphere. Mr. Sutton obtained a patent for his arrangement, being naturally anxious to benefit himself as well as the navy, and, provided with a letter of introduction, he paid a visit to Sir Jacob Ackworth, the obstinate old knight who had proved so obstructive to Dr. Desaguliers. Sir Jacob made an appointment for Mr. Sutton to call on him on a future day at seven in the morning, when, being engaged, he allowed him to wait about till the evening. As he did not succeed in exhausting Mr. Sutton's patience he saw him, and after a little interrogation, he told him that no experiment should be made if he could hinder it. Mr. Sutton, however, was not the man to be easily thwarted. He succeeded in obtaining an order from the Admiralty for his contrivance to be tested, and, after some obstacles, his pipes were fitted to a man of war at Woolwich. Before the work was completed, however, a messenger came from the king's yard to remove the pipes; and, as Mr. Sutton foresaw nothing but continued obstruction from government officers, he determined to seek assistance in a different quarter. He obtained an interview with Dr. Mead, F.R.S. and physician to His Majesty, which led to another interview, when Mr. Folkes, the president of the Royal Society, was present. Both these gentlemen approved of the scheme, and interested themselves in its behalf. Dr. Mead immediately went to the lords of the Admiralty and represented in a strong manner the advantages of Mr. Sutton's system, whereupon they were pleased to order that it should be tried on board any of His Majesty's ships in the river. Mr. Sutton chose a hulk at Deptford, and superintended the erection of his pipes. At last, in September, 1741, a day was appointed for an official experiment. The lords of the Admiralty, the commissioners of the navy, Dr. Mead, Mr. Folkes the president, and several other members of the Royal Society were present, when Sir Jacob Ackworth addressing them said: "I am sorry that you are come to see the trial of such a foolish experiment that I tried myself yesterday and it would not shake a candle;" to which Mr. Sutton replied, that, "It would be in good humor to-day, and the end of every one of the pipes would blow out a candle." Mr. Sutton states that he was as good as his word, notwithstanding some attempt to thwart him, and that all the lords and gentlemen expressed their approbation. The result appeared promising, for Mr. Sutton was requested to go to Portsmouth to apply his plan to a vessel intended to proceed to the coast of Guinea, and was provided with a recommendation that he should meet with no obstruction or discouragement from anybody that might think themselves wiser.*

Mr. Sutton executed his commission. The vessel was

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* The following sensible letter from Sir Charles Wager, Secretary to the Admiralty, conveyed these instructions:—

"Admiralty Office, 24 Nov., 1741.

"Sir,—I send this by Mr. Sutton, who has found out a way to draw bad air out of close places, particularly from wells of ships, which you know are sometimes so bad as to stifle men before they can be drawn up, as happened on board the 'Lynn' while I was at Helvoet-Sluys, one man being killed by it and two narrowly escaped. This contrivance is approved by much wiser men than I am in such things, and therefore I desire you would let Mr. Sutton have all the encouragement and assistance you can give him. I take Mr. Alleyn, your builder, to be an ingenious man; if you recommend Mr. Sutton to his care, he will see that he meets with no obstruction or discouragement from anybody that may think themselves wiser. There is an order from this Board to the Navy, from whom you will have it, to have the 'Norwich,' who is to go to the coast of Guinea, to be fitted according to Mr. Sutton's scheme, which will be a very good experiment. I am, Sir,

"Your humble servant,

"Charles Wager."

despatched, and, as he had spent a large amount of time, and been at considerable expense with his project, and as he in all probability resembled the vast majority of men with respect to a readily exchangeable commodity, he was anxious to obtain remuneration. But, like other inventors, he had to find that governmental bodies have generally little sympathy except with their friends and dependents. Time after time he petitioned the Admiralty without even receiving an answer to his applications, until, after great delay, the Norwich returned. The captain gave an equivocal report on Mr. Sutton's ventilating pipes, and insinuated that there had been danger of their taking fire. In the end, their lordships drew up an order on Mr. Treasurer, in which they stated that it appeared from the captain's report the invention did not in all respects come up to the expectation, and that the use thereof was dangerous and liable to accidents by fire, yet as the said Mr. Sutton had employed a great deal of pains and time about the said invention for the benefit of the navy and had encouragement from their lordships so to do; and their lordships *being desirous to give encouragement to persons who might turn their thoughts to any inventions that might tend to the advantage of the navy*, did thereby desire and direct a bill of £100 to be made out to the said Samuel Sutton as a reward for the loss of time and expenses he had been at about the said invention.

This was all the satisfaction Mr. Sutton could get two years after his first successful experiment, a sum which, he bitterly said, scarcely paid his expenses. But he was not beaten even yet. Dr. Mead brought his suggestions before the Royal Society. New men succeeded at the Admiralty, and Mr. Sutton at last had the satisfaction of informing his influential friend that his invention had surmounted all obstacles:

"through the wisdom and zeal of the present right honorable the lords of the admiralty, and the right honorable and honorable the principal officers and commissioners of his majesty's navy, who, having taken the whole affair into their serious consideration, were so thoroughly satisfied of the great advantages that must accrue to the nation from the faithful execution of my scheme, that the said principal officers and commissioners of his majesty's navy have contracted with me for fixing my engine on board his majesty's ships, whether laid up or in commission; for which act of general concern, as I well know the warmth of your heart for the good of our country, I doubt not but you will readily concur with me in making cordial acknowledgments to their lordships and those honorable gentlemen in the name of the public. "Yours, etc.,

"SAMUEL SUTTON."

Thus ends this rather characteristic account of official obstructiveness and indifference. How long Mr. Sutton remained satisfied with his honorable and right honorable friends does not appear from his narrative, but, according to Mr. Bernan*, naval authorities objected to the recompense he demanded, and "in a year or two no other method of ventilation was known on board ship but the 'old way,' by wind-sails." He had also to contend with powerful rivals. Dr. Desaguliers foolishly condemned Mr. Sutton's system. Dr. Hales took no notice of it in his book on ventilators, which occasioned the following outburst:

"Dr. Hales' ventilators, which were designed to answer the same purpose as my pipes, had by some means or other got such an ascendant in the esteem and regard of some leading persons in the affairs of the navy, as, in spite of conviction itself, to admit of nothing to come in competition with them; though even that darling scheme is now out of date and exploded. Far be it from me to insult and triumph over a conquered adversary, and it is needless as well as cruel to spend much time in confuting a scheme that experience has shewn to be absurd and ridiculous. However, I think it incumbent on me to observe how much I was

* 'History and Art of Warming and Ventilating, &c.' Vol. II., p. 60.

surprised to find no mention made, by the candid author, of the description of ventilators of my invention; whereas he himself saw an experiment made before the Royal Society with a model of it, and heard Dr. Mead's account of it read to that learned body, which account was published in the 'Philosophical Transactions.'"

This was probably quite enough for Dr. Hales of the not-over-refined and indomitable Englishman, with whom the early stage in the introduction of ventilating arrangements closes. Dr. Hales's ventilators no doubt had their day and were forgotten, and it is certain that Mr. Sutton, in promulgating the principle unconsciously used for centuries, of ventilating by the common fire and chimney draught, recommended the special application of a system that was intrinsically superior to the mechanical contrivances of his reverend contemporaries. The blowing-wheel of Dr. Desaguliers and the bellows of Dr. Hales were powerful, but they occupied a certain amount of space, and required the systematic application of manual labor; but, by Mr. Sutton's method, a power was utilized that already existed, and which might be purposely developed without occasioning much trouble.

From this period for many years there appears to have been no one actively engaged on the subject of ventilation, but there were careful observers who noted and recorded the baneful effects of foul air on the human constitution, and who were conspicuously useful in manifesting the necessity for good sanitary arrangements. Sir John Pringle lamented, in 1776, that "by a humiliating fatality so often accompanying the most useful discoveries, the credit of Dr. Hales's ventilating bellows was yet far from being firmly established in the navy; but he himself rendered considerable service by the publication of his 'Diseases of the Army.' The excellent John Howard was indefatigable, and Captain Cook notably demonstrated what could be done by those who, with good intelligence, took a hearty interest in the well-being of their subordinates. The great circumnavigator, with a company of a hundred and eighteen men, performed a voyage of three years and eighteen days, passing through all climates from fifty-two degrees north to seventy-one degrees south, with the loss of only one man by disease, whose lungs were affected before he went on board. So extraordinary a result followed from the wisest precautionary measures. Captain Cook avoided excessive fatigue for his men, by appointing three *watches* instead of two. He protected the men from excessive heat and cold. Regularly every morning in the week he passed his ship's company in review, and saw that every man was as clean as circumstances permitted. He ordered the hammocks and bedding to be brought on deck in fine weather, and had every bundle unlashed and exposed to the air. He would have the sweetest water he could get; he provided fresh water for washing, and, when opportunity offered, his casks were carefully emptied of their contents and filled anew. His ship was of course duly scrubbed and washed. Fires were burnt purposely in stoves both to dry the timbers and renew the air. The well of the ship was dried and purified by an iron pot containing fire being let down into it, which of course occasioned a rapid change of atmosphere.* With such precautions and happy results, it is not surprising that Captain Cook did not consider the use of fresh air-bellows or blowing-wheels to be a practical necessity. Indeed, the early systems of ventilation became so much forgotten, that some twenty to thirty years later, when Count Rum-

* These facts are taken from 'A Discourse upon some late Improvements of the Means of preserving the Health of Marines, delivered at the Anniversary Meeting of the Royal Society, Nov. 30, 1776, by Sir John Pringle, Bart., President.'

ford published his essays, he made scarcely any allusion to ventilation, his chief concern being to promote the better warming of rooms, the economy of fuel, and the prevention of smoke. Count Rumford was, however, the author of one suggestion, which has been renewed by others. He proposed that the rooms of a house might be supplied with fresh air from a large shaft built in the party-wall, the object being merely to provide air from the roof of a house, which would probably be more free from dust and other impurities, than when allowed to pass through the doors and windows at a lower level. Open gratings fixed in the rooms would allow the air to enter from the air-shaft. A peculiarity of the system is that it would be generally inoperative except when a fire was burning, and that its success would have to be insured by excluding, in a great measure, the entrance of air to a house by other means. This important proposition will have to be alluded to again.

It was in the year 1811 that Sir Humphrey Davy, the next conspicuous contributor, undertook to improve the warming and ventilation of the House of Lords. The fresh air, previously warmed in cold weather, he admitted through innumerable apertures in the floor, and foul air he withdrew at the ceiling, by the same system as that first attempted at the House of Commons by Dr. Desaguliers. He had two apertures made in the ceiling, which were covered by open wire-work, and from the apertures he arranged metal tubes, which were led into the external atmosphere. These tubes were considered sufficient for ordinary purposes, but when extra ventilation was required, fires were burnt around a part of the tubes to accelerate the velocity of the air passing through them. The ascending current caused by the rarefaction of the air was, however, insufficient to maintain the chamber in a state of purity, as "his attempts are stated to have been a signal failure from a miscalculation of the diameter of the pipes necessary to carry off the vitiated air in so large a building, and became a source of considerable mortification to himself, as well as of malignant pleasantry to the witlings of that period."* There may be some satisfaction in reflecting that the great philosopher failed where other able men, who have devoted a far greater amount of attention to the subject, have but partially succeeded.

Another and a more successful contributor to the theory and practice of ventilation was the Marquis de Chabannes, a member of the old aristocracy of France, who, with fortunes almost ruined in consequence of the convulsions in France and St. Domingo, made his home in this country at times when revolution or despotism placed insuperable obstacles to his prosecuting an active career in his own. Certain pamphlets† of the Marquis, written with considerable clearness and force, explain the circumstances which led him to propound new theories and plans for the warming and ventilation of public buildings and dwellings. He states, that on landing in England for the first time, in 1787, he was struck with the multiplicity of the first conveniences of domestic comfort among rich and poor. He admired the cleanliness, neatness and seclusion of English homes, and, while admitting the superiority of the fundamental principle upon which houses were con-

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* 'Ency. Britt.' Eight edition. Art. 'Davy.' The following lines have been quoted :—

> "For boring twenty thousand holes,
> The Lords gave nothing d—— their souls."

† 'On conducting air by Forced Ventilation and regulating the temperature in Dwellings, with a Description of the application of the principles, as established in Covent Garden Theatre and Lloyd's Subscription Rooms, and a short account of different patent apparatus for warming and cooling air and liquids, the whole illustrated with copper-plate engravings, by the Marquis de Chabannes,' 1818. Also 'Appendix to the Marquis de Chabannes' Publication on conducting air by forced ventilation and equalizing the temperature of dwellings; published in 1818.' The date of the appendix is not given.

structed in Great Britain—viz., seclusion—he thought it surprising that so little attention had been paid to the means of preventing damp, and the ill-effects of cold draughts of air. Had the Marquis lived in our days, his opinion might have been somewhat modified, and he would probably have been appalled at the abject condition of the dwellings of a great portion of the laboring classes amidst so much prosperity and wealth. His actual observations, however, occasioned him to direct his attention to the general question of improving the temperature and salubrity of dwelling-houses, in the course of his various travels "through almost every country in Europe:" and he states that—

"In the year 1809, I published in Paris a slight sketch on the subject, and it is my intention at some future period to illustrate by practice what in theory appears perfect. To seek to create in man new wants, would be, instead of rendering him a service, aggravating the evils of his existence; but to point out a variety of enjoyments within his grasp, yet which escape his penetration because unthought of, will, I think, be deemed adding to his happiness. This is my hope and has been the occupation of my leisure hours for many years past.

"In 1793, I rented a house on Barnes Terrace, and, at a little expense, I rendered it as comfortable as any in England. I afterwards occupied a house in Welbeck Street, which, during three winters was completely warmed by the fire of the kitchen alone, and in the various houses I have since inhabited in France, I have followed and improved upon this plan.

"In January, 1814, writing the whole day in London before a large fire, burnt on one side and frozen on the other by the current of cold air rushing into the room by every aperture to supply the draught of the fire, I felt more sensibly than ever the great defects of the present construction of stoves. In this situation, I first conceived the plan of the calorifere, and had a model executed with the intention of having some stoves made and taking them with me to France for my own use, when an order from the king obliged me to depart early in February for Flanders.

"Sorrow and affliction induced me to quit France soon after the re-installation of the king, and I returned to England in the month of September following, weeping over the destiny of the house of Bourbon and the future miseries of my too-unhappy country. I then had a calorifere stove made from it with the sole design of guarding myself from cold, but the importance of the invention appeared to me to be so great, from the equal and agreeable warmth I immediately experienced in every part of my apartment, that I resolved to take out a patent, and to make public my long meditated plan for regulating the temperature and conducting and purifying the air in our dwellings."

A portion of the preceding paragraph is to be accounted for by the fact that the Marquis aimed to be a politician as well as a man of science, and was one whose advice was unacceptable to the power he wished to uphold. But loyal to his own liberal opinions and to the house of Bourbon, the winds were always contrary, and opportunities from which he found himself incessantly debarred, occasioned him to embrace others which afforded scope for his abilities in matters of a less pretentious nature than those relating to the political well-being of his countrymen. By introducing the "calorifere stove," alluded to in the extract, he was probably the first to make an attempt to establish a more powerful and economical means of warming the rooms and halls of houses than by the old open grate. The stove was very largely used some forty to fifty years since, and it may still be seen occasionally. It consisted of a metal case, sufficiently open in front to allow the fire to be seen. At the back and sides of the fire was a series of iron tubes, each tube about two inches in diameter, arranged vertically, through which a current of air coming from an external source passed, and, after becoming heated by contact with the hot inner surface, entered the room by apertures provided at the top of the stove. Such a contrivance, by presenting a large amount of radiating surface to the room, by lessening the current of air up the chimney, and providing for the entrance of a constant current of fresh warm air, effectually preserved the Marquis from being "scorched on one side, and frozen on the other," and must have effected a great change for the better in the many spacious places where it was introduced. This is essentially the same principle as that introduced by M. Gauger, and in all the ventilating grates which have succeeded his. The other contrivance alluded to by the Marquis is the plan now well known of heating a large quantity of water, at a distance from the kitchen boiler, by means of circulating pipes, the water being made in its course to travel through coils of pipe for the purpose of warming a hall, and the air about the stairs and landings of a house, and also for the additional purpose of supplying water for a warm bath. It was, in fact, the Marquis de Chabannes who first actively introduced the system of heating buildings by hot water in this country.

The Marquis took out patents for his inventions, intending, as he says, to abandon them to persons already engaged in trade, and to reserve to himself "a small acknowledgment" from those he licensed, but, he proceeded in the first instance to get the leading physicians, architects, &c., to express an opinion upon his schemes. He addressed a circular to them, in which he invited them to survey his improved systems at his private residence, and it is curious that this circular appears to have contained the first attempt to call the attention of the scientific to the necessity of ventilating the ordinary apartments of our dwellings. The Marquis said:

"Nothing would tend so much to the salubrity of dwellings as the expulsion of miasmata, more or less putrid, which arise from our breathing and perspiring, especially in bedrooms. The exclusion of damp air, the avoiding too sudden a passage from a warm to a cold room, and the guarding against noxious currents of air (all of which are causes of numberless diseases), are the objects I have endeavored to attain, and, I trust, I have completely succeeded." "Air being the great agent of our existence, on its purity depends in a great degree our breath and all the comforts of life. Every one knows that wherever man breathes, the constant introduction of fresh air is indispensable, and that the breathing of tainted air produces languor, decay, and finally death. The experience of all ages leaves evidence of its influence on health and longevity. Under these circumstances I apprehend, gentlemen, you will be of opinion that an efficacious method of purifying it, and regulating its admission at pleasure into your dwellings, is a most desirable object."

In a chapter "on air and its properties relative to respiration," the Marquis anticipated much with which the public has become familiar. He explained the nature of a pure atmosphere, the means by which it is rendered impure, the noxious and perhaps ultimately fatal effects resulting from impure air, the inconvenience and distress encountered in crowded theatres, ball rooms, small bedrooms, &c., and the absolute necessity of precautions being taken by those who valued a healthy constitution. Of the special means used by the Marquis in the withdrawing of vitiated air there is first a "chimney ventilator," shown in section in fig. 8, which was fixed so as to allow air to pass from the room into the chimney just below the ceiling, in exactly the same manner as by the "Arnott ventilator," introduced nearly thirty years subsequently. It operated by allowing an escape of air from above the room into the chimney whenever there was an ascending current in the chimney. A chain was provided to close the valve when not required for use, or when likely to allow the entrance of smoke. A second contrivance was a ventilating lamp, partly enclosed in a case of metal, which was so arranged as to give light to an apartment, and, at the same time, assist to ventilate it, while the products of combustion from the lamp effectually passed away. The arrangement is shown in fig. 6, and in section as fixed in fig. 7, with the lamp behind the mantle-shelf, and the frame-work of iron let into the wall. The arrows indicate passages provided for the escape of air, &c., to the chimney. A more important arrangement is that shown in fig. 5, which represents an arrangement of gas-burners attached near to the ceiling of a public room, with a large tube of metal to convey away the products of combustion, and an external tube to allow the escape of air for ventilation, the whole being discharged by a cowl at the roof. Various openings are indicated by the arrows which were intended to provide for the escape of air from different parts of the chamber.

The Marquis obtained numerous certificates from professional men and others, in favour of his various contrivances, provided with which he invited the stove-makers of London to offer them to the public; but he found too much ignorance, prejudice and want of enterprise in that quarter to expect any practical assistance, and he was reduced to the necessity either of abandoning his inventions, or of carrying them out himself. The Marquis did not abandon his inventions; for possessing too sound an understanding to think that it would be derogatory in him to submit to the necessities of his position, and promote his various objects by every honorable means in his power, he commenced and established a house of business in the now wretched locality of Drury Lane, where he rapidly gained considerable support. If the Marquis was in advance of his time, in attempting to introduce special means for ventilating ordinary apartments, he yet found ample scope for his talents in places where the most stolid could hardly fail to find reason to complain. The House of Commons was at this period by no means the worst ventilated chamber in the country, the ventilating wheel of Dr. Desaguliers, erected when requirements were smaller, having remained to be of some practical benefit till this period. Advice and assistance were sought from the Marquis, who removed the blowing-wheel, and also Sir Christopher Wren's air tubes, and who both contrived and carried out a far more elaborate system of warming and ventilation than had previously been conceived of. For the purpose of warming, the Marquis applied a number of coils of iron pipe under the members' seats, which coils were heated in winter by steam passing through them from a steam-boiler placed in a convenient position beneath the chamber. Air was allowed to flow into the house at various positions after being warmed by the steam coils. For the purpose of removing vitiated air from the upper part of the chamber, the Marquis adopted the analogous system of placing a number of steam coils in various positions over the ceiling and over the galleries, which were designed to create by rarefaction of the air surrounding them currents at various parts, and thus to occasion a general ascent of air from the body of the chamber through the air apertures in the ceilings, and past the steam coils into certain channels which terminated in one main channel of exit at the roof of the building. The air was then discharged at a cowl four feet in diameter. The heated products from above the chandelier were allowed to pass away direct into the main ventilating channel, and contribute to the general efficiency. The Marquis's method, elaborate and ingenious as it was, was not entirely successful. He was probably unable to regulate sufficiently the temperature of pipes heated by steam to adapt such a system to the necessities of our varying climate, though steam is the medium now actually used for heating the air in the House of Commons, with the assistance of certain arrangements that render its use more practicable. For the escape of foul air, the power employed was greater than before, though still insufficient. The Marquis was a great innovator on previous practice, but it was reserved to a later period for it to be established what a truly enormous quantity of fresh air is required to pass on certain occasions through the House of Commons, to maintain it in a state of purity.*

The Marquis carried out similar plans at Covent Garden Theatre, which he rendered the only tolerably well ventilated theatre in London. Besides exhibiting his plans for a time in operation at his own house, he ventilated at his own expense, for public exhibition, a metropolitan bazaar, which was destroyed by fire, and numerous other public buildings mentioned in his pamphlet. But though he was so far successful in gaining public attention to his improved methods, it is doubtful whether he ever got that measure of worldly success which often follows from the resolute and systematic exercise of the selfish instincts. It is the frequent case of the ingenious and inventive that their generosity is more noticeable than a less amiable quality, but, whatever may have been the case with the Marquis he retired to France, after a few years career as a tradesman, and spent his latter days near to Rouen, where he died.†

At about the time the Marquis was most active, Mr. Thomas Tredgold, a civil engineer, took up the question of warming and ventilation, and published a practical

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* The author hopes no one will be so inconsiderate as to consider him to be sarcastic.

† The following are the titles of the Marquis's patents.

A.D. 1799, No. 2364. Separating large from small coal, and consolidating the latter.

A.D. 1815, No. 3875. Apparatus for consuming smoke, and warming apparatus.

A.D. 1815, No. 3963. Pneumatic apparatus for producing currents of air in flues: apparatus for evaporating and cooling fluids: ventilation of chimneys.

A.D. 1817, No. 4191. Constructing metal tubes.

A.D. 1817, No. 4192. Apparatus for ventilating apartments, ships, &c. and for promoting draught in flues.

work of some value,* which reached a third edition in 1836. Mr. Tredgold was a strong advocate of the use of steam for warming, but he appears to have been remarkably ignorant of what had been done by others, as he made no allusion to the Marquis, or to the system adopted in the Houses of Parliament. Mr. Tredgold was a tolerably careful observer of facts rather than an originator, and his observations on the movements of air were chiefly of assistance in facilitating the labors of others.

Following immediately on Mr. Tredgold, is the well-known name of one who has probably contributed more effectually than any other to enunciate scientific principles of ventilation, and to reduce those principles to practice. In the year 1834, Dr. David Boswell Reid was lecturing at Edinburgh on sanitary subjects and chemistry, and had class rooms so admirably arranged to illustrate principles of warming, lighting and ventilation, that when the British Association for the Advancement of Science held a meeting at Edinburgh in that year, Dr. Reid became a centre of much public attention. In the month following, a great portion of the Houses of Parliament was destroyed by fire. What up to that time had been the House of Peers was thenceforth used as the temporary House of Commons, and the Peers removed to another chamber. The ventilating arrangements of the new Commons' chamber, imperfect before, were found utterly insufficient for the larger assembly. A committee on the subject was appointed in the year following, when Dr. Reid was examined and consulted. This led to a recommendation that he should be employed, both with a view to his giving present relief, and that his arrangements might afford guidance with respect to the requirements of the new legislative building that was to be erected. Dr. Reid dealt

* 'The Principles of Warming and Ventilating Public Buildings, &c., by Thomas Tredgold, civil engineer, &c.' Third edition, 1836.

with his subject in such a manner as to throw completely into the shade what had been attempted before. Previous to commencing, he wisely made experiments at Edinburgh for the purpose of ascertaining the quantity of air that must pass periodically through a chamber occupied by 240 persons so as to enable those persons to remain for any length of time without suffering the slightest inconvenience from a tainted atmosphere, and he varied his experiments with less and lesser numbers. His calculations led him to provide an area of discharge for air of no less than fifty square feet, a far larger quantity than any one had ever imagined to be necessary, Sir Humphrey Davy having, it is said, provided an area of only one square foot in the same chamber for the House of Peers, and the Marquis de Chabannes nine square feet in the late chamber of the House of Commons. For the purpose of withdrawing air through so large a space, Dr. Reid had adequate means. The air in the first place passed through numerous apertures in the ceiling; it then entered a large main channel which descended perpendicularly against an outside wall and passed along an underground channel to a chamber in which was a furnace connected with an elevated chimney shaft built expressly in a piece of ground adjoining the building. No air was allowed to pass to the furnace except that which came from the house by the descending and underground channel. It was soon evident that the motive power of the furnace and chimney shaft were amply sufficient for the ventilation both of the chamber and other parts of the building, the air passing away with greater or less velocity according to the amount of fire burning in the shaft, and according as a certain door placed in the main channel was more or less opened, the latter means enabling the quantity of air escaping to be increased or checked instantaneously. It must be noted that Dr. Reid had no object in using a descending flue for the air to pass to his furnace to be finally discharged by the shaft, beyond that of utilizing the means at his disposal by the best possible makeshift arrangement. He had thereby to incur a loss of power, and he recommended for new constructions, that the ventilating furnace shaft should form a part of the building with the fire burning above the level of the ceiling.

For the supply of a due quantity of fresh air to the House to replace that withdrawn, Dr. Reid had most elaborate arrangements, with a view to prevent the slightest inconvenience from draught or inequality of temperature. He desired that air should enter the House with the utmost possible diffusion. Instead of the twenty thousand holes of Sir Humphrey Davy, or whatever the number may have been, he had nearly a million. These holes were everywhere about the floor, in the upright portions of the members' seats, and in similar positions in the galleries. They were covered with a porous and elastic hair-cloth carpet, which vastly assisted diffusion. Between the floor of the House and the external atmosphere there were certain chambers of a highly useful nature. The fresh air first entered the lower chamber from Old Palace Yard, through the meshes of a veil, forty-two feet long and eighteen feet six inches deep, which served to exclude visible particles of dust or soot floating in the atmosphere, and which was so useful that, on one exceptional occasion, it was said to have retained no less than two hundred thousand particles on a single evening. The air in summer, when it did not require to be heated, traversed certain other chambers, and entered an equalising chamber below the flooring of the House, which was so constructed as to facilitate the spreading of the air equally to every portion that it might enter the House through the perforated floors and porous carpet, in all cases imperceptibly, and, as far as possible, with a uniform degree of force. It was not often that air thus entered the House without other preparation. During the winter and a great portion of the spring, it of course had to be warmed. For this purpose the air after passing through the veil in the court-yard, was allowed to traverse ranges of hot-water pipes. Occasionally it had to undergo further treatment. In certain states of the atmosphere the air was unpleasantly dry, and, as its capacity for moisture was further increased on heat being imparted to it, Dr. Reid provided ample means for imparting moisture —as much as seventy gallons of water having been evaporated on a single evening. There were also contrivances for cooling the air in hot weather, and for drying it when unpleasantly moist. Dr. Reid was not, however, satisfied with even all these provisions, for, to carry out his scheme with the utmost refinement, he dealt with another contingency, by means that would have never entered the conception of one less enthusiastic or less fertile in resource. The contingency is that which arises from a public chamber being exposed to considerable and sudden fluctuations in the number of persons present. It is familiar to every one that the presence of many persons in a building or chamber assists powerfully to warm it, in consequence of the temperature of the body exceeding considerably, as it does, that of the surrounding atmosphere, and, it is a natural result that as a public room becomes emptied of its contents, there is a sensible reduction in the temperature of the air. This operates to the relief of those remaining when it happens that the atmosphere has hitherto felt close and offensive ; but, in the case of a chamber that is well ventilated, and where the warming arrangements are under such careful supervision that the temperature of the air in the chamber does not exceed that which is generally agreeable, even when a large assembly is present, the effect of a considerable number of persons withdrawing is to leave an impression of chilliness on those who remain. A great portion of the heating power is, in fact, suddenly abstracted. And thus it was often calculated to be at the House of Commons. A debate suddenly closing, a prolix speaker and other causes might suddenly relieve the benches of a great portion of their contents. The evident remedy for the evil was to increase the power of the heating apparatus below the House. This, however, could not be done instantaneously. It took a certain amount of time to increase the temperature of a large mass of hot-water pipes. Dr. Reid was able easily to regulate the *quantity* of air that flowed into the house by simply regulating the amount of passage way in his main air channel, by which the air flowed from above the ceiling to the ventilating shaft, and he desired, as far as it was practicable, to regulate with equal rapidity the temperature of the air. He wished to satisfy completely the member who clung to his bench and those members whose presence was more ephemeral. His arrangement was to heat the air for the House to a temperature greater than it was actually required, and to obtain the temperature he thought necessary at any moment by mixing it with air at a much lower temperature. He therefore had what he called his mixing chamber between the veil that admitted the air and excluded the dust in the court-yard, and the equalising chamber that distributed the air under the floor of the House. Dr. Reid had one door that admitted cold air into the mixing chamber and another door that admitted warm air, and he hoped, by simply regulating the opening of his doors and thus altering the proportions he admitted, to gain with great rapidity the exact temperature he desired. To what extent he succeeded with respect to this one point it would be impossible, without special experience, to say with precision, but it is impossible to doubt that the arrangement altogether was a most admirable one.

No less than sixty thousand cubic feet of air per minute were allowed on certain occasions to pass through the House, an amount of ventilation that was perfectly agreeable on a sultry day. Never before had a body of legislators so much science brought to their assistance to enable them to devote their energies to the good of their country. The preceding account by no means comprises all of Dr. Reid's providing. There was an open grating in Old Palace Yard communicating with a drain, which was capable sometimes of emitting foul air. This drain he controlled by making it communicate with his ventilating shaft. Every internal possible means of contamination had careful attention. In the lobbies he had mats and "Russian scrapers" liberally provided, that the members' boots might be relieved from dirt or dust by an involuntary process, and, if he could not prevent emanations from the river when there was a low atmospheric pressure, or the wafting of impurities from gas works and other manufactories across the river, or the passing of barges laden with manure during hours of debate, or occasional emanations from a neighbouring churchyard, it was certainly not from want of a will. If chemical preparations could have relieved the atmosphere of impurities, Dr. Reid was the man to endeavour to discover and apply them; but what he considered most practicable was to have the power of taking his supply of fresh air from more than one quarter, so that if tainted at any time at one point, he might avail himself of the other.

Dr. Reid did not succeed in his efforts without having obstacles to encounter, resulting from a want of appreciation on the part of some members of the legislature. At any early period exception was taken to his arrangements, and among the parliamentary papers of the period are some humorous letters by Sir Frederick Trench, who, with many others, was evidently afraid of too much philosophy. Sir Frederick thought that the most simple and obvious remedies were the best, and instanced the ease with which Dr. Reid himself had relieved the House of inconvenience from noise; for, he said, "nobody suggested a carpet or double doors, or a less ponderous and noisy lock, till Dr. Reid appeared."* The doctor succeeded in satisfying the good-natured Sir Frederick, and so thoroughly successful was the system considered, that several years afterwards the strongest testimony was borne to it.

A committee reported, in 1846,

"The great improvement which Dr. Reid has affected in the atmosphere of the existing House of Commons can be appreciated by every member of the House, and your committee entirely concur in what they consider to be the general opinion in its favour."

Lord Sudeley, chairman of the building committee for the new Houses, said:

"The pestilential atmosphere of the House of Commons was notorious: its baneful effects on the health and energies of the members were painfully felt and admitted. Means from time to time were resorted to, to correct the evil, till scarcely a hope remained even that it could be lessened, and the most sanguine never dreamt that it could be cured, much less that the ventilation of the Houses could be brought to such a degree of perfection as to defy the chills of winter and the heat of summer, or the effects of numbers, however great, congregated within the walls lessening its beneficial effects."

Dr. Arnott, in 1856, thus bore honorable testimony for his contemporary and countryman:

"Until the late House of Commons existed as ventilated by Dr. Reid, there never was in the world a room in which five hundred persons or more could sit for ten hours in the day, and

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* The ponderous and noisy lock has disappeared, but it is probable the lock has not yet been constructed which will keep out members who are useless or worse than useless.

day after day, for long periods, not only with perfect security to health, but with singular comfort."

Such unequivocal success ensured the engagement of Dr. Reid's services for the new buildings. He removed from Edinburgh to London * to enter upon his formidable undertaking. An enormous pile of buildings, containing some hundreds of rooms, as well as the chambers of assembly, had to be provided for with respect to warming, ventilation, and the carrying off of the smoke from hundreds of chimneys by main out-lets. A portion of the arrangements fell to Sir Charles Barry, and a portion to Dr. Reid. It was of the highest importance that these gentlemen should work amicably together. Whatever Dr. Reid contemplated was inextricably mixed up with the general construction of the building. Dr. Reid was far from being the man to spare personal attention to every point of detail, and he was not therefore to be the man to yield if the fullest possible information was withheld from him. Whether he was too exacting in his demands, or whether Sir Charles Barry was unsympathising and unyielding, would be a thankless subject of enquiry, but it is certain that there were unfortunate matters of difference which extended over nearly the whole period of the construction of the building. There was no authority competent to interfere and pronounce decisively on the points at issue, and the result was of course disastrous. Dr. Reid went on loudly protesting, and at last an architect was appointed as arbitrator, to enquire fully into the whole business. Dr. Reid, Sir Charles Barry, and many other witnesses contributed an enormous mass of evidence, which was published by authority, and the result as regards the House of

* The writer remembers Dr. Reid at about this period, nearly forty years since, when Dr. Reid gave practical demonstrations on chemistry to a class of pupils at Willis's rooms, St. James's. The pupils assisted in the experiments.

Peers, and the greater portion of the entire building was, that a certain noble lord succeeded by a motion in relieving Dr. Reid of any further responsibility with respect to them, and the warming and ventilating arrangements for those portions devolved entirely on Sir Charles Barry. Dr. Reid retained his appointment with respect to the House of Commons and appertaining parts, but an improvement was effected henceforth by the appointment of a special officer, from the office of the architect, to be always at Dr. Reid's service, for the purpose of providing him with the information he wanted, and to carry out his plans. If no new subject of complaint had arisen, few would happily have heard anything more of the differences between Dr. Reid and Sir Charles Barry, but, unfortunately, after the building was occupied, there were great complaints of the ventilation. A committee to enquire into the subject was appointed in the House of Commons, who found it necessary entirely to decline to go into the old subjects of contention. The evidence furnished explained fully the system which Dr. Reid set in operation, and render it clear that whatever defects might have existed, Dr. Reid approached his subject, as before, with the comprehensiveness and boldness of a great inventor. Not satisfied with the considerable success he had had at the temporary chamber, he aimed at yet higher things. There, it will be remembered, he took his supply of air from a court-yard, but now, he sought to take it from above by making it descend one of the high towers into a vaulted chamber, where he provided a powerful fan-wheel worked by a steam-engine to propel the air into the chambers for heating, drying, moistening, mixing or equalizing, before it entered the house through a perforated floor and hair-cloth carpet. A constant descent of air in the tower was occasioned by the law of gravity, as soon as the propelling machinery was set in motion.

To withdraw vitiated air, Dr. Reid had, as before, a large coke fire, but he arranged it in one of the towers of the building above the level of the ceiling of the chamber, the air escaping at openings in the panels into a chamber above, from which it passed to the ventilating shaft. The new system therefore differed from the old one, chiefly by the vitiated air being discharged from the ceiling without having subsequently to descend, and by fresh air being taken from a high level instead of a low one. It was not, however, solely to ensure an adequate supply of air from above that Dr. Reid introduced his powerful propelling machinery. He had another very important object in view. He sought to introduce the novel feature of maintaining the air in the House at a higher pressure than that situated without, so that instead of air being likely to leak into the house around doors and windows, occasioning draughts, the tendency should be exactly the other way. Such a feature, so characteristic of Dr. Reid, could only be obtained with mechanical assistance. It may be thought that by taking air from a high level, and seeking to prevent draughts at a lower level, Dr. Reid did enough to save the House from sewer gases, emanations from the river, or from manufactories, but if he could have had his way, he would have done more. He wished to have the choice of two towers situated a considerable distance apart, so that if one were at any state of the wind affected by emanations from a certain quarter, he might take his supply of air from the other, and if both were in evil case he wished to be able to take air from one of the court-yards.

This was going too far unquestionably. If Parliament would not suppress nuisances in its own neighbourhood, it might be left to endure them, for the personal experience of our legislators might be useful to hasten legislation on great sanitary questions. It was one result of Dr. Reid's previous success, that he had trained the House to become fastidious. Men, who would have shrunk with disgust from the old chambers described by Lord Sudeley, soon began to ascribe the slightest personal inconvenience to the imperfect ventilation. Much as Dr. Reid was capable of doing, and willing as he was to apply to the most elaborate extent the science at his command, there were some things altogether beyond his powers. He could not satisfy both the man who liked a temperature of seventy degrees, and the one who was satisfied with fifty-five. He could not provide that the atmosphere should be equally agreeable to the member who entered the House after a sharp walk, and one who had been sitting in it for a couple of hours; and he could not satisfy the man who joined the chorus of grumblers without having any understanding on the subject. There was a great complaint of dust, which it was said fell from the members' boots* through the hair-cloth carpet and perforated iron floor, and was raised again by the fresh air coming in, and then carried to the members' lungs. The chamber below was therefore kept carefully clean, and the carpet walked over was taken up and cleansed daily. But if unreasonable complaints had stood alone, they would probably have been silenced. Unfortunately there was some sound reason for dissatisfaction if the temporary chamber so admirably warmed and ventilated was taken as a standard of comparison. There were, at certain times, conspicuous inequalities of temperature in different parts of the House, and in some parts disagreeable currents were complained of, especially in the reporters' gallery. The committee soon discovered that a division of the ventilating arrangements of the entire building between Dr. Reid and Sir Charles Barry, as effected by the motion in the House of Peers, together with the unfortunate state of the relations subsisting

* Nothing appears to be heard of dust now-a-days, except from the lungs.

between those two gentlemen, had operated disastrously. Dr. Reid required for the full success of his scheme to have a certain control over the House and all the approaches to it, but though this might account for many defects in various portions of the building, there appeared hardly room to doubt that he failed to some extent in the calculations upon which he based his elaborate contrivance. The very thing Dr. Reid had striven for he failed to get. Instead of forcing such an abundant supply of air into the House that draughts could only occur from the House outwards, the reverse was the fact, and he had a deficiency of pressure, the consequence being that the House was in much the same position as any ordinary room where a fire is kept burning, and fresh air cannot enter with sufficient freedom—that is, there was sometimes a sensation of closeness, and there were sensible currents in certain parts.

Whatever deficiencies existed were traced out carefully by Mr. Goldsworthy Gurney, at the request of the committee, and laid before them in special reports. Dr. Reid made the best he could of his case, but, if he had erred to some extent with reference to the size of his air channels or the power of his fan-wheel, he was naturally loth to admit it, for everyone was so heartily tired of the whole subject, that it was perhaps hardly possible for the committee to show him much mercy. He was allowed to make certain alterations, which were not considered sufficiently satisfactory, and the inevitable end came. Dr. Reid was removed from his position, and went subsequently to the United States of America, where he died. At the present moment the system of ventilation at the House of Commons consists of an extracting power for the vitiated air from above the ceiling, and the free entrance of fresh air from a low level, a system identical in its main essentials with that instituted by Dr. Reid at the temporary chamber. The system of bringing fresh air down one of the towers, and propelling it by machinery, has been long entirely dispensed with.

It is impossible for any one not to sympathise considerably with Dr. Reid in his fallen position, for, to a man of such activity and earnestness, the blow must have been a very severe one. Where he erred was unquestionably from excess of zeal. He was not the man to be satisfied with a small success, and to regard a respectable income and certain honors as his highest reward. He took up the subject of ventilation when it was in a very crude state, and he applied himself with unwearied industry to such consideration both of the leading points and details as might raise it to the dignity of a science. Great inventors have risen to eminence often after years of dreary toil, and all who have a just conception of an inventor's career are perfectly aware that it is only by a steady overcoming of difficulties and determined perseverance, in spite of failures or pecuniary loss, that success is finally obtained. It would, therefore, be most unreasonable if the name of Dr. Reid should suffer because his labors were not free from the imperfection which attends everything human.

Dr. Reid's principal literary contribution was a volume published in 1844, called 'Illustrations of Ventilation,' the most valuable and suggestive book on the subject still existing in our language. Being appointed in 1843 one of the commissioners to enquire into the state of towns and populous districts, he contributed an able treatise on the state of the Northern Counties, accompanied by an excellent series of colored plates illustrative of ventilation, which were published in the voluminous report of the commissioners. His latest contributions were a publication issued at New York 'On the Ventilation of American Dwellings,' which did not manifest any offensive spirit towards his detractors, and a revised article on Ventilation in a late edition of the 'Encyclopædia Brittanica.' Dr. Reid ventilated St. George's Hall at Liverpool and very many public buildings in this country. He made many suggestions with respect to the ventilation of dwellings, particularly the characteristic one that wherever the cost could be maintained a special ventilating shaft should be constructed, in which a fire was to be kept burning, and which should be in communication with every chamber or closet, and allow of stagnant air nowhere. He taught much both by writing and practice, and showed his genuine power both in his successes and in his more daring attempt.

On the cessation of Dr. Reid's labors, divided responsibility was henceforth avoided. The warming and ventilating arrangements were placed under the charge of an officer of the board of works, who had no power to make alterations less authorised. It was resolved to relieve the members of some of their troubles. The portions of the place commonly walked over were made impervious, so that there was less chance of dust from their boots being carried to their lungs. Free access for the admission of air was given at other points, so that any sensation of closeness and disagreeable draughts might be avoided. Matters thus continued till 1854, when, in consequence of some members being still dissatisfied, a new committee was appointed. Mr. Goldsworthy Gurney,* who had been introduced into the Houses of Parliament many years before by Sir Charles Barry, and had been occasionally employed in the building with reference to the lighting, found his services to be again in request on the subject of the ventilation. He drew up one more report containing several recommendations. He first recommended that the committee should carry out the general desire of making

* Sir Goldsworthy Gurney, now deceased.

the windows to open. Dr. Reid and Sir Charles Barry had agreed in avoiding this, the first considering it to be totally unnecessary and calculated possibly to interfere with his system, and the latter for constructional or architectural purposes. Mr. Gurney next recommended "that the present cumbrous and complicated mass of warming apparatus be removed, and that a more simple and manageable arrangement be made." Mr. Gurney, it appears, preferred his system of heating by steam. The third recommendation was "that the system of ventilation be changed to the downward system." In this he followed plans which have been much in favor on the Continent. It has been often considered that in hospitals, criminal courts, &c., the emanations from the bodies of sick, unhealthy or unclean persons were less perceptible when the general tendency of the air in a chamber was to descend instead of rising, and that therefore the system of introducing fresh air at or near the ceiling, and withdrawing it at or near the floor, was preferable for such places. The open mind of Dr. Reid perceived its probable advantages under certain circumstances. In fact, a downward system of ventilation operates in every dwelling where the air comes in at the top of a window and the escape is by the fireplace. Mr. Gurney carried his theories in support of the system very far. He considered that impure emanations from the body fall to the ground instead of permeating the atmosphere, and that at the floor was the proper position for the escape of vitiated air. He instanced repeatedly, in his various examinations, his notions relating to dogs scenting the ground and the case of bloodhounds.

Mr. Gurney also strongly advocated the use of the steam-jet for assisting to withdraw vitiated air into the many ventilating shafts of the building. The steam-jet consisted of a small tube from which a rush of steam acted (by its propelling power and the heat it communicated to the air in the shaft) to create or accelerate an upward current, the air in the shaft being continually supplied from the rooms with which it was in communication. The special object of the steam-jet was to supersede to some extent the use of fires for ventilation. At last Mr. Gurney was urged to take on himself the charge of effecting alterations and to undertake the general superintendence thereafter, to which he consented, deprecating at the same time the notion of his being actuated by the desire of gain, and because he had independent means and a desire to oblige his friends. It appeared by Mr. Gurney's evidence, that he was in early life a surgeon in Argyll Street, but was enabled to retire from his profession and devote his attention to some scientific subjects. He introduced the Bude-light and different systems of lighting in the Houses of Parliament, alluding to which, and his propositions for the ventilation, he said, that "he had had a child, and he had set him going, and now he wished to see this go." Sir Goldsworthy Gurney's motives were of course disinterested, but it may be permitted to regret that his paternal instincts have not found further scope, as no one has had such excellent opportunities as himself of making useful observations for the benefit of the public and the constructors of large buildings. Mr. Gurney abandoned Dr. Reid's system of taking fresh air from the top of the clock tower. He removed the propelling machinery. He introduced fresh air in one of the courtyards from about a level with the ground, and he substituted a system of heating by steam for the previous arrangement of heating by hot water. The downward system of ventilation has not been introduced, but it appears that Mr. Gurney has successfully applied it elsewhere. In the new system of heating, Mr. Gurney applied a principle for which a patent was taken out in 1845 by the late Mr. Silvester, a warming and ventilating engineer. Mr. Silvester proposed to increase the exterior radiating surface of a close stove, by means of several leaves of iron placed parallel to each other, and about an inch apart. The effect of the iron leaves was not of course to increase the heating power of the stove, but to gain an increased surface of iron at the cost of reducing its temperature. The advantage was that the stove produced a more wholesome atmosphere than if there had been a possibility of overheated iron, while the power of the stove for warming purposes was very little impaired. The same principle, but with some modification as regards size and proximity, Mr. Gurney applied to the exterior of steam pipes, and termed "Gurney's batteries." These "batteries" would be useless for ordinary hot water pipes, which do not become overheated, but they may be beneficially used with steam pipes. Sir Goldsworthy Gurney, some years ago, resigned his appointment as "ventilator" to the Houses of Parliament, and his place is now filled by Dr. Percy. In a report presented to the House of Commons, Dr. Percy gave many interesting particulars of the system of ventilation in operation. He said, with reference to the theory of bodily vapor sinking to the floor, that "we know nothing either of the chemical or physical nature of this matter; and it is therefore vain, and may be mischievous to attempt to found symptoms of ventilation on what are at present mere assumptions," and with reference to ventilation by the steam-jet, "that Sir Goldsworthy Gurney long before he resigned his appointment had completely discarded it."

The multiplicity of the arrangements in connection with ventilation, smoke, &c., may be judged of by the following extract:

"There are many hundreds of air-courses under as well as above ground, beneath floors, in walls, over ceilings and in roofs;

some for supplying cold air, others for supplying warm air, and others again for carrying off vitiated air ; there are air-valves in every part of the building ; there are enormous smoke flues running horizontally within and immediately under the roofs, with hundreds of chimneys in communication ; there are, it is asserted, steam pipes of which the aggregate length is about fifteen miles, and about 1,200 stock-cocks and valves connected with these pipes ; and there is a multitude of holes and crannies as intricate and tortuous as the windings of a rabbit warren."

In such a building it is not surprising that Dr. Percy should still find room for improvement.

There is yet one whose name has been but little associated with any system of ventilation, and who, without being a practitioner, has made certain suggestions. About five and forty years since, when the attention of observing men was generally called to the deplorable results which arose from the concentration of the masses of the working classes in large towns, without there being any adequate provision for their decency and health, many writers of ability contributed to public enlightenment on such subjects, and among them was Dr. Neil Arnott, a physician, who was present at the death-bed of Napoleon the First. Dr. Arnott published in 1828 the first edition of his 'Elements of Physics,' a book whose familiar illustrations and clear language rendered the causes of common phenomena plain to the most ordinary reader, and that at a time when little or nothing was known of physical science by men who were called well-educated. The publication was a popular one, and went through several editions. Subsequently, when Dr. Arnott interested himself in the subjects of warming and ventilation, he received a large amount of attention. In 1835 he attempted, with a certain amount of success, to introduce the continental system of warming apartments by means of close stoves, but so little did Dr. Arnott at that period appreciate the necessity of ventilating the chambers of our dwellings, that he expressed his opinion that an apartment would be sufficiently well ventilated even with one of his stoves in use, which allowed exceedingly little air to enter the chimney, and he instanced the case of Russia and other continental countries, where people universally used stoves, and yet did not complain of the ventilation. He considered that the apertures around doors and windows were sufficient for ventilation, except in a room holding a crowded company, when a window might be opened.* Dr. Arnott, like other able men, had both to live and learn. He since repeated in substance the teachings of the Marquis de Chabannes, and introduced a ventilator to be fixed in the chimney, figs. 9 and 10, below the ceiling, for the purpose of utilizing the chimney-draught from the upper part of a room. The Marquis provided a chain or wire wherewith to close his ventilator, but Dr. Arnott improved on this by so balancing the door that when air passed from the room to the chimney, the door opened spontaneously, and when there was no pressure from within, or a reverse pressure, the door remained closed. As Dr. Arnott has never expressed any acknowledgment to his predecessor, it must be supposed that he did consider himself to have profited by his teachings.

In 1854, Dr. Arnott published a revised and extended edition of his book on warming, wherein he urged fully the advantages of his ventilator, and of his other contrivances. He now took up the question of ventilating public buildings, and advocated for such places the use of a modification of Dr. Hales's bellows. Instead of the heavy flaps of wood, suspended by leathern hinges as valves to open and close the air apertures, Dr. Arnott was able to make use of the modern refinements of wire gauze to cover the

* See 'Arnott on Warming and Ventilating, with directions for making and using the Thermometer Stove,' &c. Longman, 1838. Page 66, also at page 76.

openings, and oiled silk suspended behind the gauze, to open and close with the pressure of the air. In one conspicuous instance where Dr. Arnott's services were invited, he arranged a system of working his bellows by means of the pressure of a high column of water, which dispensed with hand labor. Dr. Arnott intimated that Dr. Hales did not make his channels for the passage of air sufficiently large, but one thing was done by Dr. Hales which Dr. Arnott unfortunately neglected. Dr. Hales explained by what means he could ventilate wards at a distance from his bellows, but it is impossible to know from Dr. Arnott's book in what way he would effect the same object. Possibly Dr. Arnott confined his apparatus to benefit the hall and staircase of a building. In the course of the investigations on the ventilation of the House of Commons, an amusing incident occurred, illustrative of conflicting opinions with respect to different systems. A number of monkeys had died some time previously at the Zoological Gardens. Dr. Arnott had attributed the calamity to the want of ventilation from above in the monkey-house, and said they were living under an extinguisher. Mr. Gurney, however believed in downward ventilation, and ascribed their disease to over-heated metal. Dr. Arnott, it appears, believed that in ordinary apartments pure air was only enjoyed by dogs, cats and children till they gained the height of the fire-place. Mr. Gurney, on the contrary, evidently thought that the dogs and cats were the worst off. Such difference of opinion shows unquestionably how necessary it is that systems of ventilation should be founded on the demonstrations of science, and not upon hypotheses.

Of the various systems of ventilation which have been adopted, blowing-wheels or ventilating bellows are now scarcely known. The very efficacious principle so long used unconsciously of withdrawing vitiated air by means of chimney draught, aided by a fire, is most deservedly in favor. The usual method is to withdraw the air from above, and to allow the fresh air, whether warmed or not, to enter spontaneously at a lower level, discomfort being avoided according to the excellence of the arrangements provided for diffusing the air. Sometimes the reverse system has been used, and the suction power working from below has made it possible for the fresh air to come from above. Much detail respecting the various systems will be found in Dr. Reid's 'Illustrations of the Theory and Practice of Ventilation' (Longman, 1844); in Mr. Ritchie's 'Treatise on Ventilation, Natural and Artificial,' (Lockwood, 1862), and in General Morin's 'Etudes sur la Ventilation,' 2 tomes, (Paris: Hachette, 1863), and a variety of useful information in the compilations of Bernan, ('History and Art of Warming and Ventilating,' &c. Bell & Daldy, 1845), and Mr. Charles Tomlinson, ('Rudimentary Treatise on Warming and Ventilation.' Third Edition. Virtue, 1864.)

Since the writing of this first chapter the writer has practically but little to add. Allusions to Captain Galton's grate, and to the Tobin system, will be found further on.

CHAPTER II.

ON SOME SIMPLE APPLIANCES FOR VENTILATING DWELLING-HOUSES.

THE considerable amount of attention which was devoted to the ventilation of the Houses of Parliament operated most beneficially in manifesting the possibility of effective systems being applied to other public buildings. The necessity for much enlightenment on the subject was very great. So much had the subject been neglected, that no special provision was usually made by our architects for ventilation ; an encyclopædia of architecture did not even contain the word within it; any aperture to admit air was liable to be taxed as if it were a window to admit light, and, if it was for a long period considered hopeless to preserve the atmosphere of the House of Commons in a state of purity, we may be sure that our theatres, hospitals, poor-houses, prisons and chambers of justice were in most evil case. It was the temporary chamber of the House of Commons, the one formerly used by the House of Peers, which afforded the first notable instance of what science could really effect, and furnished the practitioner with practical and elaborate demonstrations by the aid of which he might apply simple and effective systems in less complicated cases, instead of having to attempt the more difficult process of improving on such imperfect methods as had been occasionally used.

Attention to ventilation has been further stimulated by those revelations of the deplorable condition of the dwellings of the laboring population with which many persons have in past years been familiar. It is to a considerable extent, a subject of concern and regret, that the enormous advance which our country has made during the present century in manufacturing skill and in wealth, and which has brought a great addition of the comforts or luxuries of life to many hundreds of thousands, cannot be considered to have profited to a satisfactory or a corresponding extent the skilled and unskilled labor upon which our success and its benefits have so largely depended. As working-men and their families have increased in number, no adequate provision has been made for them. All large centres of industry have contained districts, which, for concentration of inhabitants, filth, absence of decency and abject wretchedness, could hardly have been equalled by any other country or time. The evils, a few years since, were found to be so appalling and so dishonoring, that the national conscience was much roused—The Government was forced to act—Commissions were appointed—Reports and masses of evidence were published. A Board of Health was established, and useful acts passed the Legislature which dealt with the questions of crowded lodging-houses, drainage, crowded church-yards, supply of water, and other matters connected with health and decency. It soon forced itself on the attention of those who were actively engaged in investigations, that existing means did not suffice to permit a proper change of atmosphere in the confined and crowded dwellings of the poor. The evidence of the senses was far more than sufficient. Sickness, disease, death and evil habits developed or fostered in a great measure by the evil conditions in which the helpless occupants were placed, were found to be invariably associated with dilapidated dwellings that were never touched by paint or whitewash, with windows that would not open, with rooms crowded with persons of both sexes and of all ages, and certain other disgusting causes of contamination. Alarmingly, but most mercifully, came certain epidemics, which found their congenial home where impure air and impure water ever accompanied filth and disease. The cholera visitations of 1832, 1848 and 1854, in particular, acted a terrifying and therefore useful part in exciting the attention of thousands, and many began happily to be careful about breathing pure air with the instinct of self-preservation. The question then arose, whether the air of any enclosed place which was liable to be contaminated by the body's exhalations passed away with sufficient rapidity to be perfectly innocuous to the inmates. It was successfully urged that if in theatres, hospitals, &c., the air became so contaminated by the presence of many persons as to produce great inconvenience, and if the foul condition of dwellings in the poorer districts was the means of developing baneful diseases, and of constantly exercising a depressing or deteriorating influence on the condition of mind and body, that unquestionable evil, though not so immediately perceptible, must result from the retention within our dwellings of even slightly contaminated air. A case of the destruction of much human life in consequence of many persons having been forcibly confined together for many hours in the cabin of a steam vessel sailing from Ireland to Liverpool, came to furnish a practical proof that poisoned air may be as bad as no air at all. The old open fireplace was fast going out of use—contracted grates were substituted. Coal gas, often very impure, was being largely introduced for lighting, and the natural result followed, that the ventilation of dwellings began to be regarded as a practical necessity. When the Marquis de Chabannes recommended the ventilation of bed-chambers, he found few or no listeners, but, some thirty years later, when the subject was better understood, Dr. Reid, Dr. Arnott and other writers, countenanced attention to the subject with considerable success. The inevitable result followed, that numerous applicants appeared year after year at the Patent Office to ask for the monopoly of the use of some suggestion that had occurred to them for letting fresh air into a chamber, or contaminated air pass out, and so familiar has the subject become, that an old use of the term *to ventilate*, used in some figurative sense, seems to be quite a favorite expression among occasional writers to newspapers who wish to discuss some one or other of our administrative or social deficiencies. Of the various schemes which have been proposed, some have received attention and are in frequent use; others of not less utility have been insufficiently put forward; but before reviewing those which may appear worthy of note, it may be expedient to attempt a few general considerations on the ventilation of dwellings, both for the purpose of facilitating a proper conception of the relative value of different methods, and of leading to conclusions as to the nature of the special provisions which might advantageously form part of future constructions.

It is familiar to the general reader that a man in ordinary health makes about twelve hundred inspirations per hour, and that a large proportion of the air which enters the body becomes decomposed, that the oxygen unites with carbon, produces heat, and forms the poisonous carbonic acid gas which is constantly discharged both from the skin and the lungs. An atmosphere rendered deletérious by the presence of this gas alone, as in the burning of charcoal, does not give warning to the sense of smell, but it occasions great oppression, and, under certain circumstances, death. When discharged from the body, it is accompanied by certain vapor, which is said to be of unknown composition, but which, unless largely diluted with air, is apt to manifest its presence offensively in the manner familiar to every one who has ever entered a crowded and unventilated space, and it gives thereby the useful warning that the air is quite unfit to be breathed. In the open air abundant provision exists for the dispersion of vitiated air and the supply of fresh. That which a man vitiates is soon afar from him, whether he be at rest or in motion, and that which would be poison to him becomes food to the vegetable creation, which takes carbonic acid from the atmosphere, decomposes it, retains the carbon, and returns the oxygen, so that, by such compensatory process the air surrounding our globe is maintained in a condition of suitability for both animal and vegetable life, and, for aught we can tell, with our not unlimited powers of observation and comprehension, such compensatory process might be adequate in the eventuality of this world's possessing a population infinitely greater in number than at present.

The means which thus relieve a man of concern with respect to the air he breathes without his dwelling, may also be effectual with respect to myriads of human beings congregated in our most populated cities. The incessant change in the temperature of every portion of the earth's surface, occasioned by the earth's motion on its axis and its revolution round the sun, causes incessant disturbance of the atmosphere by which the earth is surrounded, and hence the constant dispersion of the air which has become unfit for human life. We are conscious of aerial disturbance when it is sufficiently violent to be felt as a wind or a breeze, but we are not conscious of the motion by which we are surrounded at every instant of time, and which, there cannot be the slightest doubt, operates to an extent altogether beyond our powers of investigation or conception. It can be easily shown that what we call a stagnant atmosphere is simply one which gives us no indication of its being in motion. We displace, unconsciously, a considerable quantity of air with every movement of the body. We are not directly conscious of the currents which pass in and out of the mouth. The warm breath ejected from the lungs cannot usually be traced at a few inches from the mouth. A door must be closed with a certain rapidity for us to be conscious of its displacement of air. A fan, for the same reason, must be moved quickly to occasion relief, and an odour becomes dispersed in a chamber by means of imperceptible currents, with such inconceivable rapidity, that we may readily credit the assertion of Dr. Reid, that many thousand currents are occasioned by burning gas in an argand gas burner. Such considerations may enable us, in some measure, to conceive how the never-ceasing variation of temperature and pressure in the atmosphere insures the extensive spread of contaminated air, and happily, thereby, its dilution and dispersion; and it may hence appear that in aerial motion, as in other things, Nature operates for our benefit, both with manifest power and with silent subtlety, and that it becomes our chief concern to beware that we do not exclude ourselves in any measure from her beneficent provisions.

Though in our open streets many hundred thousand inhabitants may not appreciably contaminate the restless ocean of air in which they are immersed, it is an undoubted fact that the air of large towns does not afford the exhilaration or maintain the high state of health with which many may be familiar in the country. By various processes of manufacture in certain districts, and by the collection and retention of putrifying matter, we often contaminate large volumes of air to an extent which any amount of motion in the atmosphere cannot remedy. The poison becomes diluted, widely dispersed, and therefore to a great extent, rendered innocuous, but it still gives us warning of its hurtful nature. Our remedy for such evil is invariably to require that injurious processes should never be carried on in populated districts, and that matter which might be noxious to animal life should never be retained within or near our dwellings, except under strict precautions, but, as far as possible, be incessantly utilized.

Though, however, external causes of contamination were entirely removed or avoided, it is still probable that some difference would be found to exist between the health-giving power of air in urban and in suburban or country districts. Though the air in towns may often be technically pure, there is less sensible motion than in open districts. Such motion, there can be no doubt, largely stimulates the animal functions and promotes health. It appears, also, that the electric condition of air in the country differs considerably from that in the confined quarters of towns, and that a difference, with respect to invigorating properties, is often to be traced to this cause. Upon this point science has much to discover, but the bodily sensations of the healthy may suffice to indicate that free movement of air should invariably be facilitated by straight and continuous channels of communication, and that such desirability should be constantly regarded in the arrangement of new districts for building purposes, and in any possible rearrangement of those already occupied.

If a free circulation of air in our streets removes impurities and is otherwise conducive to health, it is necessarily of great moment that such circulation should extend to the enclosed structures which protect us from wind, rain and cold, and in which most persons spend the greater portion of their existence. That the change of air in dwellings is often manifestly insufficient is familiar to every one who enters an unventilated bed room, dining room, sick chamber, room where gas is burnt, or where many persons remain together above a very limited space of time. The air in any chamber, of course never continues entirely unchanged. The forces which operate so incessantly without do not leave unaffected the air within the most carefully closed building. Internal and external temperature are never exactly the same. The temperature within a building itself is never uniform, and there is, consequently, incessant motion, occasioned by difference of pressure, with respect to a building or a chamber and the external atmosphere, with respect to one portion of a building and another, and with respect to one portion of a chamber and another; and all openings existing around doors and windows, openings between floor boards, open chimneys, keyholes, and even porous material used in construction, afford facilities for the spontaneous interchange of air.

In the summer, when the difference of temperature is inconsiderable, the interchange is not always very perceptible, and we may therefore freely open doors or windows without inconvenience, but, in winter we have, on the contrary, often to check the impetuosity with which air would enter at very restricted openings. The great difference in this respect is but partially due to the greater difference in temperature, and is chiefly owing to our use of open fireplaces, which in addition to their express purpose of providing warmth and removing smoke, have an accessory advantage which should never be lightly regarded. The air which supports combustion, and that which becomes heated and expanded by contact with the fire, or proximity to it, passes from the room and ascends the chimney with rapidity. The withdrawal of air rapidly effects a diminution of pressure in every portion of the apartment, and there ensues a rapid entrance of air at any openings, wherever situated, and a far greater amount of general disturbance in the atmosphere than when no fire is burning. Our fires become consequently powerful ventilators, which rapidly withdraw and discharge the air of our rooms, and command the constant entrance of fresh air around windows and doors in place of the gentle interchange we should obtain without them.

The use of chimney openings is far from being confined to the time when fires are actually burning. It is generally found that the heat communicated to chimneys by the constant ascent of warm air is such as to insure an upward current long after the fires are extinguished. When chimneys are built in party-walls, an ascending current is often observed even in summer. Sometimes there are double currents, air from the room passing away and the cooler air of the chimney entering the room, and occasionally a strong descending current is the only one perceptible. So much, indeed, is an open fireplace known to influence the change of air in an occuped apartment, that we naturally shrink with repulsion from the close atmosphere of a bed-chamber not provided with a chimney, or in which the aperture has been foolishly closed.

The motion of air in rooms becomes further complicated by the varying intensity of the fire, by the variation in the temperature communicated by the fire to different portions of a room, by the amount of window surface, by the difference in the temperature of the walls according as they may be partition or external walls, and, in the latter case, face the north, east, south or west; by the heat of the body and by its movement, by the constant inhalation of air and its discharge at a higher temperature, by the demand made in the combustion of gas and candles, and by the heat those substances communicate. It is hence evident that the circulation of air in houses is a very complicated matter, and one that if fully investigated would be sufficiently abstruse to tax considerable powers and the most refined means of observation. Dr. Reid's experiments, extending over many years, enabled him to throw much light on the subject without exhausting it; and in the parliamentary report on the Warming and Ventilation of Dwellings, issued in 1857, the results of certain useful experiments were given, which are of considerable utility both from the information they convey and from the distrust they awaken as to the value of theories, by whomsoever propounded, that are not based upon systematic observation.

In the absence of conclusions drawn from elaborate investigations, we must endeavour to seek the assistance of a little wholesome common sense. The first point to consider is whether, under ordinary circumstances, we require any further provision for ventilation than what is furnished by fireplaces, doors and windows. Many writers, to elucidate this point, have endeavoured to estimate the minimum quantity of air per individual that should enter an apartment in a given time. Dr. Arnott, many years since, thought that "to be safe" there should be "a ventilation supply of from two to three cubic feet per minute." Dr. Reid, who, it has been seen based his opinions upon elaborate experiments, recommended ten feet, but in sultry weather at the House of Commons, provided much more. Others have suggested fifteen or twenty feet, and a late writer, Dr. Percy, prefers thirty-three feet, but expresses his approval of General Morin's safe but expansive notion that as much fresh air should be provided as can be borne without inconvenience. This last suggestion would involve the introduction of much more than twenty cubic feet per individual, provided there

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* "Arnott on Warming and Ventilating, with directions for making and using the Thermometer-Stove," 1838. Page 66.

were careful provisions for ensuring imperceptible movement in the air.

There cannot be the slightest doubt that in the chambers of our dwellings the change of air is very often such as to satisfy the fullest requirement. In mild or warm weather, when windows or doors are opened, and in cold weather, when so powerful a ventilator as the open fire is in use, there is little need for apprehension, provided a room is not occupied continuously by many persons, and that gas is not burnt. The amount of air which escapes by a chimney, in fact, frequently occasions inconvenience from the unpleasant draughts which traverse the room, so that what is then required with respect to ventilation is to check its amount rather than to increase it. Our rooms, however, are very commonly differently circumstanced. They are sometimes appropriated for the use of many persons, or entirely closed and used continuously as in the case of bed-rooms, and, to mention other particular instances, in the case of dining-rooms, smoking-rooms, school-rooms, work-rooms, and any place where gas is burnt, they commonly proclaim their want with respect to ventilation in a manner not to be mistaken. Whatever may be the amount of interchange, a question impossible to arrive at except approximately and indirectly, it is not sufficient for healthy purposes. In numerous other cases, and in any closed room where no fire is burning, it is often not evident to the senses as to whether the ventilation is sufficiently perfect or not, and there may appear, therefore, reasonable room for hesitation as to the proper course to be adopted. In cases of doubt, however, the safest course is often clearly indicated, and if we consider the rapidity with which impure emanations become dispersed, and that animal vapor must pervade the air to a certain extent before we can become conscious of it, it will not appear unreasonable to those who value healthy habits, and wish as far as possible to breathe untainted air, to introduce in their dwellings as liberal a supply of fresh air as can be obtained without discomfort.

It may not be readily apparent to every one what it is that such a conclusion really involves. Many would be disposed to judge of the quantity of fresh air they could bear by their familiarity with rooms that in winter are justly called draughty. It is generally conceived that such rooms admit too much air. Sometimes this is actually the case, but sometimes it is not so. Whenever the chimney fire-place is large and open, the quantity of air it allows to escape often occasions so much draught as to produce inconvenience. The passage of air up the chimney in that case requires to be checked. For a room to be draughty, that is insufficiently supplied with air, may appear to some a paradox, but the explanation is simple enough. If, when a fire is burning, as much air cannot readily enter the room as passes away by the chimney, the pressure of air in the room becomes reduced, there is a disagreeable sensation of closeness, and, wherever there are openings, such as around doors and windows, the air rushes in with great violence in obedience to the low state of pressure of the air of the room. On opening the door, the pressure becomes restored, the disagreeable closeness is removed, and draughts in positions contiguous to the windows are less offensive. A proper supply of air, therefore, so admitted as not to occasion inconvenience might enable such a room to be occupied by any person with comfort.

To introduce imperceptibly into a room all the air that is required both for ventilation and chimney draught, is not a thing to be very easily effected. Speaking generally, it may be said that if draught over the floor to the fire is checked by allowing air to enter in winter in proximity to the fire-place; if the apertures used for admitting air are very small; if they are dispersed over a certain amount of surface, and if they are removed from proximity to any person, there can be no perceptible draught. The most elaborate arrangement that has been yet contrived is the one adopted by Dr. Reid at the House of Commons, where, as will be remembered, he introduced the fresh air warmed in winter through innumerable apertures in the floor, and withdrew the air through numerous apertures in the ceiling, endeavouring to insure with a general ascent of the whole body of air equal pressure, equal temperature, an absence of conflicting currents, and therefore perfect ventilation. There is not the slightest probability of our introducing any such system at present in our dwellings, whatever may be suggested some day, but a little consideration of its real or apparent advantages may serve to render it clear that certain inevitable imperfection must attend any more localised arrangement for the entrance and escape of air.

The various contrivances which have been suggested may be divided mostly into two classes—viz., those which provide for the entrance, and those which provide for the exit of air. They are mostly applicable to existing dwellings. Those which are not readily applicable it may be useful, for the sake of clearness, to consider apart from the others.

I.—*Contrivances which provide for the entrance of fresh air.*

No. 1. Perforated zinc.—This useful material has been made by machinery for many years at a very low price. The perforations are of all sizes required for ordinary purposes, and are sometimes arranged to particular designs. See figures 11 to 18. Perforated zinc is used occasionally in place of a pane of glass in closets, larders, and other places, in the panel of a door, at the top of a window sash, or in the skirting-board of a room.

No. 2.—Wire gauze, of various degrees of fineness, as figures 19 to 22, is used occasionally in place of perforated zinc.

No. 3. Air-bricks.—As figures 23 to 26. These have been usually made of iron, of the size of one or two bricks, and have been commonly put into an external wall to admit air to the basement or under the floors of a house. In such cases they preserve timbers and walls from damp, by the passage of air carrying off the moisture evaporated from the soil. "Air-bricks," if made of iron, should in all cases be coated with another metal, as by the process of galvanising, so as not to be liable to become rusted. They are now extensively made of brick or terra-cotta, as figures 27 and 28, with the perforations occasionally arranged so as to accord with the architectural features of a building.

No. 4. Sliding valves.—A few of these are shown in figures 29 to 31. They have been used in or over doors, or in walls, and frequently in conjunction with perforated zinc. Sometimes a frame of wood or metal is provided, with perforated zinc on one side, and a sliding valve on the other, so that air may be excluded or its admission regulated at pleasure. See fig. 63.

No. 5. Perforated glass.—This was first introduced under Lockhead's patent in 1848. See figures 32 and 33. It is frequently used in place of an ordinary sheet of glass, particularly over the doorway of a house. The patentee proposed that a shutter of glass, with a sliding valve to regulate the admission of air, as figs. 34 and 35, might be applied along with a sheet of perforated glass to the window of an apartment. Occasionally perforated glass has been made very thick, and put into a frame of iron for use in an external wall in place of the common air-brick.

No. 6.—Baillie's louvre ventilator, figs. 36 and 37, patented in 1837, is made of slips of glass fitted into a metal frame of the size of a window pane. It is usually fixed to the upper part of a window, and is provided with a simple mechanism for opening and regulating it. A similar ventilator was made many years ago by Mr. Moore and by Mr. Fairs.

No. 7.—Cooper's ventilator, figs. 38 and 39, is a modification of fig. 34. It consists of a sheet of glass, having a few large perforations arranged within a circle, and a circular plate of glass having similar perforations, and made to turn upon the face of the other in such a manner that air might be excluded or its admission regulated at pleasure. It is fixed in the upper part of a window sash.

No. 8.—Sheringham's ventilator, shown in figs. 40 to 42, is fixed in an external wall near the ceiling. The opening, which allows a very free admission of air, may be graduated by means of a door, which can be opened more or less by a cord and pulley. An inclined plate of iron is said to deflect the current of air upwards, and thus prevent inconvenience from draughts. It is mostly used for passages, staircases, schoolrooms, &c. An air-brick, such as shown in fig. 32, is usually put outside the wall in communication with the ventilator.

No. 9.—Mr. William Cooke recommended that air should be admitted through wire gauze at the top of a window, as shown in figs. 43 and 44, and that the wire gauze should be so arranged in folds and fitted with joints, that when the window sash was opened the gauze became more or less extended at pleasure, and when the sash was closed the gauze became doubled against itself and prevented the admission of air. Mr. Stephen Flexen has adopted a similar system, but used perforated tin instead of wire gauze.

No. 10.—Figs 45 and 46 represent a somewhat neat looking arrangement, patented in 1849 by Mr. Obed. Blake. Mr. Blake proposed to make a few circular apertures either in the upper or lower part of a window sash, and to protect the apertures by a coarse description of wire gauze or perforated zinc on one side, and a finer description on the other. A sliding valve between the inner and outer perforations, moved by a handle, was arranged to close the openings when required.

No. 11.—Some ingenious arrangements have been introduced by Mr. Thomas Boyle. Figs. 47 and 48 represent a ventilator fixed in a window pane. A round hole of a few inches in diameter is made in the pane, and fitted with a piece of fine wire gauze. On the face of this gauze, and in the apartment, a disc of coloured or ornamental glass is hung upon joints in such a manner that it can be pulled forward a short distance and allow air to pass through the gauze into the room, or it can be pressed against the wire gauze and exclude air. By another arrangement, Mr. Boyle introduces fresh air at the skirting board of a room. Fig. 48* represents a disc of metal, made to screw upon a circular frame fitted with wire gauze. This is fixed to the skirting or elsewhere, and a tube from it led to an air-brick in an external wall, permits the entrance of a certain quantity of air.

No. 12.—Mr. Charles Gammon, solicitor, patented in 1861 an ingenious contrivance, which is readily adapted to a window sash. Figs. 49 to 52 represent the ventilator, which is in the form of a long narrow box, having a perforated face of brass, a perforated back of zinc, and some perforated reticulations of zinc between them to break the force of the air, and arrest particles of dust. The face is divided into compartments, as shown in the fig., which are alternately perforated and plain. A plate similarly perforated and plain is made to move over the surface of the perforated parts, by means of a pulley, to which a cord is attached, so as to regulate the amount of air admitted, or exclude air. The ventilator is usually fixed at the top of the sash, and has a cover hinged above the perforations, so that when the sash is pulled down the cover may be opened, and any dust that may have collected be either blown or brushed away.

No. 13.—Another method, applicable in some cases, consists of a wooden frame, containing two or three louvre boards fixed above a doorway, as shown in figs. 53 and 54. The boards can be opened at pleasure for the entrance or escape of air by a similar machinery to that used with the louvre glass ventilator, fig. 36.

No. 14.—Ventilation by tubes against an external wall, commonly called "Tobin's System."

This consists of placing tubes made of wood or other material against an external wall, the lower ends being allowed to communicate with the outer air by means of a grating or air-brick, and the upper ends opening into the apartment at a height of 6 feet or more from the ground. The tubes should have an area internally of from 30 to 50 square inches, and might therefore measure 6 inches square, 4 by 8, 8 by 6, or any size we please of similar area. For a small room one tube might be sufficient. For large rooms and for public assembly rooms the number of tubes might be greatly increased. The principle consists, as every experienced person knows, in nothing more than this—that when the air of a room becomes of less pressure than the external air, whether by means of the expansion of air occasioned by warmth or the withdrawal of air occasioned by open fires, "sun-burners" for gas, &c., air will pass up the tubes and enter the chamber, without occasioning inconvenience to those present. It is simply a mode of admitting air without draught, and, as an alternative plan, may be well worthy of consideration. There are many modes of admitting air without draught, particularly by Sheringham's Ventilator; but as most of them admit of means for closing, there is the chance that they might be found to be closed when they ought to be open.

That a system of tubes to let in air over your head can be supposed to offer a solution of the whole question of ventilation is totally out of the question. In all assemblies and rooms much occupied there must be a real power of abstraction of vitiated air, and this Tobin's system does not offer at all. That it appears to have had a great success in some quarters appears to be entirely attributable to the fact that before the tubes were used there was no ventilation provided for except what proved to be unbearable, such as opening a window and letting in a sudden rush of cold air. One disadvantage of the tubes is that they might become receptacles for dirt, insects, &c., and require periodical cleaning.

II.—*Contrivances which provide for the exit of air.*

These are usually placed in communication with the chimney of the apartment.

No. 1.—The Chabannes ventilating lamp for bedrooms, placed in a niche over the mantel-piece, with a channel leading from it to the chimney for the escape of air and the products of combustion, together with the opening from the room into the chimney, (figs. 6 and 7) have been already described in the notice of the Marquis's labors. See page 25.

No. 2.—The Chabannes chimney ventilator, shown in fig. 8, with a chain or a cord to regulate the opening. See page 25.

No. 3.—Dr. Arnott's self-regulating chimney ventilator, figs. 9 and 10, contrived so that the door which closes the aperture should only open in obedience to a pressure of air from the room to the chimney, and on other occasions remain closed, has been already mentioned under the notice of the doctor's labors. See page 46.

No. 4.—A simpler contrivance of chimney ventilator was suggested by the late Mr. Joseph Toynbee. Fig. 55 represents a metal frame having a front of perforated zinc and a curtain or valve of oiled silk suspended behind the zinc. The oiled silk opened spontaneously below as long as there was any pressure of air from the room to the chimney. On other occasions, when there could of course be no escape of air, it remained closed.

No. 5.—Mr. Thomas Boyle, whose arrangements for the admission of air have been already described, has also a chimney ventilator (fig. 56). Instead of using a single valve of metal or silk, Mr. Boyle divides the face of his ventilator into compartments, and behind each compartment he suspends a thin plate of mica,* which is sufficiently light to open in obedience to a slight preponderating pressure of air.

No. 6.—A contrivance for utilising chimney draught, but the true principle of which has been but little understood, in consequence partly of the curious title given to it, is the *inverted syphon system* of Dr. Chowne, which was patented in 1848. Dr. Chowne proposed to make a channel in the wall of a room from the ceiling to the fireplace, with an opening into the channel from the room just below the ceiling, and the other end of the channel so made to communicate with the chimney as to prevent the ascent of smoke in the channel. Dr. Chowne said of this system: "My invention consists of applying a principle which I have found to prevail in the atmosphere, of moving up the longer leg of a syphon and of entering and descending in the shorter leg, and this without the necessity for the application of heat to the longer leg of the syphon." If the doctor had been correct in his supposition, the whole question of ventilation would have

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* Mica is used because very light, but will not close with the same accuracy as a heavier material.

become effectually solved, for it would only have been necessary to construct a sufficient number of his "syphons" to ventilate any building whatever. All that Dr. Chowne was able to do was to utilize chimney draught in a fashion of his own. As long as there was an upward current in the chimney, and the opening above the fire-place was partly closed, air descended Dr. Chowne's channel by the force of gravity; but, if Dr. Chowne had simply knocked a hole into the chimney below the ceiling, he would have found the air to pass away more readily from not having to undergo the preliminary process of descending. The system of Dr. Chowne was propounded long before by Mr. Tredgold, but has never been found to be of real practical value.

No. 7.—Systems of ventilating gas burners. See fig. 5 and figs. 57 to 60. The extensive introduction of coal gas for business and domestic purposes has led to the adoption of means for carrying off the products of combustion direct from the burner, so that they might not mix with the air used for respiration. Gas evolves in combustion a very large amount of carbonic acid; it is sometimes deleterious from the presence of impurities arising from a want of proper attention in the process of manufacture, and it is often offensive from the defective state of gas burners. The entire removal of the noxious products should therefore be regarded as highly essential, but, though the matter has been to some extent urged for fifty years past, it is to this moment most strangely neglected. In some early attempts to avoid contamination of the air by gas, the crude contrivance of a tube, with a trumpet mouth fixed over the burner and led into a chimney, gave a certain amount of relief, but the more elaborate attempt of the Marquis de Chabannes, to combine the removal of the products with the ventilation of a public chamber, as shown in fig. 5, was not by any means appreciated as it should have been; for, after having been entirely forgotten, it has been revived of late years under the title of the "sun burner" system of ventilation. At the temporary chamber of the House of Commons, an excellent system of removing the injurious products from numerous gas burners, without any visible arrangement, was proposed by the late Professor Faraday, and carried into effect. In 1846, Mr. Rutter published a pamphlet,* in which he strongly recommended the system of ventilating gas lights whenever used in dwelling-houses, and suggested the use of a single light in a glass globe suspended from the centre of the ceiling, and channels from the ceiling to the chimney, for the escape of air from the room, as well as of the products of combustion. Figs. 57, 58 and 60 are taken from Mr. Rutter's pamphlet, from which it will appear that a system identical in all its main essentials, and largely advertised, a few years since was made to bear the name of another. An indispensable precaution is that the channel for the escape of air from the room should be of ample size, or it would be quite ineffectual. The system, as far as the use of gas is concerned, should need no comment. Wherever gas is burnt there should be such a system, but, so much trouble and expense are involved in applying it to existing buildings, that it is highly necessary proper provision should be made while a house is in course of construction.

It has been occasionally attempted to ventilate a room from the centre of the ceiling, by carrying a tube from it into the chimney, the ornamental plaster work called "a rose" being provided with apertures or suspended a short distance below the ceiling, so that air might escape above it into the ventilating tube. This has been quite irre-

* "Practical Observations on the Ventilation of Gas Lights." By J. O. N. Rutter, F.R.A.S. London: John W. Parker, 1846.

spective of the use of gas. Fig. 64 represents a sketch given by Mr. Tredgold, but slightly modified. There is an apparent advantage in the system from its dispensing with the sight of a chimney ventilator, but it is not equally effectual. The air has to travel horizontally in the channel before it enters the chimney, and whatever some persons may consider air ought to do under such circumstances, those who have a little familiarity with its movements are aware that a current of air would enter the chimney less readily than if the communication were more direct. When assisted by the powerfully-heated products from a gas burner, the ventilation may be sufficient, but seldom so on other occasions. Another difficulty is that it cannot always be very practicable to provide a channel of sufficient area for effective ventilation. Very small tubes are good for nothing. The channel should seldom have a less sectional area than twenty-four inches; sometimes double the quantity or more.

Of the preceding propositions for the admission and exit of air, the same general principles run through nearly all, viz., that fresh air should be introduced at a high level in a room, and that the chimney should be utilized as far as possible for the escape of air. There have not been wanting many persons who have seriously questioned the propriety of introducing fresh air at the upper part of a room. It is usual for them to contend that the warm vitiated air from the lungs ascends and contaminates the fresh air. Practice has, nevertheless, almost invariably followed a course in discordance with such theory, and not without good reason. When cold air is introduced below, the sensation to the feet is very disagreeable, but, when carefully introduced above, it increases in temperature by contact with warmer air, and mixes with the general body of air in the room without occasioning the slightest inconvenience. These remarks, it must be borne in mind, refer only to the supply of air for domestic and other ordinary purposes, and do not apply to public rooms or buildings where different conditions demand different treatment.

Whenever there are arrangements for warming the air before it enters the room, the air is of course admitted near to or at the floor. Dr. Reid, it has been seen, had a perforated floor, an open carpet, and his warming apparatus below. For domestic purposes, it is common to use hot-water pipes fixed behind the skirting-board, with gratings to admit air from an external source into the main air channel containing the pipes, and thence through other gratings, or slips of perforated zinc, into the room. Others have used a metal grate, as figs. 68 and 69, with a warm air chamber behind, which has been placed by means of an air channel in communication with an external wall, and by means of certain apertures on the front surface of the grate, in communication with the room. A certain amount of fresh air enters after becoming warm by contact with the back part of the grate.

With respect to the notion that fresh air, when introduced above, is more liable to contamination before it is inhaled than when introduced below, this may appear to have some plausibility, but a little consideration may render it doubtful whether it has much force. There is no doubt that air escaping from the body is warm and charged with that which is unfit to return to the lungs, and it is also true that warm air ascends; but it is equally open to observation that the air propelled from the mouth takes a forward movement for a short distance, that it rises a little, and that the further motion of the particles is lost altogether. It would take more delicate instruments than have ever been devised to trace any continuous current of air occasioned by the process of breathing or by the heat of the body. What we know very well is, that vitiated air becomes instantly distributed, and is found very generally to pervade an apartment when present in sufficient quantity to be perceptible, notwithstanding any theory that may be formed on the subject.

The various contrivances at present described for admitting air differ in value according as they distribute the air over an extended surface, according as they provide means for checking the impetus of the air, and according as the quantity of air admitted is easily regulated. Perforated zinc, wire gauze, perforated glass, air bricks and sliding valves, figs. 11 to 33, are all useful in certain cases, particularly when they form part of some special contrivance. Mr. Lockhead's ventilator, figs. 34 and 35, appears to be a very good one, though, perhaps, not readily applicable to large panes. Baillie's or Moore's louvre ventilator has been very largely used, but draughts from it cannot always be avoided. Mr. Cooper's ventilator, fig. 38, and Mr. Sheringham's ventilator, figs. 40 to 42, appear to be clearly open to the same objection, though the latter has been used for a long number of years, and on the whole very satisfactorily. Mr. Cook's or Mr. Stephen Flexen's plan, figs. 43 and 44, offers a considerable area, and its success would depend probably on the joints being always in proper working order. Mr. Obed. Blake's plan, figs. 45 and 46, satisfactorily fulfils several conditions. The air is distributed, draughts are prevented by the double gauze, and the means of regulation are simple, but care should be taken to remove the pieces of gauzes occasionally which face the room for the purpose of removing dust. Mr. Boyle's arrangement for putting a ventilator in a window pane, figs. 47 and 48, has some good points. Within a chamber, the disc of glass to cover the wire gauze is by no means unsightly, but the appearance of the bare disc of gauze without would often be objectionable. His plan of introducing fresh air at the skirting by fig. 48 is unobjectionable in winter, provided the air is warmed. Mr. Gammon's ventilator, figs. 49 to 52, is carefully constructed to admit air and prevent draught, and, as it is readily applicable, is undoubtedly a useful little contrivance. The last plan, shown in figs. 53 and 54, that of providing louvre boards above a doorway, is capable of admitting more air than the other contrivances, though, under most circumstances, it would act as a means of interchange, air both passing in and out between the louvre boards. It is not very sightly, and appears to be most applicable for smoking-rooms, workrooms, and other places where greater provision for a change of air is required than in an ordinary apartment.

It will be inferred from the preceding observations, that the contrivances of Messrs. Lockhead, Cooke, Flexen, Blake, Boyle and Gammon, are preferable to those of Messrs. Baillie, Moore, Cooper and Sheringham, from their greater power of avoiding draught, but it must not be supposed that the latter are objectionable in halls, passages, and many lofty rooms, where cold air may be admitted with much greater freedom than in ordinary bed rooms and sitting rooms, or that wherever double windows are used, the ventilators of Baillie, Moore and Cooper, may not answer their purpose perfectly well. In this latter case, the ventilator may be fixed in the external sash, and air admitted into the room by slightly opening the inner sash at the top. Of the other description of ventilators Mr. Gammon's is least perceptible when fixed, but it does not disperse the air so much as the contrivances of Cooke, Flexen and Blake. If applied to every window, it may however be sufficient for all practical purposes, and there appears to be no reason why it should not be made of any length that is desired. Irrespective of these various contrivances, however, it is easy for any one with a little ingenuity to contrive, with the aid of perforated zinc or glass, wire gauze, air gratings and sliding valves, any arrangement that may suit his own fancy, and if he can be trusted not to rush off to a patent agent to get him a patent, he may have served himself without losing his money.

For the escape of air from the room the chimney is nearly always available, and it would be more frequently so than it is if the supply of fresh air from the doors, walls, or windows were in all cases sufficient. The upward current in a chimney is of course greatly interfered with if a rarefied atmosphere is allowed to exist below. When a fire is actually burning, the chimney answers the purpose of ventilation most powerfully, and occasionally excessively, so that a contraction of the fire-place becomes indispensable for the purpose of warmth. It is exactly this contraction of the fire-place which makes it possible to utilize the chimney draught above. It is only necessary to break a hole into the chimney anywhere below the ceiling for an additional amount of air to pass away, and that without occasioning personal inconvenience from any current. A contrivance of some kind is invariably provided to close the aperture when there is no draught, or when there is a down current. In the Marquis de Chabannes' chimney ventilator, fig. 8, there was a door with a chain, while Dr. Arnott, Mr. Toynbee and Mr. Boyle, (figs. 9, 10, 55 and 56) have had self-acting doors. Much disappointment has arisen to many persons from their being unfamiliar with the essential conditions for a chimney ventilator to be successful, and in some quarters its utility has been too hastily questioned. It is worse than useless for one to be put into a chimney when the fire-place is large and open. As long as a body of air, filling the whole chimney, passes freely through it from the fire-place, none will pass through the ventilator, and smoke may very possibly find its way through the ventilator into the room, but if the fire-place be contracted the two openings will do quite as well as the one did before. A chimney ventilator is generally useless in a very small chimney, for if the latter is only large enough to allow of the passage of air from the fire-place, there can be no escape above. It is also useless when there is a down current in a chimney, or when there are reverse currents, and of feeble use when there is a very gentle current. It is only unquestionably useful on those occasions when the air in the chimney is more rarefied than the air without, and the opening into the chimney is partly closed below. It is most useful when a fire is most active, and this is exactly the time when it is generally least wanted, but it must be remembered that the chimney ventilator has the advantage of turning the chimney to the fullest account of which it is readily susceptible, and that in existing buildings, the reasonable course is, to make the best of any resource already at command.

Objection has often been made by architects and others to the liability of sooty particles being blown into the room, and to the flapping noise made by the door of the ventilator in gusty weather. If soot is liable to be blown through the ventilator, it appears probable that it may also be blown down into the fire-place. The ventilator in this case should not be blamed, but the malconstruction of the building, which must allow a strong current of air to descend the chimney, or the chamber itself may be insufficiently supplied with air, and therefore frequently occasion down-draught. With a sufficient pressure of air below, and a simple protection above, down-draught, whether from wind or otherwise, could hardly be known. The same precautions would doubtless suffice to prevent the flapping noise of the door. Upon this last point, however, it may appear that the little mica valves used by Mr. Boyle, fig. 56, would be less likely to occasion the slightest annoyance than the single metallic flap of Dr. Arnott, and be therefore preferred.

It was unfortunately propounded by Dr. Arnott, when he urged the general use of his modification of the Marquis de Chabannes' ventilator, that a broad distinction was to be drawn between the air below and that above the chimney mouth,—that the former was pure, while the latter became extensively charged with unwholesome emanations, which could only be removed by an aperture being made in the chimney below the ceiling. This theory supposes that the whole body of air in a room below a certain level is in a state of motion, and passes away sooner or later by the chimney, to be replaced by fresh air, while the air above that level is in a state of comparative stagnation. There do not appear to be strong grounds for believing that this theory accords with facts. There is no doubt that a considerable quantity of air passes away by a chimney, and chiefly when a fire is burning, but where the air comes from is not so readily ascertained. Air enters the room wherever it can, and there is often a current over the floor, and a current up the chimney. What is not so well known is, that there is a constant ascent of air in the room in front of the fire-place, so that much of the air which arrives there becomes expanded and circulates in the room. Apparently the only safe conclusion that we can come to, from many experiments which have been made, is that the whole body of air in a room is in motion, that certain currents are to be occasionally traced, and that sooner or later, by the powerful action of a fire, the air of a room becomes entirely changed. As the same thing happens, but to a less extent, as long as there is an upward current in a chimney, we need not perhaps go so far as to apprehend that our children will begin to ail when their heads rise above the fire-place, if we do not give them the benefit of a chimney ventilator.

If a ventilator to admit air in moderate quantity be provided to every window, if an open fire-place be used, and the chimney be otherwise turned to account; and if gas be only used along with effective means for removing the products of combustion, there can hardly be reasonable grounds for supposing that the chambers of our dwellings will not be as well ventilated as existing circumstances will readily permit. A slight addition might however be made in the shape of such an article as shown in fig. 63, which could be fixed below the cornice over a doorway, and be used instead of a window ventilator in very cold weather, so as to allow the exit of air or a gentle interchange according to the existing circumstances of the apartment.

We will now proceed to a consideration of the special application of the principle of good ventilation to the different portions of a dwelling. The question so far as it is connected with the case of open fires in winter and the prevention of smoke is considered in the next chapter.

Ventilation of Basements.

It is beyond the scope of this volume to enter fully upon such questions as the avoidance of damp, the removal of refuse, the burning of vegetable and animal matter which may be liable to decompose, the trapping and flushing of drains, and the use or abuse of sink traps, but considering the obscurity in which many basements of great houses are suffered to exist, we cannot forbear from quoting a passage from Captain Douglas Galton's recent book on the subject of light:

> "A dark house is an unhealthy house, an ill-aired house, and a dirty house; therefore light should penetrate to every part. There should be no dark staircases, corridors, corners or closets. Direct light by means of windows easily opened to the outer air is required to ensure the frequent renewal of the air."*

* Healthy Dwellings, page 158.

When light is freely admitted to a basement, defects may easily be perceived, otherwise they may remain for years undetected. The admission of fresh air to a basement is very essential; it is required for the purpose of maintaining dryness and to supply the air drawn off by kitchen and other fires. Sheringham's ventilator, fig. 40 will answer the purpose, or the wooden channels known as Tobin's. In many cases, however, these channels can be best used in basements when inverted, the fresh air entering the channels from above and passing into the house from below, say a foot or two above the floor line. By this means the fresh air may be taken from a higher level than the ground line, and be admitted without draught.

Ventilation of Kitchens.

This is a very essential matter, one of the great inconveniences of modern houses arising from the use of the kitchener, which when not properly ventilated allows the fumes of cooking, the smell of burnt animal or vegetable matter to pass up the stairs into the body of the house. It may be considered to be a point which hardly requires demonstration that a sufficient supply of fresh air should enter the kitchen to replace what passes away by the flues. This may be obtained by air from the adjoining passages, by Sheringham's or window ventilators, or by wooden channels against the walls, as already described. It is extremely necessary that the dampers to the flues should not be opened more than absolutely necessary, both for the purpose of checking a waste of fuel and an unnecessary escape of air. As gas hot plates are often used it is well to state that they should always be provided with a canopy with a flue from it leading into the chimney, protected at top so as to prevent the falling of soot, down the flue. The canopy and flue allow the noxious fumes to pass securely away.

For the ventilation of the hot plate of the kitchener a very successful contrivance of the author has been the ventilating funnel shown in fig. 61, which is fixed over the roof of the kitchener and is left permanently open, the draught which carries off the heat, &c., not interfering with the action of the flues. A simple covering provided at top prevents the falling of soot on the hot plate. This funnel can be fixed in its place or removed when necessary by means of two turnbuckles (screws which can be moved by the fingers) which attach it to a fixed metal frame, removal being only necessary when the chimney itself has to be swept.

An important point in connection with kitcheners is the absolute necessity of using the roasting dish with water trough, which prevents the burning of fat inside the roasting oven, also the use of the simple ventilating arrangement introduced by Count Rumford, which allows a current of fresh warm air to pass incessantly through the oven. It is by these two contrivances that the disagreeable flavour of baked meat is entirely avoided.

A further point connected with kitchens will be alluded to further on in speaking of the upper floor, where means require to be used to prevent the passage of air from the kitchen department. The necessity of lime-whiting the walls, having clean paint and floors, and of exterminating vermin needs not to be insisted upon.

Ventilation of the Ground Floor, generally consisting of Hall, Dining Room, Library, &c.

Admission of air to the hall and at different windows on the landings or stairs must be considered to be indispensable. A fire is often burning in the hall which, unless carefully regulated, may send many thousand cubic feet of air per hour up the chimney. The air must be provided from somewhere; if it cannot enter the house by the hall door or other suitable means, air will pass up the chimney from the house itself, exhausting it to the disadvantage of other fireplaces; or it will enter from the kitchen department, whether on the same floor or below, and bring with it a smell of cooking. Possibly the chimney is found to smoke which generally indicates that there is not a due supply of air to replace what has passed away. And we must bear in mind that it is generally from the hall, landing windows, &c., that a large body of the air enters our rooms and passes up our chimneys, and that if it does so, it must be in some manner replaced. This may be done by Sheringham's ventilator, ventilators in the windows or ventilating tubes.

Ventilation of Dining Rooms.

The admission of a sufficient supply of fresh air to a dining room without draught is very essential, as such a room becomes rapidly contaminated by the breath of many persons, by mastication, by the heat of the viands, and by the means used for lighting. Sheringham's ventilators or Tobin's tubes are very beneficial.

Ventilation of the Library.

This is a more simple business as it is seldom occupied by many persons. A simple ventilator which will allow fresh air to enter imperceptibly is all that is generally required.

Ventilation of Drawing Rooms.

These sometimes present great difficulty in consequence of their being occupied occasionally by many persons and much light being then used. If the body of the house be sufficiently supplied with fresh air, drawing rooms will receive a better supply than they now do, and they may receive a still better supply by the means indicated for other rooms. The gas lights may be ventilated by the means already described and a supply of air may be given to each fireplace by the method described in the next chapter.

If these means are insufficient the only sensible alternative is that we should avoid entertaining a larger company than can find air fit for respiration, say three persons to a thousand cubic feet of air. Drawing rooms are not provided with special means for extracting air like Theatres, Music Halls, the Houses of Parliament, &c. It is therefore worthy of consideration whether public rooms specially ventilated might not be utilized or constructed for the private entertainment of a large company. A great difficulty, which often exists in a suite of three drawing rooms, is that while two of the fires burn very well the third is an inveterate smoky one. This is due to the cause which the writer has often pointed out, viz., that the rooms are not sufficiently supplied with air to replace what passes away, so that the deficiency has to be made up by air rushing down the troublesome chimney and a steady upward current is impossible. The only sensible remedy is to reduce as much as possible the air which does pass away by means of proper registers and to supply the rooms sufficiently with fresh warm air, admitted without any draught.

Ventilation of Bed Rooms.

For a bed room to be properly ventilated it should give no indication to the sense of having been occupied a very short time after a person has slept in it. This can be attained by admitting air at the door, window or walls. By means of the door we may admit air or allow an interchange. A door-chain may be used which will allow of a door being opened three or four inches without any probability of disturbance. Some persons have used in the case of travelling a wedge of wood to be pushed underneath the door which would allow of a bed room door being secured to such an extent that it could not be opened more than the regulated space allowed, say an inch or so without their becoming alarmed.

Another simple plan, applicable to our own dwellings, is to allow air to come in between the upper and lower window sash by raising the lower sash and filling the space below it by a piece of wood, measuring in length the width of the window sash, in depth, one, two or three inches, and in thickness exactly the thickness of the window sash, probably about one and a half inches. This fills up the space below the lower sash so that air can only enter vertically, generally without draught at the open part between the upper and lower sash. Captain Galton has suggested making a slit vertically at the bottom of the upper or at the top of the lower sash. This answers the same purpose, and it enables the window to be fastened.

Perhaps the principal source of contamination in a bed room is the emanation from the liquid matter which the body rejects. Glazed earthen covers might be used, or some other contrivance which requires the authority of a leading physician to suggest and introduce.

When a lamp or a gas-light is used in a bed room, the simple ventilating lamp of the Marquis de Chabannes, shown in fig. 6, might be used with a tube from it to carry off the products into the chimney.

Ventilation of Attics.

This is not a very difficult matter, the attic floor being frequently the most healthy in a house. It is far from the basement of a house, far from drains and from impurities on or near the surface of the ground. Contaminated air from below seldom reaches the attics. There is often a skylight of some sort by which light and air are admitted. The evils to which attics are exposed are generally of a different character to those which are encountered in lower stories. These evils are due entirely to the deficiency in the necessary supply of air to the lower stories, so that there is a constant tendency of air to pass down from the attic floor to the floors below and thus remedy to some extent the evils existing there.

To replace the air which descends from the attic floor, fresh air comes in by openings in the skylight, if one exists, air enters by the windows and air descends the chimneys, rendering it difficult or impossible for fires to be used. There is thus ample ventilation and possibly too much of it. It gives to the upper floor a sense of coldness, to which the fireplaces offer no effectual remedy. The only way to render the attic floor as comfortable as the lower floors is by admitting sufficient air to the lower floors for respiration and to replace what passes away by the chimneys. If this be duly attended to, the attic floor may be as comfortable as any in the house.

One useful suggestion of Captain Galton is to admit air in the skylight by inverted louvres, which divert the air upwards before descending and prevent a sudden descent of cold air. The use of the ventilating slip at each window is highly to be commended.

Ventilation of Cupboards and Closets.

This may generally be effected by means of a slit cut out of the bottom of the door and a slit or a few holes being cut at top.

Ventilation of Water Closets.

This is a far more important matter than many would readily or willingly conceive. Modern ideas of comfort and refinement require that they should be comprised within the interior of our dwellings, but a sufficient provision for maintaining a purity of air is scarcely ever to be found. When fires are in use and the air of the house becomes reduced in pressure, the window of the w. c. is one medium by which air passes into the house. Air may even ascend the soil pipe and enter the house. It is not easy to suggest a remedy, as it is a subject that can only be fully dealt with when the house is constructed. We may say that the chamber of accommodation should always be against an external wall and if possible at the end of a passage, with an *intervening* door and window by which window fresh air could be insensibly admitted. In the chamber itself some means of admitting fresh air left permanently open must be provided. A most useful provision would be a wooden trunk or channel protected by louvres, which could be carried as high as convenient against the external wall and allow a gentle interchange of air. The ventilation of the soil pipe has been alluded to elsewhere.

Ventilation of Rooms without Fireplaces.

This can be done at the window or the wall. Such rooms may often be greatly relieved by a somewhat large tube (say about nine by four inches) being led from the partition below the ceiling into the chimney of an adjoining room. Such a tube would look like a beam, and though not very elegant, is better to be borne with, than that any persons should be required to subject themselves to unrefreshing sleep amidst the stagnant air of an entirely closed chamber. It requires no great amount of ingenuity to make it as ornamental as useful.

Public concern with respect to ventilation has led some persons to enquire what special arrangements could be made in the original construction of dwellings, which would provide more effectually for the entrance and escape of air than any adaptations to existing buildings, and there have accordingly been several suggestions, which have been applied occasionally within a few years. The suggestions for the escape of air generally involve the construction of perpendicular ventilating shafts or flues in the walls of the house, by which air can pass away from a room independently of the chimney, the object being to dispense with the use of chimney ventilators and the inconvenience which has been sometimes found, necessarily or not, to result from them. The simplest description of shaft is a mere channel formed in brickwork in a position contiguous to the chimney, so that it may receive some heat from the intervening brickwork. An open grating fixed below the ceiling places it in communication with the apartment, and where it terminates above the roof, some simple provision is used to prevent the descent of wind or rain. It may answer its purpose very fairly, provided the means for admitting fresh air below furnish a larger area than the apertures into the chimney and into the ventilating shaft, but there is, of course, never so powerful an upward current as may be sometimes obtained through the chimney ventilator by the use of a fire.

An improvement on the common ventilating shaft was patented a few years since by Mr. D. O. Boyd, by which more of the heat of the chimney becomes utilized for ventilating purposes. Mr. Boyd's plan is to construct the sides of each chimney of thin iron plates instead of brickwork, as shown in figs. 70 and 71. The iron plate alone divides the chimney from the ventilating shaft. A shaft may be formed on each side of a chimney, and between two chimneys, according to circumstances. Metal being a rapid conductor of heat, the temperature of the air within the shaft is increased to a greater extent than if there were the interposition of brickwork, so that an upward current is more easily created or accelerated when there is a fire burning. An open grating below the ceiling allows the escape of air as in the last case.

Another suggestion has been the combination of chimney and ventilating flues proposed by Messrs. Doulton and Co. Their method is for chimneys to be constructed of glazed earthenware pipes made in lengths, as shown in figs. 72 and 73. Distinct from the smoke flue are two ventilating flues, one on each side, which are placed in communication with the room below the ceiling. The contrivance appears to provide for economy in construction, but with respect to utility, it is probably a little more serviceable than the ventilating shaft formed in brickwork, and somewhat less so than the better-heated ventilating flues of Mr. Boyd.

A more elaborate arrangement, and one calculated to command attention in consequence of the quarter whence it proceeded, is the system of ventilation and smoke flues, described in the Board of Health Report on the Warming and Ventilation of Dwellings. Plate A in the Report, represents the section of a house having the whole of the fire-places arranged back to back against a partition wall, and a single smoke flue to receive the smoke from every fire-place from the kitchen and scullery in the basement to the bed rooms on the top story. The smoke flue is supposed to be formed of clay pipes about ten inches in diameter, and to be connected with each fire-place by a short branch tube, which is to be carefully closed when not in use. Around the smoke flue is shown a ventilating channel reaching also from the basement to the roof, having no communication of course with the smoke flue, but terminating a short distance below it above the roof, and being made to communicate with each apartment by means of suitable apertures below each ceiling. The considerable amount of heat communicated to the ventilating channel by the constant ascent of heated air from a kitchen fire, as well as from the other fire-places when in use, is supposed to command an upward current of sufficient capacity and power to withdraw air from every chamber. A provision is made for sweeping the chimney from the basement, and the comprehensive arrangement is completed by the suggestion of the system of introducing to every room, in winter, a supply of fresh air in close proximity to the fire.

The commissioners rightly state that the success of this system "cannot be vouched for," but they consider it "entitled to the attention of architects and builders as an experiment worthy of trial." If no response has hitherto been made to the appeal, it is possibly because the commissioners have not shown themselves to be even aware of the difficulties that would have to be encountered in departing from existing practice. Such difficulties have been encountered invariably when it has been attempted to use even a chimney of the present large dimensions (14 by 9) with more than one fire-place. It is obvious enough that if a single chimney could be used for several fire-places, by simply connecting chimney and fire-places together, our builders would long since have availed themselves of so economical a method. Nevertheless, it is not impossible for two or more fire-places to be used with a single chimney, provided certain precautions are taken, which appear simple enough when once understood, and the necessity of which would have been evident, if the subject had only been experimented upon and duly considered.

It may first be remarked, that a radical defect of the arrangement consists in the suggestion that so many fire-places could be used with a single *small* chimney. This is so far from being the fact, that a chimney of such diameter as ten inches, would barely suffice for the kitchen alone. Many unfortunate builders have got themselves into trouble, and many householders have suffered considerable annoyance in consequence of the kitchen chimney being built too small. If the common open range is used, the current of air through the small chimney is not sufficient to take away all the smoke, and an oppressive atmosphere is the consequence. Perhaps the chimney is barely sufficient in size, and then the sweep's attendance is constantly required to make the best of the restricted channel. Perhaps the open range is abandoned and the close range substituted, which, being more of the nature of a furnace, has a better chance. But though the close range may be used with a smaller chimney than an open range, due provision must be made for the escape of the currents of warm air, laden with gases resulting from combustion which seek to escape by the flues. It would be uninteresting to enter into details, but it is safe to assert, that our cooking arrangements, as at present constituted, could scarcely ever be carried on with a chimney of less than ten inches in diameter, and frequently require a much larger capacity.

Due provision being made for the escape of smoke from the kitchen fire, the requirements of the other apartments require careful consideration. It is utterly useless to make an opening into a channel that is already filled with a current of air, and expect that air will flow into the channel from the new source. The unreasonable expectation may possibly be rewarded by the channel discharging a portion of its contents at the aperture. It is therefore absolutely indispensable that a main channel should be of no less capacity than all the small channels put together. To settle the dimensions of the smaller channels great care is necessary. The current of air charged with smoke and other offensive products, must pass readily away or there will be great annoyance. A tube three or four inches in diameter to remove smoke from a fire-place having a much larger area would be quite ineffectual. There might possibly be a passage of air through the tube, and that is all we can say. The successful and proper arrangement appears to be a vertical channel of the whole width of the fire behind, made narrow from front to back, and with an enlarged opening where the tube is made to communicate with the fire-place. This form enables the channel to be restricted to the smallest dimensions compatible with the effectual escape of smoke.

The effect of the minor channel being made to enter the main channel vertically is, that there is but little likelihood of one current checking the impetus of another, and that therefore the main channel may be reduced to the smallest dimensions consistent with the various demands made upon it. What the dimensions of the main channel should be, must of course differ in different cases. Anything like ten inches diameter would, it is clear, be totally out of the question, and the fact of such a size having been deferentially suggested for ten fire-places by men so undoubtedly worthy of respect for their scientific labors as the commissioners, is but an instance of what very erroneous notions may be formed upon any subject in the absence of careful observation or experiment. If we take half the number of fire-places suggested, *i. e.*, one tier only, or five in a house of four stories above the basement, the main chimney could hardly have a less capacity in clear area than two hundred and sixteen square inches, and would therefore be about twenty-four inches by nine.

If the dimensions of the main and the minor smoke channels be carefully attended to, as well as the mode of communication, and if the various chambers be properly supplied with air for the support of combustion, there is no reason why one smoke chimney, with various branches, may not supersede the distinct chimney now used to each fire-place, and one or two architectural terminations at the roof may take the place of a row of chimney-pots. The sweep's labors may then, as suggested by the commissioners, be incurred at the basement of the house instead of in the separate chambers.

Those who believe contrary to common-place experience, that small smoke channels may be made to prove quite efficacious for open fire-places, would do well to profit by some of the experience which has been gained at the whole range of buildings comprising the Houses of Parliament, respecting both smoke and ventilating channels, or they may, if of mechanical turn, devise a method by which the gaseous products of a fire may be collected into a small compass, and shot up the chimney.

If a main smoke channel may be made effectual for several fire-places, there is no reason why a main ventilating channel should not be made effectual for several rooms. In a previous volume the author has illustrated the system suggested by the commissioners, but greatly modified, showing the smoke flue contained within a large ventilating channel, and various openings from the rooms into the channel. It is not perhaps so necessary that there should be a short vertical communication from each room, as in the case of the smoke flue, as the passage of air is more gentle, but it is absolutely necessary that the main channel be of sufficient capacity for its different requirements, and that the apertures communicating with each room do not exceed in area such a proportion of the ventilating flue as can be alloted to the use of such room. It is also essential for the prevention of return currents, that the amount of fresh air admitted by various means to the room, be quite equal to that which it is desired should escape both by smoke and ventilating channels. Instead of making the communication with the ventilating channel by means of a grating opening immediately into it, a perforated strip of metal might communicate with the ventilating channel just over the centre of the mantel-piece, and similar perforated strips might also enter it just below the cornice. Any one familiar with design or decoration may easily arrange that such apertures may form part of any general ornamental features.

In the commissioners' section two different ranges of fire-places are shown, put back to back, and opening into the same chimney, and it is suggested in their report that in the case of such a system being found to occasion inconvenience from the smoke of one fire-place being liable to escape at another fire-place, that the evil would be avoided by the smoke channel being divided in the middle, so that the fire-places on one side might not communicate with those on the other, or that two smoke flues might be arranged in one ventilating channel, one of the smoke flues to be used for one set of fire-places, and the other smoke flue for the other set. These propositions involve an entire change in constructional arrangements with respect to the position of fire-places, for the purpose of combining the smoke and ventilating flues for an entire dwelling. Dr. Reid suggested the possibility of such a thing being effected, but he was probably too much absorbed in other matters to elaborate his notions. There might possibly be some advantage arising from the suggested alteration, but not in the use of a single smoke or a single ventilating flue. These it would be necessary to divide. A certain benefit might be gained by the heated air from the kitchen fire being made to contribute warmth in some way to both ventilating flues, and there might be some advantage in providing channels for the escape of air in positions opposite to the windows instead of at right angles with the front and back wall, but the disadvantages would be enormous. Fire-places would often necessarily be found in close proximity to the doorway, and there could be no communication between front and back rooms by means of folding doors. That on certain occasions fire-places might readily be arranged back to back may be quite clear, but this appears to be far from being the case in the great majority of dwellings.

Instead of a ventilating channel in connection with the smoke-flue, a system of providing for the escape of air from the partition-wall opposite the windows might be used sometimes with advantage. Perpendicular ventilating channels some few inches broad, but very shallow, might allow the escape of air just below the cornice. The partition being generally warm, from its position between rooms in which fires are used, would insure an upward current, provided the supply of fresh air from the usual sources was sufficient. There might also be such channels provided in the hall, or about the staircases or passages of a house. The water-closets should in all cases be provided with a ventilating flue, in which a jet of gas within reach of the hand might be used in dark hours.

Of arrangements for the admission of air which are rather applicable to new than to existing dwellings, there is the combined ventilating and smoke-flue of Mr. George Jennings, the sanitary engineer, which is shown in fig. 74. Instead of using the four hollow channels shown at opposite points of the smoke-flue for the escape of air in the same way as Messrs. Henry Doulton and Co. by their scheme (figs. 72, 73), Mr. Jennings endeavours to apply the suggestion contained in Count Rumford's book, and put into practice at the House of Commons by Dr. Reid, viz., that of supplying fresh air to a room from a high level. He therefore makes his flues descending flues, in which the air becomes warm by contact with the earthen chimney before it enters a room. Open gratings and regulators are provided to control the admission of air. The scheme appears very pretty as illustrating what can be done, but it is open to question whether its advantages preponderate over or are equal to the advantages of others. The essential conditions for its success are, that other means for admitting air should be carefully closed up, and that the air in the room should become rarefied by the action of a fire. Air then, whether warm or not, descends the ventilating flues by the force of gravity, and enters the rooms. As it is natural for warm air to ascend, there appears to be a loss of power incurred by its being made to descend. Such loss it might be worth while to incur if the air were unquestionably purer. That it is necessarily more pure may appear doubtful. Smoke and other offensive products from our chimneys are discharged at a high level, and necessarily contiguous to the ventilating flue, and though many might feel more motion in the atmosphere upon the roof of a house than at a low level, and a certain benefit therefrom, that is not to say that the same air, without perceptible motion, is more wholesome than other air. At a low level we are occasionally exposed to offensive emanations, but, as we must of necessity breathe air from a lower level than the roof of a house whenever we are abroad and whenever we open our windows, it may appear that the proper remedy is a compulsory avoidance of certain nuisances.

Another system of admitting air is by a perforated cornice, but the title may mislead, as the cornice is only used to cover and conceal some other appliance for the admission of air. Sometimes the cornice has been made of wood, with large perforations. One or two air-bricks fixed in an external wall, with a regulating valve, have allowed air to enter a hollow space between the cornice and the wall, and thence by a few apertures into the room, all the remaining apertures serving only for ornament. Fig. 65 represents a ventilator for admitting air at a cornice, which was used with much success by the commissioners appointed for improving the sanitary condition of barracks and hospitals, and recommended in their report.* The upper portion is of perforated zinc, the lower portion of wood, and is fixed, as shown in fig. 66, with an air-brick or grating without, a regulator, a provision for dispersing the air right and left, and the perforated zinc so placed that the air may ascend to the ceiling on its entrance. The contrivance may appear crude for dwelling-houses, though perhaps perfectly applicable, with a little cautious treatment; but it may be possible to suggest for ordinary purposes simple and unobjectionable methods of introducing air above the windows, which might be preferable in some respects to this and to other methods already described.

Fig. 87 represents in section the upper portion of a window-opening so arranged as to admit air quite independently of the window sash. Air from without passes through the apertures of fig. 90, into an open space of about six inches square, and through pieces of gauze or zinc, as shown in fig. 89, into the room. A flap of very fine perforated zinc or gauze, shown in fig. 88, and as fixed in fig. 87, might be so arranged that when pulled forward it would greatly reduce the amount of air admitted without excluding it, and be pulled back again to admit the maximum of air; certain facilities required to be provided for the removal of dust. Fig. 91 represents a similar system, but instead of the perforated apertures of fig. 89, and the finely peforated flap, fig. 88, a cylinder might be used as fig. 92, of about four inches in diameter, formed of strips of gauze or zinc soldered or wired together, and so suspended and made to revolve that more or less air would be admitted, according as a finer or coarser descrip-

* Issued in 1861.

tion of gauze or zinc faced the room. The appearance from within would be as shown in fig. 92*. The arrangement would require a provision to be carefully made for the easy removal of dust.

If arrangements be adopted for admitting air imperceptibly at our windows, and warm in winter, at positions near the floor, and if air be removed by ventilating channels and the open fire-place, we shall have done much that is readily within our power to maintain both a comfortable and wholesome atmosphere in dwelling-houses. Such atmosphere will be much more pleasant and invigorating than the rarefied air which many have often to breathe, which some get accustomed to, to such an extent, that the cold external air is offensive and hurtful to them, while others, more habituated to a dense atmosphere, either within or without, find the rarefied air to injuriously affect the nervous system and the agreeable and systematic operation of the mind. Such an advance as we may unquestionably make may not quite compare with such an ideal system as Dr. Reid's, viz., that of the whole body of air in a room being maintained at uniform temperature and pressure, ascending, passing away, and being replaced without the slightest perceptible motion ; but, if we have no option but to submit meekly to the laws of development, we can make the very satisfactory reflection that we leave something for our successors to attempt, and can be thankful if less refined but effectual methods may secure for our ruder natures a due supply of fresh air.

A short series of ventilating contrivances, not applicable to ordinary apartments, and but seldom applied to dwelling-houses, have often been used with advantage over the ceiling of a public school-room, workshop, or room of assembly, &c. The first of these is Mr. McKinnell's ventilator, fig. 93. It consists of two concentric tubes, the inner one longer but much smaller than the other. They are attached to the roof so that both of them may communicate with the chamber below, and with the external air. When from any cause the air in the room has a less pressure than that without, a movement of air takes place in the tubes; air is found to descend the short space between the tubes, and an ascent of air often takes place within the inner tube. As the air enters the chamber it is deflected, as shown in the figure, that the persons situated below may not be inconvenienced by draught. If the double current could always be depended upon, the contrivance would be of considerable value, but its action is liable to be disturbed by common causes. The only reason why air passes away at the inner tube is because it does not pass away by the chimney or other means. The contrivance acts best in a perfectly close room. If a considerable quantity of air is allowed to enter the chamber, the balance of currents becomes disturbed, and both channels may serve for the exit of air or for a gentle interchange. If, on the other hand, a fire exhausts the air in the room, there is a descending current in both tubes. A sufficient and independent supply of air for the fire must then be provided. Mr. McKinell's ventilator appears to have been found extensively serviceable in places where the requirements with respect to ventilation are greater than in dwelling-houses, and where the chimney, windows, and doors have not offered sufficient facilities. Figs. 95 and 96 represent a similar system, known as Muir's, which has four compartments for the movement of air.

A similar contrivance by Mr. Watson, figs. 97 and 98, consists of a tube divided in the middle. A useful arrangement for ventilating also by a double current was devised by Mr. Thomas Harris, the architect, and patented with his consent by Mr. John Davis. In this case an external wall is used instead of the roof. Figs. 99, 100, and 101 represent a frame of iron or other material in two compartments, each compartment being provided with a series of apertures and valves by which air can either enter or escape. The lower valves open inwards, and therefore admit air. The upper valves open outwards and allow it to escape. The valves require to be accurately poised, so as to yield to a slight preponderating pressure. The contrivance, if very carefully made, is found to be highly useful. It is generally known that when a door is opened air enters the room at the bottom, and air passes out above. The same thing may occur on opening a window above and below, and some have therefore suggested the ventilation of rooms by applying perforated zinc or gauze at the bottom and top of a window sash. Messrs. Harris and Davis' ventilator is founded upon the same principle, which is of course identical with Mr. McKinnell's. Like Mr. McKinnell's ventilator, it is adapted for school-rooms, and places requiring a similar amount of ventilation, but for its success to be insured, the apertures for admitting air must have a larger total area than the apertures for the escape of air, and the supply of air to the fire in use from other sources must be quite ample.

Another ventilating contrivance used for ejecting air by mechanical power, is set in motion by the wind. Fig. 94 represents Mr. Chadwick's Archimedean screw ventilator, which is attached to the roof of a building. The upper portion is made to revolve like a common chimney cowl. Certain blades or fans within propel the air in an upward direction, and occasion thereby an ascending current, while fresh air enters the building spontaneously below at apertures provided for it. If there were no wind, there would be a descending current, or a mere interchange of air.

Of these systems Mr. McKinnell's and Mr. Watson's ventilators have, it appears, been occasionally applied to the roof of a large house or building for the purpose of insuring about the stairs, passages, or hall, a considerable change of air. By large openings being made over the doorways of the various rooms, it has been sought to extend the operation of the system considerably, but though such openings would undoubtedly allow of an interchange of air, whether there were a ventilator attached to the roof or not, they could never be depended upon alone for the ventilation of the various chambers of a dwelling.

CHAPTER III.

LONDON SMOKE AND FOG.

THE gloom of the winter of 1879-80 was so disheartening, so dangerous, or in each sense of the word, so appalling, that on a recurrence of fog just recently, some have asked whether nothing can be done to relieve our Metropolis from the pernicious smoke which in certain states of the atmosphere exposes us to a gloom seldom to be found elsewhere on the surface of the earth, and utterly unknown in the great cities of past times. Dr. Carpenter, of Croydon, has pointed out in the *Times* how we may leave such a place as Croydon with a clear sky and sunshine, and enter gradually an atmosphere that is utterly repulsive. Residents in most parts of the suburbs have had similar experience. The question how we are to deal with the smoke question, has therefore been asked. Many answers may be given, but it is probable that not a single answer may be given that could at once be accepted as satisfactory, for the simple reason that it is beyond any man's power to suggest a remedy that could be speedy and complete in its application. As therefore it is useless to dream of impossibilities, we must be content to consider the only schemes which have the slightest appearance of being practicable.

Into the question of fogs simply the writer does not propose to enter. They probably arise in a great measure from the want of drainage of open spaces. He must leave this matter in the hands of scientific men who make a special study of it. It is more within his province to deal with smoke, which is only connected with fog by rendering the latter exceptionally offensive.

1. *The Use of Gas.*

One scheme for getting rid of smoke is to warm our houses entirely by gas, but this scheme is met by exceedingly strong objections. The cost is very great, as gas has to be produced from coal, and we have to pay the expenses of manufacture, the expenses of supply, salaries of collector, measurer, secretary, and other officers, together with interest on money invested. Next our houses are so constructed that we have incessant down draughts in some chimneys, and sluggish currents in others, rendering it most disagreeable in some cases to use a fire at all, and in all cases of down draught it would be impossible to use gas. We may just as well have a smoky room as a room filled with the products of combustion from a gas stove.

The author would upon no account state anything to the prejudice of modern inventions, but as a justification for his remarks he must state the unsatisfactory experience he had, as a manufacturer, of the use of gas for warming some twenty-five years ago or more. The cost was so great and the smell of gas so often complained of that few continued to use it except for small purposes, such as giving occasional warmth in a small office or dressing room. The use of gas for cooking has been a great deal more successful.

2. *Anthracite Coal or Coke.*

A second scheme is to burn coke or anthracite coal, but these are unfit for open fireplaces as they are flameless and easily emit offensive products when not burnt in stoves specially constructed for them. Such stoves are close stoves, used generally in halls, to burn on the slow combustion principle, with no open fire and only a small supply of air admitted below the fire. We must bear in mind that in Wales and elsewhere, anthracite coal is used from necessity and not from choice. It is within easy reach and very cheap. In introducing it for open fires in England two suggestions are made, the nature of which should be clearly understood. One is that a blower should be used by which a fire might be lighted with moderate ease and a dull fire brightened. The disadvantage of the blower has been often pointed out. It may brighten a fire for the time being, but it causes a powerful draught in the chimney, through which the air from the room passes away with greatly accelerated velocity, and it checks radiation into the room from the heated fire-bricks at the back and sides of the grate. The escaping air has of course to be replaced by fresh air from doors and windows, otherwise a room becomes unbearably close. This may occasion draughts. If, moreover we check draughts, by closing windows and doors very carefully, the closeness increases, the draught in the chimney becomes sluggish, and products of combustion pass into the room simply because they cannot pass freely away by the chimney.

Dr. Siemens' Grate.

This grate, just introduced, is an attempt to combine the two systems of using gas and anthracite coal. As the writer has no personal experience of the grate, and an enquiry is about to be held into the comparative merits of different systems, he abstains at present from expressing any positive opinion upon it.

Tax on open Fire-places.

A third scheme is to levy a tax on all open fireplaces, but this would be so opposed to our habits that we can hardly conceive a proposition that would be more unpopular. Those who remember how rapidly Mr. Robert Lowe's proposition to tax lucifer matches was extinguished by a storm of unpopularity or opposition, and how detestable the window tax was considered some thirty years ago, will probably consider that a tax on open fire-places would be as unpopular as a tax on any necessary article of wearing apparel. Dr. Carpenter has been reported to have recommended that the tax should be on all fire-places not constructed so as to consume their smoke. If this was the case he should surely have been prepared to show that the prevention of smoke was easily within the reach of the public. His panacea is gas.

4. *Heating a number of houses from a single source.*

A fourth scheme is to heat a large number of houses, say 20, 50, 100, or more, from a single source, by means of hot-water pipes, steam pipes, or heated air, the furnace to supply the hot water, steam or warmed air being under the control of a superintending engineer and fireman. The author has discussed the scheme in previous volumes, but the only attempt to carry out the suggestion, so far as he has heard of, has been at Lockport, in the United States, where as many as 200 houses have been heated, supplied with hot water, and heat for cooking from a single source. This plan was described by Mr. George Maw, F.G.S., in a letter to the *Times* some two or three years ago. The difficulty of applying this system to existing houses appears to be overwhelming. It could therefore, only be attempted in new districts as at Lockport, and by capitalists of good intelligence and enterprise.

5. *Heating Houses entirely by Hot Water, Steam or Hot Air.*

A fifth scheme is to heat our houses entirely by hot water, steam, or hot air, having a furnace in the basement, a single furnace chimney, and requiring under penalties that this furnace should be so constructed and used as to consume its smoke. The objection to this scheme is that it is quite inapplicable in so variable and temperate a climate as ours, and is only suitable for places where the temperature in winter is permanently low. The scientific difficulties are great and the cost places it altogether beyond the reach of the ordinary householder.

6. *Carrying off smoke by descending flues into sewers, and thence into powerful chimney shafts, to be erected at suitable intervals, the smoke to be consumed as far as possible in powerful furnaces burning perpetually at the bottom of each shaft, the unconsumed smoke and other products to be discharged in the open air at a great elevation.*

An alternative scheme has been to utilize our present chimneys to discharge the smoke over our roofs into horizontal channels and to carry these channels into great chimney shafts, for the smoke to be consumed and discharged. Who was the originator of the first suggestion is not at all clear. It was alluded to by Dr. Reid very many years ago, and at the Exhibition of 1851, a model of the section of a house was exhibited by a civil engineer, in which the chimneys were shown to be placed in communication with the sewer, by means of smoke drains, descending currents being supposed to carry off the smoke from every fire-place. The sewer was probably supposed to be placed in communication with a powerful furnace and chimney shaft, which kept constantly at work, would both ventilate the sewer and withdraw the air and smoke flowing into it from the smoke drains. The smoke was of course to become consumed in the furnace, and assuming this to be effected, the advantage of the system would be a purer atmosphere, a system of ventilating sewers, and the substitution of a large number of ornamental chimney shafts in place of a multiplicity of chimney-pots. Some, it appears, have gone so far as to suggest that we might then enjoy gardens on the roofs of our houses.

Between conception and execution, however, tough work has often to be done. It would be a good thing to ventilate the sewers. They now sometimes vitiate the air of towns most abominably, and it appears to be not improbable that furnaces may be extensively erected for ventilating them. There can be no doubt that the constant rarefaction of the air in the sewer would occasion air to flow into the sewer at any existing openings. If these openings were in the roadway, air would descend at such openings. If the openings belonged to the smoke drains from the houses, air and smoke would flow down those smoke drains. It is, however, absolutely necessary that each part of the arrangement should be carefully adapted to each other. If the smoke drains were not of sufficient size ; if the sewer did not exceed in dimensions all the various openings put together ; and if the furnace were not of sufficient power to maintain a constant state of rarefaction throughout the sewer, there could only be a most disastrous and complete failure. If, to look at the question of dimensions, so small a computation as three square feet be assumed for two smoke channels from a single dwelling, and if it be assumed that a furnace and chimney-shaft be allotted for a double line of houses containing fifty on each side, the sewer for the purpose of removing smoke alone must have a sectional area of three hundred square feet, or be about seventeen and a half feet square, and there can be no doubt that the chimney-shaft would have to be still larger; for, however powerful the furnace might be, if the whole body of air in the sewer were not perpetually maintained in a high state of rarefaction, the inevitable consequence would be that there would be a descent of air at some channels and no descent, or a variable descent, at others. Any computation with respect to the cost of maintaining such a furnace may be left to those who believe in the practicability of building a sewer as large as a good-sized room, and a chimney-shaft still larger at every 500 yards; and if they are dubious as to the size of the channels requisite for the effectual removal of smoke from every dwelling-house, and, should it be necessary, from every chamber in every dwelling-house, they have but to make a few experiments with descending flues, and they will probably find that the safest course is to profit by a little experience before propounding a startling theory. It may be that other comprehensive schemes for dealing with chimneys and smoke are more likely to command attention than the removal of smoke by the sewers.

Those who have hitherto expressed an approval of the conception have not generally ventured to expound their proposal with any completeness. Nevertheless one of them, Mr. Peter Spence, an able chemist and alum manufacturer of Manchester, published a pamphlet in 1857, called "Coal, Smoke and Sewage, Scientifically and Practically Considered," which has attained some importance from having been brought forward in a most unexpected quarter.* The tone in which Mr. Spence propounds his theories is unexceptionable, but the conclusions

* "Quarterly Review," April, 1866. Art. "Coal and Smoke." The plan has been recently revived.

at which he arrives, and the calm confidence he entertains with respect to the practicability of his scheme, it appears impossible to contemplate without amazement. Mr. Spence begins by asserting that the foul and smoky atmosphere of manufacturing towns is more wholesome than it would be if the sanitary smoke consumer had his way, and the combustion of fuel were made more perfect. Mr. Spence does not like a smoky atmosphere. He pleads only the cause of health. He argues that if we had more perfect combustion, we should have a much larger amount of carbonic acid gas emitted from our chimneys; that this gas is heavier than common air, and descends despite the law of diffusion. Carbonic oxide, on the contrary, which is largely formed in all badly-constructed furnaces, and is the result of imperfect combustion, Mr. Spence considers, remains in the upper regions of the atmosphere, in spite of the law of diffusion, being lighter than common air. The solid carbon of smoke, Mr. Spence considers, does *all that it can* to arrest and destroy noxious and miasmatic vapors, but whether it is very useful in doing so at a low level, where we move and breathe, he does not state. Mr. Spence concludes, therefore, that we had best be content with imperfect combustion and a smoky atmosphere, unless we will adopt a most comprehensive scheme for the removal of all difficulties. He would not only remove smoke by the sewers, but in the case of Manchester, his own city, he would remove all the products of combustion from all the fire-places and from all the furnaces by smoke channels into sewers, and from sewers into conduits, and from conduits to a chimney 600 feet high and 100 feet in diameter, situated away from Manchester, and then discharge the whole into the upper regions of the atmosphere, leaving his now gloomy city as pure as the open fields. Our marvel is not lessened by the anticipation he expresses that artificial heat would not be required at the chimney to maintain the perpetual working of his wondrous system. If there were sufficient power in a chimney to draw warm air down hundreds of thousands of smoke channels, and along miles of sewers and conduits, perpetual motion would be discovered indeed, and it would only be necessary to build a few gigantic chimneys to work all the mills of the United Kingdom without the use of any coal at all. In the event of the chimney not being sufficient, Mr. Spence says "artificial heat could then be supplied to effect that object." He therefore is actually in doubt whether artificial heat is wanted or not. What value that artificial heat would represent, what would be the size of the main sewers and conduits, what would be the cost, and what would be all the conditions for maintaining the air within sewers and conduits, most of enormous and some of gigantic size, in a state of great rarefaction to ensure the perpetual descent by the law of gravity of smoke and air at every fire-place and every furnace, it is, perhaps, hardly within the capacity of an ordinary mortal to determine, and if some of Mr. Spence's computations are examined, it can hardly be supposed that he would be exceptionally fortunate. Mr. Spence has probably no special device for collecting all the noxious products of a fire, of dismissing them into the sewer, and thence dismissing them out of reach. If, therefore, they had to travel there in a current of air, as we now get rid of them, though in an opposite direction, and if the very modest calculation of three square feet were taken as an average for the different chambers of each dwelling-house, it would appear that Mr. Spence's main chimney should not have a less area than 195,000 square feet for 65,000 houses, and if half as much were added for the furnaces and fire-places used in manufacturing operations, the chimney would require to be about 720 feet diameter, or nearly the eighth of a mile, leaving out of consideration any allowances to be made for friction and the avoidance of conflicting currents.

If we may first be allowed a little time to breathe, we may proceed to hope that some other conclusions of Mr. Spence, if also extraordinary, are not entirely convincing. We do not want to be obliged to conclude that we had best retain a smoky atmosphere for the sake of health. The purifying powers of charcoal are well known, but the practical utility of particles of carbon scattered about in large volumes of air is not altogether so conclusive. Our safest course is probably to prevent or neutralize noxious vapors by systematic means where they are generated, instead of allowing them first to pollute the air we actually do breathe and then ascend to a higher level for purification. The opinion that carbonic acid gas falls despite the law of diffusion, and contaminates the lower regions of the atmosphere in large towns, we may hope also reposes upon an unsound theory, and not upon fact. What carbonic acid may do in a perfectly closed vessel is one thing and what it is known to do in our restless atmosphere is another. It has been well ascertained that carbonic acid pervades the air, even to the highest levels where man has travelled in almost exactly the same proportion, and that, though particle for particle heavier than air, it becomes so rapidly diffused that there is little or no appreciable difference in this respect between the air of towns and that on the mountain top or the open plain. It may be satisfactory, too, to add that in the case of some experiments instituted by the commissioners on warming and ventilation for the purpose of ascertaining whether in a crowded school-room and in barrack-rooms at night, occupied by many persons, there was any evidence of the carbonic acid evolved collecting near the floor, the most careful observations demonstrated that there was no such evidence, but that, on the contrary, the carbonic acid became diffused with an extraordinary amount of equability throughout the apartment.

As those gentlemen who bring forward these schemes seem to be in doubt whether a furnace fire would be required at the bottom of each shaft or not, and as they evidently do not realize the enormous cost and the certain failure of the gigantic undertaking, it may be as well they should know that smoke would not be got rid of unless it was consumed in every separate fire place. The scheme has recently been revived in a letter published by the *Spectator*, entitled "*the Smoke Difficulty conquered*," in which the case is cited of a mansion near Ashbourne in Derbyshire, where there are no chimney-pots on the roof, but the smoke is carried off by descending flues and underground channels to a shaft situated in the grounds. As no information is given of the real working of the system, the cost of coal in the district, and the annual cost of keeping a furnace going at the bottom of the shaft, the example is of no real value. We may be quite sure that few gentlemen would care to have something that looked like a factory chimney within their grounds for the mere pleasure of having no exits for smoke over the roofs of their houses. It is perhaps characteristic of a portion of the Press that though the letter suggesting this scheme was inserted in the *Spectator*, another letter from a person of some experience, entitled "*the Smoke Difficulty unconquered*," was refused admission by the impartial and magnanimous editors of that paper.

As these schemes appear to afford us no prospect of relief whatever, so far as this great metropolis is concerned, we may turn to a last scheme which, though it may afford us no immediate prospect of relief, may not be so hopelessly unpromising as the six schemes mentioned above, and be well worthy, therefore, of very serious consideration. Gas and anthracite coal may be used by those who like them, but the great mass of consumers will be glad to retain the use of the bituminous fuel to which they are accustomed and to know how this may be done with considerable economy and an almost entire immunity from smoke.

How to use bituminous fuel in open fire-places with little or no smoke.

If we carefully observe a coal fire, we will soon see that there we have scarcely any smoke, except when a fire is lighted or when fresh fuel is thrown on the fire. The reason of this is that smoke consists chiefly of vapour driven off from the fuel by the application of heat, which carries with it minute particles of carbon, giving the vapour the colour to which we are accustomed. If, however, we forbear altogether from throwing coal on the fire and reverse the process by introducing fresh fuel below the fire, the vapour escapes invisibly and the particles of carbon are consumed in passing through the superincumbent layer of heated fuel. To accomplish this a great many different plans have been suggested in past years and patented. By most of them a fire has been made on the top of a body of coal considered sufficient for a day's consumption. The lower strata of coal have been protected from the action of the air and these strata have been raised higher and higher as the fire has burnt down, to furnish a fresh supply of burning fuel, but fuel from which there is no smoke. The principle is very much the same as that on which a wick is burnt in a lamp. The author has described the whole of the different schemes in his book on "Domestic Fire-places." By Dr. Arnott's plan, introduced in 1854, which was practically a revival of Mr. John Cutler's, introduced in 1815, a coal-box was contrived below the fire bars with a lifting bottom to raise up the coal to the air as the fire burnt down. An ash-pit and machinery for lifting the coal had to be provided. In other schemes the machinery materially differed. By Mr. John Young's plan, a trough to contain coal broken small was provided on the front hearth between the fire bars and by means of an archimedean screw placed within the trough, fresh fuel was screwed up into the fire from below from time to time. These schemes have never yet taken any permanent hold on the public mind, notwithstanding the influence of the distinguished man who thoroughly understood the nature of the principle involved. This has been partly owing to the expense of introducing any new system, over which expense any manufacturer has no real control, and partly to the fact of the systems suggested not being sufficiently simple. Dr. Arnott's system failed in public estimation, not because the essential principle was a mistake, but because of defects in carrying it out. The sunk ash-pit was a mistake. The machinery for lifting the coal was a mistake. The grate was heavy in appearance, and the falling of dust and coal in front of the grate was considered unsightly. Nevertheless it has been used for a great many years by distinguished men. Sir William Gull has used it for many years and recommended it to his patients. His own grates were used by his predecessor, Dr. Todd. Sir Roderick Murchison used it with great approval, and Mr. Thomas Burgoyne, a well-known solicitor in Marylebone, in the course of about ten years changed the whole of his grates in two large houses in Stratford Place, made presents of grates for a public school and elsewhere to facilitate their introduction, and stated in his usual emphatic manner to the writer a year or two before his death, that in fuel alone he had saved enough to pay for his grates over and over again.

Figure 75 with section represent Dr. Arnott's grate. Figs. 76 and 77 represent the writer's. Instead of the old machinery he substitutes a draw or blind to move up or down in front of the body of burning coal, he avoids the ash-pit altogether in fig. 77, and he provides simple and ornamental appliances to avoid a heavy appearance and the sight of dust or cinders in front of the grate. The writer may add that in his own office one of Dr. Arnott's grates is in use which was put up twenty years ago, has been used continuously in cold weather, and that the chimney has only been swept twice during that period. If the nature of the principle be appreciated, quite irrespective of any particular contrivance for using it, there can be little doubt that invention will be stimulated and a great advance will be made. Propositions have recently been made to send our fuel to the gas works to have the vapour drawn off and the fuel rendered smokeless. This we must pay for—and it is probable we shall have a flameless and cindery fire, but by preparing the coal ourselves simply in the process of each day's consumption, we may do it without cost, without smoke, and we may readily make the fire as cheerful as we please.

Use of Fuel in Kitchens.

If by means of "smokeless" fires we get almost entirely rid of smoke from the open fire-places of our offices, sitting rooms and bed rooms, it will give us the greatest satisfaction to know that in our kitchens we may get rid of smoke still more effectually. That our whole system is utterly wrong was pointed out by Count Rumford eighty years ago. It was pointed out by the writer eleven years ago. Count Rumford's voice was that of one crying in the wilderness so far as this matter was concerned, and the writer has fared no better. To make short of the matter, we do wrong in using an open and necessarily a most extravagant fire for all the kitchen purposes of a household; to heat sometimes a large quantity of water, to heat ovens for roasting and baking, to roast occasionally in front of the fire and to provide a hot plate for saucepans, stewpans, &c. By this system we consume an enormous deal of fuel, we produce a large amount of smoke, and we stop up our flues so rapidly with soot that they have to be cleaned out once a week. The remedy is to give up the wasteful system altogether and to adopt a rational one. A rational system consists firstly in using a boiler with a closed fire burning beneath it to provide the whole of the hot water required by an establishment. In this fire anthracite coal or coke should be used, to be replenished only once in a few hours, which would enable a warm bath to be used at any time of day or night without disturbing servants. By this we may have the strictest economy, great convenience with little trouble, and no smoke. A rational system consists secondly in heating our ovens for roasting or baking by means of a closed fire placed beneath them, in which anthracite coal or coke may also be used, the fire never to be lighted except when absolutely required and allowed to go out after the roasting or baking has been done. It is now generally known that by ventilating the oven and using the water dish to prevent burning of fat, as recommended by Count Rumford, roasting may be done as effectually within a roasting oven as before an open fire. By this we may also have the strictest economy with little trouble and no smoke. A rational system consists thirdly in heating the hot plate by a separate and closed fire, in which anthracite coal or coke may be used. This, however, requires that the hot plate should be made in one piece with only a cover over the fire. This is because anthracite coal and coke are flameless and we have to depend for heat entirely on the laws of conduction of heat. In a large number of cases the gas hot plate may be used instead of a hot plate to burn anthracite, and this may undoubtedly be used with economy for this reason, that a burner or set of burners may be lighted, used just as long as necessary, and instantly extinguished. For small households an American stove to burn anthracite coal or coke may be used and a small gas boiler for occasional use. By these various means we get rid of the entire smoke of the kitchen department and in the vast majority of households we effect a very great economy. The question will however be asked: can our servants submit to or take a liking to it. Yes, undoubtedly they may. We must provide them, however, with some economical open fire-place in the basement on the smokeless principle at which they can warm their fingers, toast bread, cook a chop or boil a little water instead of lighting the gas stove. Bye and bye we may find that even this may be dispensed with. As regards using separate closed fires and a hot plate, whether for anthracite coal or gas in connection with our kitchen chimney this is quite as easy a matter to an experienced person as the adoption of our present most extravagant system. At first sight the proposed system may appear complex and not favourable to economy, but the more the whole subject is understood or carefully considered the more it will appear that it is in every respect in advance of the system at present adopted. By the various means suggested, by the use of smokeless fires in our sitting rooms and bedrooms, and by the use of anthracite coal, coke or gas for all cooking purposes we may undoubtedly get rid of about nineteen-twentieths of our smoke, and this is as much as we can accomplish as long as we retain the use of any open fires and bituminous fuel.

CHAPTER IV.

MODERN FIRE-PLACES, VENTILATION AND SMOKY CHIMNEYS.

THE intimate connexion between warming and ventilation is obvious from the fact that our fires require air, so do we. Fireplaces act both to warm and to ventilate, but in answering the useful purposes of carrying off air from our rooms and the smoke from our fires, we must see that they do not act injuriously by carrying off warm air greatly in excess of what is required for good ventilation. A short consideration will make the matter perfectly clear. When our rooms are warmed by open fires we depend for artificial heat upon that which the fire radiates on the floor, on the ceiling, on the walls, on the furniture, and on our own bodies. These different objects warm the air of a room, which is in a state of incessant movement, even when we are unconscious of it. If the air of the room be withdrawn with moderate rapidity fresh air will enter by the doors, the windows, or by other means provided to replace what passes away. Our rooms are then warmed without any great waste and we have good ventilation, but if the air of our rooms is withdrawn with great rapidity, air enters with proportionate rapidity wherever it can, it makes a room feel cold and draughty even with a good fire burning, we have ventilation greatly in excess of what we require and a great waste of fuel. If, moreover, we prevent draughts by carefully excluding the fresh air, the room becomes close and oppressive, the current in the chimney becomes too sluggish to effectually carry off the smoke and other products, some of them are emitted into the room and we have thoroughly bad ventilation. It will be seen therefore how extremely important it is—first, that air should not pass away by our chimneys with a greater velocity than is required to carry off smoke, &c., and to change occasionally the air of the room ; and secondly, that fresh air should be allowed to enter with sufficient freedom to replace what actually does pass away. Now, at what rate does air pass away from an apartment ? This depends 1. on the height of the chimney. 2. The presence of obstructions in the chimney, such as soot, bends, a damper or register to the grate, &c. 3. The freedom with which air is admitted. 4. The difference in temperature between the air within and without. 5. The sort of fire which is kept burning. The whole subject has not undergone a sufficiently thorough and scientific investigation, but we may probably take Captain Galton's estimate as approximately true. He believes that at a low computation, 4 to 6 cubic feet per second, or 14 to 20,000 cubic feet per hour, pass up an average chimney with a fire burning, and that in a room 20 feet square and 12 feet high, the air is changed four or five times an hour. He also believes that frequently from 30 to 40,000 feet per hour pass away by a chimney alone. This estimated escape of air by chimneys is fully borne out in the Parliamentary Report on the Warming and Ventilation of Dwellings published in 1857, by which it appeared that in certain rooms with lofty chimneys, 500, 600 to 1000 cubic feet of air per minute passed away by the chimney, or from 30 to 60,000 cubic feet per hour. We can now understand why it is that our system of warming is so costly compared with that in use on the Continent, in North America and elsewhere. We allow in a vast number of instances of ventilation greatly in excess of what we require, and the air which provides it comes in cold by our doors and windows. Now, a very little consideration will show, that fireplaces may be easily constructed so as to send a maximum or minimum quantity of heat up the chimney. The first are the most extravagant grates which can be used, by whatever names they may be called, and the only strictly economical grates are those which carefully regulate the escape of air by the chimney, and which provide that the fresh air shall come in warm instead of cold. Now let us apply these remarks to the consideration of some recent grates.

1. *Captain Galton's Ventilating Grate.* See figs. 78 and 79. This fire-place is very contracted, forming a sort of basket of fire lump. In the centre is a small metal grating which allows ashes to fall below, and a small supply of air to enter the fire from below. The fire lump is curved over behind, which promotes combustion and checks the rapid escape of air. Above the grate is a cast metal flue which carries off the smoke to the chimney. Behind the grate is a somewhat spacious chamber, which is placed in communication with an external wall by means of an air channel of suitable dimensions. Above the chamber is an air flue constructed in the body of the wall, and at the top of the air flue is an open grating by which air can be admitted to the room. When a fire is burning, fresh air from outside passes into the air chamber behind the grate, becomes warm, passes up the air channel, enters the room warm at the open grating and circulates freely over the room. We get thus fresh warm air instead of cold, and we have a total absence of cold draught. This air supplies

warmth to our bodies instead of abstracting it, and we have unquestionably the principal conditions which ensure economy in warming with good ventilation. No register door to check the products up the chimney appears to be provided, but as the curved metal flue is itself a great impediment, the necessity for a register or damper is not so urgent as in other contrivances. Captain Galton complains that the grate has not had a commercial success, and seems to think it is because he has not had a patent, but in this he is mistaken. It has not been commercially successful because the grate is heavy in appearance, having been constructed for barracks, also because it cannot be adapted to existing rooms, except at great inconvenience and expense, and because the subject of warming and ventilation is most rarely understood.

2. *The Country Parson's Grate.* See figure and section, fig. 80. So much noise has been made about this, chiefly through certain letters which gained the favour of admission in *the Times*, and through a costly system of advertising, that we might suppose a wonderful discovery had been made, and that in the words of the advertising poet: "It came as a blessing and a boon to men."

It is well therefore we should know exactly what it is. It appears to have sprung from the suggestion of the late Mr. Leslie, a tailor of Conduit Street, and a member of the Metropolitan Board of Works, who exhibited it at the Great Exhibition of 1851. He introduced it to the notice of the country parson, whose usual signature "S. G. O." is well known to readers of *the Times.* "S. G. O." got his contrivance made and put up by Mr. Ball, an ironmonger of Blandford, and on "a Country Parson" writing to complain that he could not warm his room comfortably and economically, "S. G. O." under the signature of *Another Country Parson*, gave the public the benefit of his personal experience. His plan was an extremely crude and inexpensive one. You were to pull out the existing grate, form a solid hearth of fire brick, build up a back and sides of fire brick, build in an upright iron bar at each side, and attach in front a "hurdle" of fire bars very thin and each bar only a short distance apart. This hurdle was to project from the brick back only $4\frac{1}{2}$ inches at bottom and $5\frac{1}{2}$ inches at top. The advantages of the system are, that it presents a broad and deep surface of heated fuel, very narrow from front to back with an interior of fire brick, which on becoming heated would radiate powerfully into the room, and that the thin bars intercept less heat than thick ones. The evident objections are :—1. That the heat would often be oppressive except in large rooms. 2. That a fire on a level with the floor does not throw its downward rays on the carpet, as Dr. Arnott clearly demonstrated many years ago. Not only so, but in the Parliamentary Report on the Warming and Ventilation of Dwellings, issued in 1857, there occurs the following recommendation of the Commission appointed. See page 94.

"8. That the fire should not be on a level with the floor; this is made evident by the experiments with Leslie's grate."

3. That the coal becomes quickly converted into coke, which is apt to look dull and to emit offensive fumes when there is not a good upward current in the chimney. 4. That a very shallow fire only suits the best descriptions of fuel. 5. That dust falls down in front and looks unsightly. 6. That when the supply of air to a fire is insufficient, carbonic oxide is formed which is the result of imperfect combustion, is very pernicious and occasions a great waste of fuel. It is just to add that "S. G. O.," as a highly honourable man, has candidly admitted that all his friends are not satisfied with the contrivance.

No scientific man having much experience in fire-places would ever have invented the Country Parson's Grate. However, the parson's letter made, it appears, a great impression on the mind of ex-Alderman Mechi, whose name is usually associated with "the Magic Strop" and amateur farming.* Mr. Mechi tried the grate at his farmhouse, became enamoured of it, wrote to the *Times*, had specimens in his shop in Regent Street, where the world were invited to see it, and finally issued an enthusiastic circular, in which he gave his own description of its merits and offered it to "his friends and the public as his new year's gift." He insisted on carrying out the recommendations of the Country Parson in all their essential features, that the front bars should be eight or ten in number, less than half an inch in diameter, nor more than one and a quarter inches apart; that a solid bottom should be used and that the depth from front to back should be four and a half inches at bottom, and five and a half inches at top. He got his local blacksmith to make his hurdles at five and seven shillings each, pokers sevenpence. He dwelt with such ecstacy on the supposed merits of the grate, as to draw an article from *Punch* of a gently satirical character. He sung its praises but did not dwell on its defects. However, in consequence of his letters in the *Times*, he was led into a large amount of correspondence, and appears to have associated himself with some ironmongers in Norwich who probably offered to make his hurdles and pokers at the same price as the local blacksmith. Mr. Mechi dwelt on the advantages of the system for hanging trivets and cooking in front of the fire, but he said nothing about the trouble of renewing and mending the fire bars when they got bent. He spoke about their being

* It is with great regret that the writer hears of Mr. Mechi's adversities, but this should not hinder him in the performance of a public duty.

effectual for smoky chimneys, and said that by means of a gaslight he could create an upward current in the most obstinate smoky chimney. Mr. Mechi did not explain what was to be done in the case of chimneys where the down current was so strong that it would extinguish a gaslight in a moment. However, the identical system has probably been very little used, and the author has not seen a single specimen in London. But instead of the Country Parson's Grate we have

The Slow Combustion or Norwich Stoves.

Some may suppose that the two are identical, but this is altogether a mistake.

We have seen what the Parson's Grate is. We will now see what the Norwich Slow Combustion Stove is. Instead of eight or ten thin wrought bars, we have three or four cast bars of suitable strength. Instead of an extremely shallow fire this is made much deeper, suitable for different kinds of fuel. The brick bottom is retained, but an option is given to the purchaser to have the open metal bottom if he prefers it. A register is provided in the chimney to check the escape of air, which you may use if you have no objection to put your hand up a hot and dirty chimney and handle an instrument which you cannot perfectly see. A sliding blower appears to be very often used, as it is shown in the whole of the sketches of the grates. This is for the purpose of making the fire burn up rapidly when desired.

The tradesmen who sell this grate claim that it possesses most extraordinary merits. They claim that it consumes from forty to fifty per cent. less coal than others of the ordinary kind, gives "the greatest (*sic*) maximum of heat," "will keep in from eight to ten hours without *any* attention," that "they have been universally praised as the only stoves capable of curing smoky chimneys," that they "will burn every description of coal, as also coke, wood, or peat;" and "will keep the room always at an equal temperature without vitiating the atmosphere."

Now as regards the question of economy, these differ from other grates chiefly in having a solid bottom. We have seen that the effect of the solid bottom is to exclude air from below and to retain the ashes in the fire, except what falls down in front. By excluding air from below, air cannot therefore come freely in contact with the portions of coal which rest on the solid bottom, and by retaining the ashes in the fire we allow them to fill up spaces around the pieces of burning coal. The solid bottom and the ashes together check, therefore, the free passage of air to the burning fuel, and what is the inevitable result? A portion of the burnt fuel is converted into carbonic oxide, and there is imperfect combustion of the fuel together with the chance that one of the most poisonous gases with which we are acquainted may enter our rooms when it cannot pass freely away up the chimney.

A second point in relation to economy is the use of the regulator in the chimney. We have seen how extremely important it is that this should be provided to every grate, and not only that it should be provided but that it should be carefully used. It is upon this that we depend as to whether we send from 20,000 to 40,000 cubic feet of air up the chimney or a quantity of far more reasonable amount. The regulator to check the unnecessary escape of warm air is exactly the same as that shown for the Parson's grate, and as before said, you must put your hand over the fire into a hot and dirty chimney for the purpose of using it. As no one would think of such a thing, the contrivance is very defective.

Another point in relation to economy is the use of the blower, and this appears to be generally or frequently introduced with the Norwich stoves. We have seen the evil of having a regulator in the chimney which cannot be used with facility. The effect of the blower is to make a fire burn with great rapidity. The fire "roars," as servants say, "like a furnace." The cause of the "roaring" is the escape of air from the room and up the chimney with immensely accelerated velocity, so that we have only to use a grate with the chimney opening unregulated, together with the sliding blower, to have the most extravagantly burning grate that it is possible to conceive. Hence no tradesman, who properly understands his business, thinks of recommending the general use of the blower, and no one who wants to warm his rooms with economy thinks of using it unless the conditions with respect to smoke are very exceptional indeed.

It may be remarked that no provision is made in the grate for the entrance of fresh warm air to the room, therefore the air which passes up the chimney has to be drawn from the doors and windows and traverse the room. We appear, therefore, to be forced to come to the conclusion that as a strictly economical grate it utterly fails.

It may be said that the regulator should be carefully graduated by the housemaid after she has lighted the fire, but in all probability there is not one housemaid in a thousand, or perhaps a hundred thousand, who understands its use and cares anything at all about the matter.

The next point alleged is that the fire keeps in from eight to ten hours without *any* attention. Is it seriously meant that the fire will really burn that length of time without requiring fresh fuel and without poking? If so, the contrivance is a wonderful one indeed. All fires require fresh fuel, and they require a certain amount of poking to prevent the coal from caking and to allow the air to find its way freely to the fuel. The only open grates which have been hitherto known to burn for a long time without attention, are the grates which provide a fire to burn downwards like Mr. Cutler's grate, Dr. Arnott's, "The Builders' Fire," those introduced by the present author, and others ; but even these require some attention if you wish to retain the slightest semblance of a fire.

As regards their capability of curing smoky chimneys, we have seen that the most inveterate cause of smoky chimneys is an incessant down current in some chimneys, to replace what passes away by other chimneys, and that this can only be effectually dealt with by providing sufficient air to a house to replace what passes away or should pass away by all the chimneys ; but this the Norwich grates do not provide for to any extent whatever. It may be well, therefore, to state for the benefit of the manufacturers that the only grate which is of itself "a certain cure for the most incorrigible smoky chimney" is the grate in which a fire is never lighted.

As regards burning every description of coal as well as coke, wood or peat, the same may be said of any grate. We may even burn our fingers if we like to do so. The question is whether we like to burn any description of coal, also coke, wood or peat. Some coal burns with great rapidity, leaves a large residue of ash and gives comparatively little heat. This requires a much larger fireplace than when coal of the greatest heating power is used. Coke is seldom used in open fires because everybody knows that it gives a flameless fire, and when the draught is sluggish emits noxious products into the room. Wood and peat giving a small heating power compared with good coal, require that the fires should be exceptionally large.

As regards keeping the room always at an equal temperature, the only grates which provide for this to any degree of perfection, are those which allow of the entrance of fresh warm air and check draughts from doors and windows, and as regards vitiation of the atmosphere this must depend entirely upon whether the noxious products of combustion can escape into the chimney with sufficient freedom.

As regards the retention of the solid bottom, this appears to be objectionable on several grounds. We have seen that the dust cannot fall below and that air cannot pass with any freedom below the lower stratum of coal. Our forefathers did not use solid bottoms even when wood was used, though this is a small matter. The logs of wood were supported on andirons or fire dogs, with an end of each log resting on the hearth, or they were supported by iron bars placed across the andirons, so that the ashes might fall on the hearth and air might assist in keeping the logs in a state of ignition. When the fire basket or *fyre cradelle* was introduced for burning coal, the bottom was made of separate bars. On the Continent the same practice appears to be universally followed. In our furnaces and locomotives no one appears to dream of suggesting that coal should be burnt on a solid bottom.

The author hopes he has not criticised these grates with an undue amount of severity, but when such extraordinary pretensions are put forward, an injustice is done to the public, who are not sufficiently familiar with the subject, and to other manufacturers or dealers who are more accurate in their statements. As the grates appear to be manufactured in Norwich, as carriage is paid to London and carriage is offered to be paid to any railway station in the Kingdom, it seems reasonable to conclude that they are sold at prices capable of remunerating the dealers after paying expenses of advertising.*

* We should probably have heard nothing of these grates but for the use that was made of the *Times*.

The "Abbotsford" Grate. See fig. 81. This is a very ordinary grate with a solid brick bottom. An open tray in front is used to hide the ashes. There seems to be nothing novel about it except the name.

Conclusions.

The great deficiencies of our modern fire-places with respect both to warming and ventilation will be evident from preceding remarks. If it be true that by some chimneys we discharge as much as twenty to forty and even sixty thousand cubic feet of air per hour in a single case, it is quite time we asked ourselves the question, where does the air come from? We may be sure of this, that we do not exhaust entirely the air of our rooms, or we should die of inanition. The air which passes away by some of our chimneys in such enormous quantity is replenished from our doors and windows, occasioning draughts of cold air. To furnish the supply which enters by our doors, air flows up the kitchen stairs from the basement, bringing with it the smell of cooking operations. Air descends the chimneys of the upper floors, especially the top or the attic floor, and finds its way down to the lower floors, rendering the upper ones cold and uncomfortable. It renders the fire-places such that a down current is extremely common, and it is scarcely possible to use a fire without the chimney smoking. And air descends the short chimneys built outside a house for additional comfort and convenience! rendering such chimneys the most incorrigible with respect to smoke of any that can be found. More than all, air enters our houses by the numerous escape pipes which communicate with our drains and sewers, bringing with it contamination that need not be dwelt upon.

As a panacea, our sanitary engineers recommend that we should prevent any direct communication between our waste pipes and our sewers, and they recommend that ventilating pipes should be carried from our soil pipes above the roof of the house. These recommendations, however, do not solve the difficulty. What is to be done in the case of the hundreds of thousands of houses already built? and what is to be done if the drain gas can enter a house with as great a facility as it can escape by the ventilating pipe? We may be quite sure the drain gas will not pass up the ventilating pipes simply to satisfy the theories of sanitary engineers. The answer to these questions is very simple, and when thoroughly understood will undoubtedly be embodied in fresh amendments to the Building Acts.

Firstly, we should and must control the enormous quantity of air which passes away by all chimneys with a powerful draught, unpolluted or unbreathed. Secondly, we should and must insist on a systematic admission of fresh air in connexion with every fire-place, to replace the quantity of air which escapes from the room by the chimney, so that we may not depend on a mere chance supply by doors and windows. As regards the first point, we would not hesitate for a moment if we had an air meter or "anemometer," with which we could as readily measure the escape of air as we can measure the passage of gas or of water. But though we cannot measure the quantity except with refined instruments and most careful observation, it is very easy to put on an effectual check to the extravagant escape of air. This is such a regulating register as shown in Figs. 76 and 77, which any person may close more or less by means of a handle in the room, and have under his entire control.

Secondly, we should undoubtedly insist on the systematic introduction of sufficient fresh air without draught, to replace what passes away by the chimneys when they are under due control. This does not mean that we should supply fresh air to go straight up the chimney and leave the room unventilated. Not at all. It means that the fresh air which enters our rooms in winter should come in near to the fire-place instead of having to traverse our rooms occasioning draughts. It is just as likely to circulate freely over the room as air coming from doors and windows, and it is more likely. Air coming in from doors and windows rushes at once to the fire-place, but air coming in in proximity to the fire-place becomes warmed, ascends to the ceiling and circulates in the room before it finds its way to the chimney. A crude method is to introduce the air cold as by fig. 67. A far preferable method is to introduce it warm as by fig. 68, by Captain Galton's plan, fig. 78, &c., or by plans adopted by the author, such as shown in fig. 84. He prefers however, to adopt the system of admitting fresh warm air by carrying a smoke flue from the grate to the ceiling, with a warm air channel around it, and to allow a second supply of fresh warm air to enter the room below the ceiling through an open grating. The utilization of the waste heat from the grate to the chimney is a distinct improvement on Captain Galton's system, and carries out to a limited extent the utilization of waste heat which the writer has written about in previous volumes, and which will be shortly dealt with in the next chapter.

Figs. 85 and 86 represent the late Wm. Pierce's system of introducing fresh warm air into a house. This system so often commended in this volume, is identical in its principle with that of M. Gauger, Dr. Désaguliers, the Marquis de Chabannes and many others, and is undoubtedly the system which we should insist on having introduced in our houses, if we wish to have them well and economically warmed. By this system we can get rid of smoky chimneys. The question of preventing or consuming smoke has been dealt with in the previous chapter.

CHAPTER V.

SOME CONSIDERATIONS ON THE UTILIZATION OF WASTE HEAT FROM OPEN FIRE-PLACES, AND ON A COMPREHENSIVE SCHEME FOR THE SUPPLY OF HEAT TO DWELLINGS.

OF the hundred-and-thirty million tons of coal which were raised last year from the coal mines of the United Kingdom, it has been supposed that about one-third are used in fire-places for warming and other household purposes. That the consumption will continue to increase at a most rapid ratio with the increase of population and the diffusion of wealth, and in spite of any possible improvements for economising it, no one can doubt, who is familiar both with the discomfort that is very generally endured from ill-warmed dwellings, and with the great amount of privation to which masses of the poor are subject. But if we have no choice but to proceed in the gradual exhaustion of our coal mines, it appears, nevertheless, only a matter of common sense and prudence that we should give the most serious attention to any schemes that may appear to be unquestionably calculated either to avoid wasteful expenditure, or to extend the utility of whatever is consumed. Coal has increased of late years in price. At all places a little removed from coal mines it forms an important item of domestic expenditure, and as, to speak with human foresight, we may never find a satisfactory substitute, it would appear to be only reasonable that if improved methods of using coal were propounded, they should rapidly command adoption. Unfortunately, however, valuable propositions often remain for a long period of very little avail. The great difficulties attending the extensive introduction of any new system, or even of a modification of an existing system, the fact that the mass of existing dwellings cannot be readily transformed, and that with reference to new structures every builder avails himself most fully of his liberty to do just as he pleases, are sufficient to render any persistent efforts most onerous and discouraging. But though, in an enlarged sense, individual effort may generally appear to be most powerless, it is to that we owe the hundred thousand ramifications which make up the sum of our civilization, and it may not, therefore, it may be hoped, be altogether an idle task to endeavour to contribute some little enlightenment on a subject that may receive fuller development at a later period.

Propositions for reducing consumption, or for obtaining increased benefit from the coal consumed, may relate either to the construction of the fire-place, with a view to obtaining good combustion and diffusing heat; or to the ventilation of the apartment, when the quantity of air admitted and the means of admitting it are taken into consideration; or to the constructional arrangements of a dwelling with respect to its capability of retaining the heat developed, and protecting against the influence of cold air on exposed walls and windows; or it may, lastly, relate to the utilization of the heated air and products which escape by the chimney. Upon the subject of the construction of the fire-place and ventilation but little need now be said. It is known to many, and should be matter of more common observation, that much may be gained by the use of proper materials in constructing a fire-place, by attention to the laws of radiation and reflection, and by such means as promote good combustion, and insure that, at the same time, a fire shall burn with steadiness, and, as far as possible, with regularity. Equally important it is that careful attention should be paid to the quantity of air that escapes from the room. It is well to have an ample amount of ventilation, but an excessive amount occasions much waste and discomfort. In many fire-places, when a fire is burning, a quantity of air is discharged by the chimney, in the course of a few minutes, equal to the whole contents of the room. We may be sure that, if there is any sensible current near to the fire-place, the passage of air in all ordinary cases is excessive, and that the evil should be diminished or removed by the use of a proper regulator to control the opening into the chimney. The Commissioners on Warming and Ventilation were so convinced of the importance of this point, that they emphatically expressed their opinion that the fire-place should be studied with a view to its efficiency for warming purposes only, and that ventilation should be effected entirely by other means. Such a conclusion does not involve the surrender of the fire-place altogether as a means of ventilation, whatever may have been the Commissioners' intention, but it involves the surrender of all ventilating power beyond what is necessary for the effectual removal of smoke. If the aperture from the fire-place to the chimney were reduced to the smallest dimensions compatible with its fulfilling its express purpose, there would still be a great deal of ventilation, though no perceptible current. It would not usually be safe to trust to such a limited aperture alone, and therefore the use of a chimney ventilator in existing buildings, or special ventilating channels in new constructions, would become necessary. If also a special supply of air were allowed to enter the room in proximity to the fire, for the purpose of checking the draught over the floor, as already described, any fire-place would appear to become transformed with respect to its capacity for warming an apartment to an extent somewhat marvellous to those whose experience is only gained from ordinary practice.

Next to the waste of heat by a too rapid escape of air, there is a source of loss of far greater importance than is generally conceived, and one that is by no means unsusceptible of remedy. We appreciate the advantage of a house being built with good solid walls, and in a situation not exposed to bleak winds, but over a considerable surface we interpose between ourselves and the cold atmosphere nothing but a thin sheet of glass. Glass is a substance of the highest utility, for, without it, what could the history of this country have been? but it is possible that its value to us might be considerably augmented. If in giving us light, it prevents the escape of heat and excludes cold to a considerable extent, what have we to do but adopt the suggestion of interposing another sheet of glass for the purpose of retaining more heat and diminishing still further the influence of the cold air without. That this would be an investment which would bring ample returns in comfort and economy there is not the slightest doubt. If our window sashes be made a little stronger, if they be provided with double panes placed at half an inch or more apart, the sensation to a person standing in proximity to them on a cold day will be something very different to what it is at present. Better still than double panes are double windows, which enable the panes to be a much greater distance apart; but this plan entails much greater expense. The merits of both systems were investigated by the Commissioners on warming, among their other useful labors, with the result that they felt compelled to recommend the general use of double panes in the same sash for small rooms, and double sashes, placed not less than five or six inches apart for large rooms. The details of the Commissioners' experiments are most interesting and valuable, but not so conclusive as they would have been if their inquiry had extended further. In the case of the double panes the glass was only separated a quarter of an inch, in consequence probably of the adaptation having been made to existing fittings. If the space between had been half an inch or more the result would have been still better. The effect of the double pane is perhaps most strikingly apparent in windy weather, when a cold blast of air striking against a window causes at intervals a sudden fall of cold air within, which is most unpleasant to those who, like clerks in counting-houses and others, cannot make a free choice of position. There are cases where so simple a remedy has made that bearable which occasioned the greatest discomfort before.

Double panes, like a good wall, are useful both in summer and winter. Like all non-conducting materials, they keep out the rays of the sun at one time and retain the heat of the fire at another, and their utility is so unquestionable, they entail so little outlay, and that only in first cost, that we may hope some day to see the system sufficiently recommended or insisted upon to ensure its very general introduction. We have probably in the matter of dwellings aimed too much at display and given far too little attention to the means of promoting health, economy and convenience.

If it cannot but be a matter of surprise and regret that a most obvious and inexpensive method of promoting the comfort of rooms in winter and economising fuel has been all but entirely neglected, there is room perhaps for equal astonishment that another promising source has remained not only unapplied but uninvestigated. We allow a large body of warm air to escape by every chimney in which there is a fire, but, from the laborer who rents a cottage with a bed-room over his sitting-room to the South Kensington mansion, rented at £800. a year, not the slightest attempt is made to turn the heated products to account for the purposes of warming. In many cases a large quantity of heated air, amounting to many thousands of cubic feet per hour, passes from the kitchen fire by story after story, by dining-room, by drawing-room, and by bed-room after bed-room, without answering in its course any useful purpose whatever, or perhaps kitchen, dining-room and drawing-room each furnish their wasted contribution. That such a subject deserves the most careful consideration none can doubt for a moment.

In the last chapter some methods were described by which the heated current in a chimney was so far utilized that it was made to rarefy the air in a distinct flue or channel set apart for the purpose of ventilation, and an attempt was also made to show how the crude suggestion of the Commissioners on warming, for uniting several smoke flues in one main flue, and several ventilating channels in one main ventilating channel, might be modified to such an extent that it could be offered to architects and builders, with a reasonable assurance that it was worthy of their consideration and adoption. Now, let us suppose that the single smoke flue, with the communications from several fire-places, was adopted, and let us suppose that instead of the large ventilating channel being used for the purpose of providing for an escape of air, it be used to supply a current of warm air to every apartment with which it was placed in communication, and that all the lower chambers of a house were made thereby to contribute heat to the upper ones we might thus utilize an enormous amount of waste heat. The only satisfactory proof of the utility of such a scheme would be to adduce an instance where it had been carried into effect, and where the various results, whatever they might be, had been well ascertained, but, in the absence of any such case, it may be useful to attempt a short consideration of what may appear to be the conditions which would enable such a system to receive the success of which it might be susceptible. In the first place, to change a channel for the escape of air into a channel to admit air, the aperture provided over the roof has to be closed, and a proper provision has to be made below for a free admission of fresh cold air from an external source to the lower part of the channel. This free admission of air to the channel is most important, and could be provided for by means of ornamental perforated bricks, fixed in an external wall, and made to communicate as directly as possible with the channel. For the admission of warm air to the rooms, apertures capable of regulation must be provided near the floor instead of near the ceiling, because a low level is generally the best position for introducing a current of warm air, and care must be taken that the total amount of apertures in the various rooms do not exceed the area of the warm-air channel, or there may be a liability of the warm air passing by one room and ascending to another. For the escape of air, the fire-place may be supplemented by ventilating flues of proper area in the partition wall opposite the windows, as already described, or in the party-wall. The remaining condition appears to be, that the smoke flue should be of cast iron, and not of fire-clay or brick. This last condition may be calculated to frighten those who object under all circumstances to the use of heated metal, but a little consideration may suffice to show that their fears in this particular instance are groundless. There can be no doubt that over-heated iron injures the air, but instead of objecting to the iron, it is perhaps best to render it impossible for the iron to be over-heated. From its power of conducting heat, iron is under some circumstances the best material that can be used. Under other circumstances it is the worst. An iron building is most objectionable, from its great susceptibility to all the vicissitudes of temperature without. A brick building, on the contrary, retains the heat within, and protects us from the rays of the sun from without. Iron is objectionable at the back of a fire, because it allows heat to pass away. Brick, on the contrary, retains the heat and radiates it powerfully. Used for the smoke channel, iron, from its conducting properties, will therefore, like the iron building, and like hot water pipes, allow the heat to pass rapidly through it. Brick or fire-clay, on the contrary, will, like the brick building, retain the heat within, but in this case injuriously. All that is necessary is, that the iron should not be over-heated, and of this there is not the slightest possibility, as the heated products could not succeed in raising it higher in temperature than from 80 deg. to 100 deg., just sufficient to impart a pleasant and wholesome warmth, but far below what is attained when air is rendered offensive.

With such precautions being taken, there appears to be no reason why a series of rooms should not be supplied with currents of warm air sufficient to protect against the chill and damp of the coldest weather, and this by the utilization of heat, which is now absorbed by the brickwork of chimneys, or otherwise almost entirely wasted. Figs. 102 to 104 represent sections of a house with the main smoke flue, the communications from various fireplaces and the warm-air channel, with its communications with the external atmosphere and with the various apartments. The arrangement being carried out as described, a constant stream of air would be found to enter the warm-air channel by means of the pressure of the external atmosphere at the apertures, which should be somewhat abundantly provided, then to ascend and become warmed by radiation from the metal flues, and enter various rooms when desired. The separate channels for the escape of air from the rooms, and attention to the fact that fresh air must not be admitted with too much freedom by windows or doors, when it is required for the warm-air channel to operate, appear to complete all that is necessary to insure a very substantial success. Several minor matters relating to construction would require to be elaborated in the carrying out of such a system, but that every difficulty would be removed with the aid of close attention and a little patience, there cannot be the slightest doubt.

It is not often that there is any attempt in periodical literature to discuss questions of Smoke and Heat, and many must have been therefore interested to observe what were the comments of a writer in the *Quarterly Review* (No. 238), who in an article entitled "Coal and Smoke," endeavoured to enlighten the public. Amidst a variety of interesting matter, very well put together, occur some observations relating to the use of fuel for domestic purposes. It is easy enough to perceive that the writer is highly dissatisfied with present arrangements, and that, desiring to take an enlarged view of the subject, but not seeing his way clear with respect to the facilities or difficulties attending any particular system, he is tempted to place faith in the schemes which appear to be the most daring, but are not possibly the most trustworthy. He follows Dr. Arnott in the opinion that, "if we could only be induced to give up our prejudices, and prefer reality to semblance, there would be no difficulty in warming and ventilating our houses *with a fraction of the* *coal which we now employ.*"* The assertion here italicized is rather a daring one.

To support his position he quotes a passage from Dr. Arnott, in which the learned doctor professes to have maintained "for fourteen years past, in a large dining-room, day and night, from October to May, a temperature of 60 deg. or more, *with good ventilation*, by an expenditure of only twelve pounds of coal for twenty-four hours" by using one of his own close stoves. The quotation is a startling one, but requires explanation to be fully convincing. Particular stress is laid upon the point that there was only an aperture equal to a diameter of three-quarters of an inch for the admission of air to the fire, and that the metal surface was only moderately warmed. Now, if the doctor's dining-room was warmed to 60 deg. or more, when the external temperature was at 50 deg., which it is during a great portion of the winter, what was the case when the external temperature was at or below freezing point? It would appear that either the moderately heated stove must have been greatly raised in temperature, or the temperature of the chamber must have become considerably reduced. If either supposition be incorrect, and if the marvellously small consumption of twelve pounds of coal in twenty-four hours was also uniform, by what means did Dr. Arnott succeed in preventing his room from undergoing some of the vicissitudes of temperature common to our climate? Did he use double windows, and what did he consider to be *good ventilation?* The doctor does not appear to state whether he used his chimney ventilator during those fourteen years, or whether, in accordance with his early teaching, he had absolutely no provision for the escape of air but the small aperture which he found sufficient to supply air to his stove. If

* 'Quarterly Review' for April, 1866. Art. "Coal and Smoke," p. 452.

the latter was the case, there are those who instead of calling the ventilation *good*, would beg emphatically to differ from Dr. Arnott, and maintain that though the room was not hermetically sealed, there was positively no ventilation at all, and that it was no wonder he could economise his coal under such circumstances. If however Dr. Arnott used his chimney ventilator, what amount of ventilation did he get? Did the feeble current of air and gas from his stove sufficiently warm and rarefy the air in his chimney to ensure a constant escape of air through his ventilator, and to what extent? Those who have known a little of Dr. Arnott's stoves, have been in the habit of supposing that such economy as results from using them is chiefly due to the absence of ventilation, and whatever respect may be due to Dr. Arnott for the zest and force with which he has urged his respective inventions on the public, it is unfortunate that he has not demonstrated the accuracy of his apparently conflicting opinions, that a room is well ventilated in which his stove and ventilator are used, while a room is badly ventilated in which an open fire-place is used, and have thus avoided the possibility of cavil.

If to introduce the continental system of heating by close stoves is what is meant by reality instead of semblance, it is much to be doubted whether such system is likely to make greater impression than hitherto in this country. However unquestionably such a system may be adapted to countries where the average temperature is much lower than it is with us, and where there are not such sudden changes, close stoves are, and not without reason, regarded by us, for the rooms we occupy, with invincible repugnance. Dr. Arnott, more than forty years ago, endeavoured most forcibly to introduce his stove generally for domestic purposes, with what amount of dissatisfaction many may yet remember. The public have perhaps wisely discriminated. Stoves are used extensively for halls and other places that are not occupied constantly, where the damp and extreme cold have to be provided against, and where a lack of sufficient heat for sedentary occupations is comparatively unimportant, but in the chambers of our dwellings, they are found to dry the air, they look most cheerless (a thing of some moment in our dull winter atmosphere), are apt to be most uncomfortable in mild weather, if made of sufficient power to protect against severe cold, and are apt to be quite insufficient for severe weather, if adapted to be used comfortably in mild; and, with respect to ventilation, they reduce it by comparison to a very small amount, if they do not practically do away with it altogether. Those who happen to be a little familiar with the amount of comfort that is to be obtained entirely from, or with the assistance of, an open fire place, and whose preference is for a well-warmed room, in which a fire is burning, where there unquestionably is good ventilation, and where the proper pressure of air is invariably maintained, will decidedly prefer what they conceive to be a very substantial *reality*, and not the *reality* of Dr Arnott and of the Quarterly Reviewer.

Fully conscious of the hopelessness of inducing the English public to take to close stoves, the writer of the article has a few general observations upon other schemes. He believes in the practicability of removing smoke by the sewers, in new towns or districts, and that with "due attention," a smoky chimney would be an impossibility. He is highly interested in Mr. Spence's pamphlet, from which he fully quotes his great suggestion. He thinks it "practicable in a great measure to supersede domestic fires, and to lay on heat, or the means of generating heat, to our houses pretty much as we now lay on gas." What he intends by the means of generating heat is cheap gas, or "gaseous fuel," which he thinks could be manufactured from coal slack, or other low priced material, and supplied to our doors, after all expenses of production, supply, and interest on outlay are allowed for, at a price to compete successfully with the solid carbon of coal or coke itself.

With respect to the supply of heat, the writer says, "it is worthy of reflection whether heated air might not be conveniently supplied from one source, say to a row of houses ; and, if so, from various sources to an entire town." The possibility of heated air being supplied from a warm air channel to a number of houses has been intimated elsewhere and by another, but the practicability of a vast extension of such a system from a single source does not follow. If it did, we should have to conclude, that because certain weights can be raised above the clouds, it would be possible to lug up a railway train or the Great Eastern. Practical considerations are found to decide everything in this hard practical world, whether the size of a loaf of bread or the size of a coin. To supply heated air to a number of houses would of itself present great difficulties, which should not be lightly regarded, but as such a consummation is greatly to be desired, however difficult of attainment, it may not be altogether useless, if only at present as a matter of speculation, to enquire shortly what might be the main outlines of a comprehensive scheme which our present state of knowledge may appear to render possible.

Fig. 106 represents in section a certain number of houses which may be supposed to be sufficiently extended to include a whole line of street, but not of considerable length. At one end and below the level of the houses is shown a furnace of great power, from which a channel of no inconsiderable size, which should probably be of iron, passes below the whole of the lower chambers, and terminates in an ornamental chimney-shaft which flanks the last house. Between this channel and the lower chambers is shown another channel of very much larger dimensions, which has communications with the external air at many points along the whole line, but which has no communication whatever with the chimney-shaft. From the crown of this large channel various minor channels ascend in the walls to supply air, which should only be pleasantly warmed, through open gratings provided with regulators to every chamber, and to the hall and landings. Ventilating channels for the escape of air from the rooms should be provided either contiguous to the warm air channels, or in the partition-wall opposite the windows, and terminate above the roof of each house. Where the furnace is placed, powerful boilers are shown from which hot-water pipes pass along the outer channel, and supply by the well-known principle of circulation through branch circulating pipes a constant supply of hot water to a hot water cistern, placed in each upper story, with branches therefrom, or from the ascending circulating-pipe for the use of a warm bath, for kitchen use, and for various other household purposes. In the kitchen and elsewhere, iron closets may be supposed to be heated by warm air circulating round them from the warm air channels. Cooking operations would be conducted by the usual means, as the warm air would be by no means sufficient for the purpose, though possibly special arrangements for supplying very hot air may some day be found practicable and economical. The great chimney-shaft may be supposed to be utilized for the ventilation of the sewer for the same length of houses, but it would require probably some furnace assistance actually within it to occasion descending currents at the various small openings communicating with each dwelling, and prevent thereby the possibility of any foul vapours escaping either within the house or in the open street. Smoke from the furnace would be avoided either by arrangements at present used in furnaces, when bituminous coal is used, or by the use of coke, or anthracite coal. The system, with the assistance of open fireplaces, whenever necessary, would render dwelling-houses admirably warmed, and be readily adapted to sudden changes of climate, as, to move a regulator would control or exclude the admission of air to any apartment. Whether economy would be practised is open to grave question, if by economy is meant an absolute reduction of expenditure for warming operations, but that there would be the economy which results from a large amount of personal comfort being obtained at the smallest practicable cost, is extremely probable.

Though upon paper such a system may appear simple and easy to put into practice, it could by no means be so as a matter of fact. To adequately warm the quantity of air for, say twenty or fifty houses, to insure a proper pressure and ascent of warm air at every channel, to turn all the heat passing from the furnace to the chimney shaft to the best account, to insure the proper circulation of water to every house, to adapt furnace or furnaces to boilers, boilers to main pipes, and main pipes to branches, to remove every difficulty which, though not apparent at first sight, must inevitably be encountered in an original undertaking, to make the whole perfectly successful, and to avoid by attempting too much the partial failure which is often calculated to bring discredit on the best endeavors; all this requires the assistance of one who, with considerable attainments, practical knowledge, and powers of discernment, could be prepared to devote perhaps the best portion of a lifetime to get such a system established in practice. One truly fit to deal with the question would also be the most competent to supply the deficiencies of all previous efforts with respect to ventilation. Upon this subject, with respect to public buildings particularly, a great deal remains to be done.

Since the publication of the previous edition of this volume, the scheme has been, it appears, most successfully carried out at Lockport, in the United States, where as many as 200 houses have been supplied with heat for all domestic purposes, from a single source, the agent being steam. It was described by Mr. George Maw, F.G.S., in a letter to the *Times*, some two or three years ago, and is also described in Captain Galton's new publication on *Healthy Dwellings*.

Fig. 1. Dr. Desaguliers' blowing wheel, used over the chamber of the House of Commons.

a, a tube by which air from the chamber could enter the drum.

b, a tube by which air was expelled from the drum.

c, handle to turn the fans.

Fig. 2. Vertical section, showing the fans used to propel the air. When it was desired to propel fresh air into the chamber, the tube *a*, was placed in communication with the external atmosphere, and the tube *b*, in communication with the chamber.

Fig. 3. Dr. Hales' ventilating bellows, shown with one side removed.

a, division board or midriff, suspended by hinges at *b*, and moved up and down by the handle *c*.

1, 2, valves suspended without, to close the aperture by which air was expelled.

3, 4, valves suspended within, to close the apertures by which air was admitted.

For air to be propelled into a chamber, valves 1 and 2 were placed in communication with it, by means of a channel, and valves 3 and 4 were left exposed to the external air. By removing the channel from 1 and 2, and placing it before 3 and 4, air entering the bellows from the chamber was expelled.

Fig. 4. A double ventilating bellows.

a, *a*, a shaft worked by two men, to keep the midriffs in constant motion.

1, 2, 3, 4, valves opening outwards, for the expulsion or propulsion of air.

5, 6, 7, 8, valves opening inwards for the admission of air within the bellows.

Fig. 1.

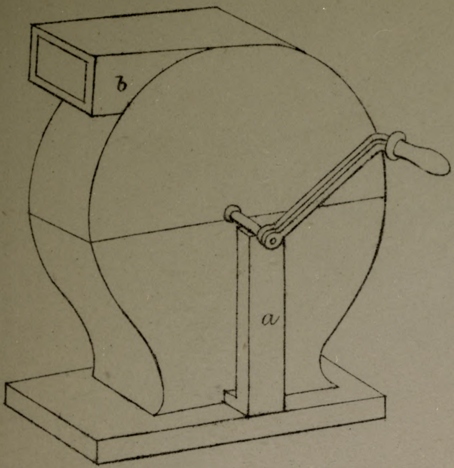


Fig. 2.

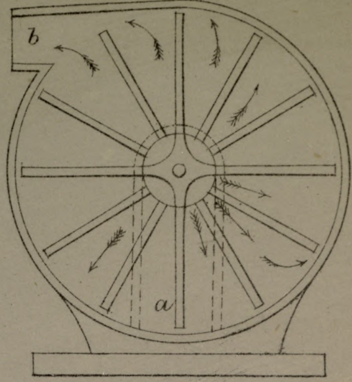
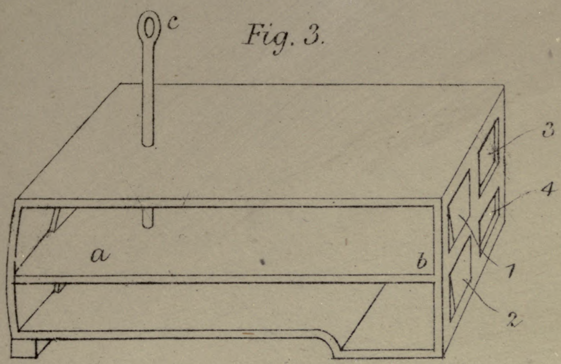


Fig. 3.



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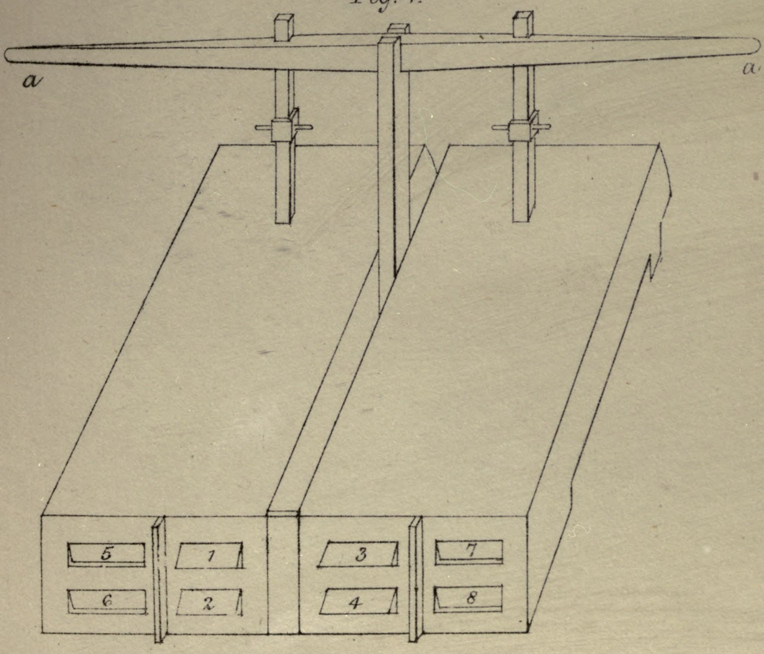


Fig. 5. The Marquis de Chabannes' system of ventilating from the ceiling.

a, a, tube by which the heated air and products from the gas chandelier below passed away.

b, b, apertures for the escape of vitiated air to the external tube.

c, c, channels from galleries.

Fig. 6. The Marquis de Chabannes' ventilating lamp, and chimney ventilator combined.

Fig. 7. Section showing the same contrivance fixed in the wall over fire-place.

a, lamp.

b, channel by which the products escaped.

c, aperture protected by wire-work, through which air from the room escaped to the chimney.

Fig. 8. The Marquis de Chabannes' chimney ventilator, shown in section, fixed below the ceiling.

a, door of ventilator, opening into chimney.

b, chain to open or close the ventilator.

Fig. 9. Dr. Arnott's chimney ventilator.

Fig. 10. Section showing Dr. Arnott's ventilator, fixed below the ceiling.

a, door or flap, balanced by the ball *b.*

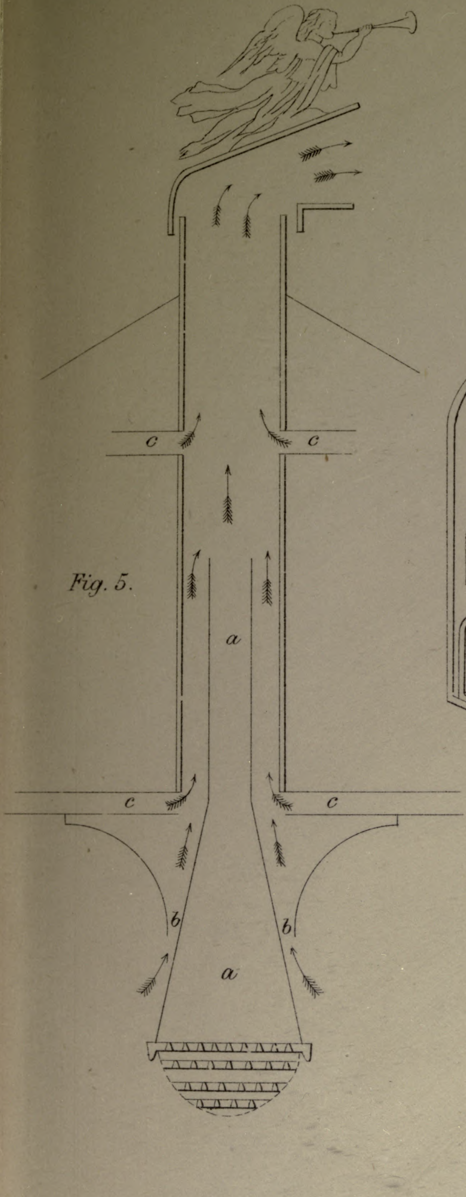


Fig. 5.

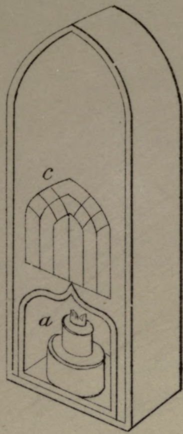


Fig. 6.

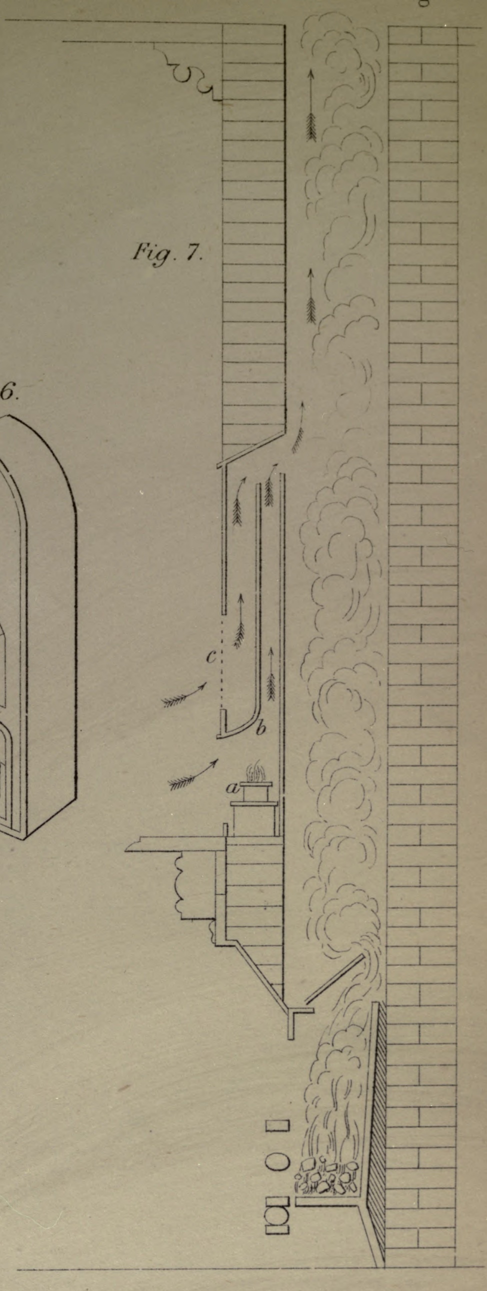


Fig. 7.

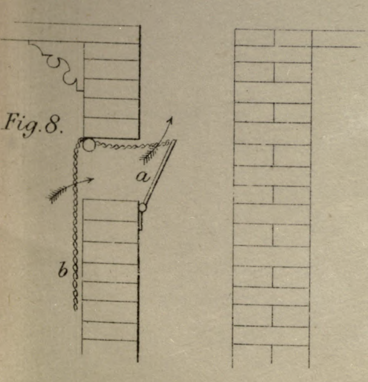


Fig. 8.

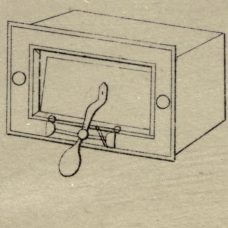


Fig. 9.

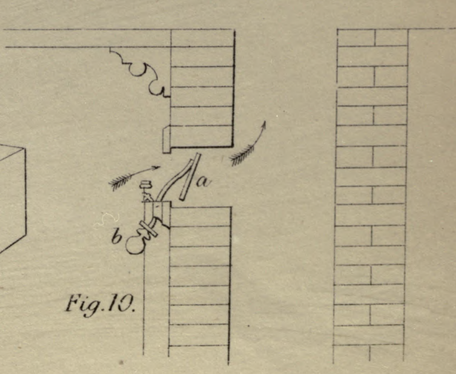


Fig. 10.

Figs. 11 to 18. Some varieties of perforated zinc.

Figs. 19 to 22. Some varieties of wire gauze.

Figs. 23 to 26. Air bricks of cast iron.

Figs. 27 and 28. Air bricks of terra cotta, manufactured by Mr. George Jennings.

Figs. 29 to 31. Sliding valves to regulate the admission of air.

Fig. 11.

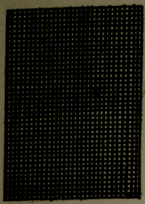


Fig. 12.

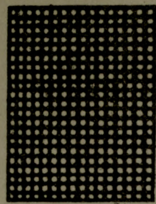


Fig. 13.

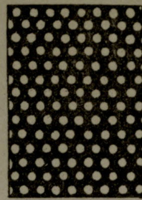
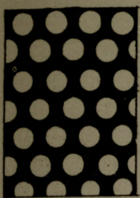


Fig. 14.

Fig. 15



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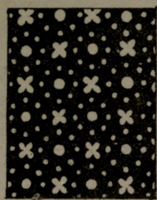

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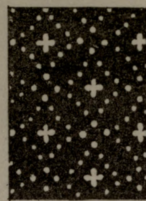
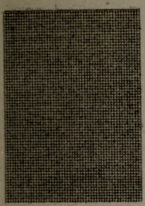


Fig. 18

Fig. 19



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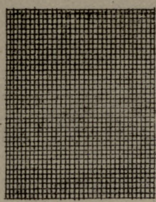

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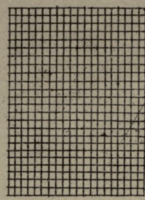

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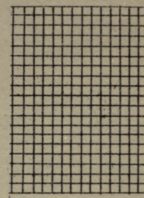

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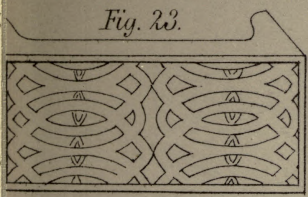
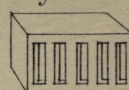


Fig. 24.

Fig. 25



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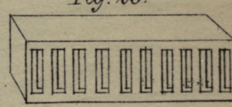

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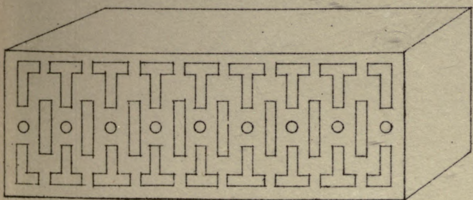

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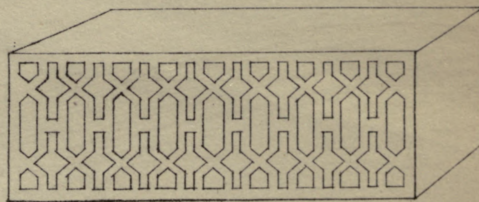

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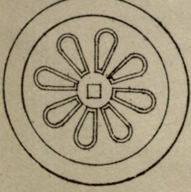

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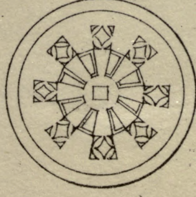

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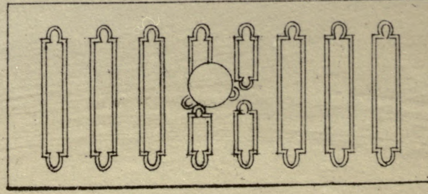


Figs. 32 and 33. Perforated glass.

Fig. 34. Lockhead's ventilator. A pane of perforated glass *a*, enclosed in a metal frame *b*, with an extra frame *c*, hinged, so as to exclude air, and provided with a regulator *d*, to admit air as desired.

Fig. 35. View of a portion of window sash with regulator, as seen from the room.

Fig. 36. Moore's Louvre ventilator, fitted to a window sash, as seen from the room. The same description of ventilator was first patented by Mr. Baillie, and was patented, with some modification, by Messrs. Fairs.

Fig. 37. Section of Moore's ventilator, half open, the air passing between the slips of glass.

Fig. 38. Cooper's ventilator.

a, *a*, &c., openings in window pane.

b, plate of glass made to turn by a handle, *c*, so as to cover the openings, *a*, *a*, &c., or regulate the admission of air.

Fig. 39. Pane of glass with the apertures closed by the moving plate of glass.

Fig. 32.

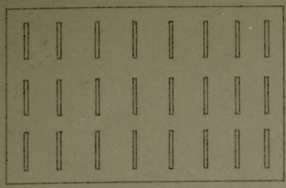
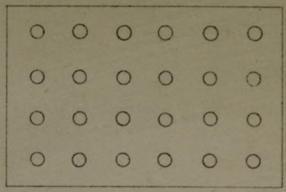


Fig. 33.



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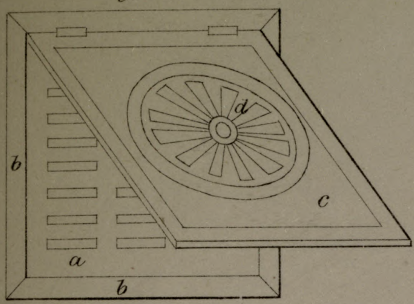

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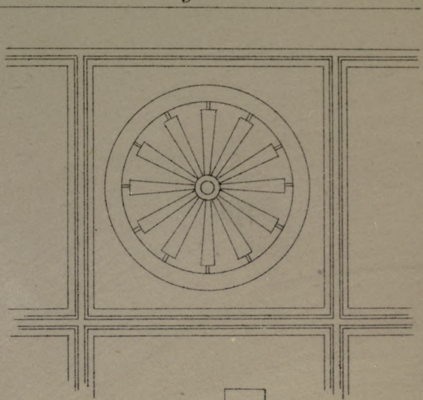
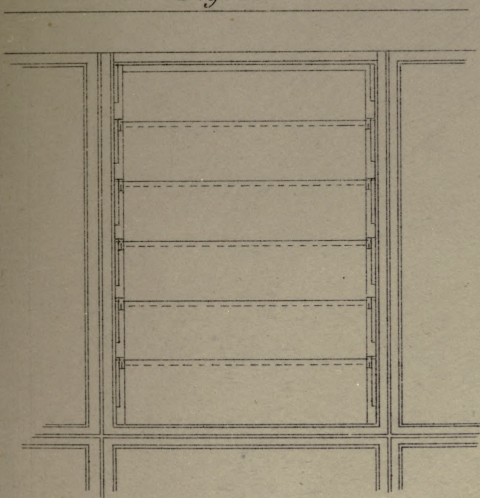


Fig. 36.



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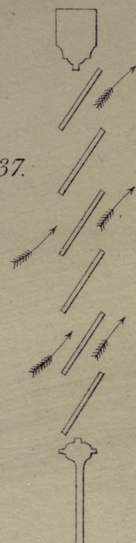


Fig 38.

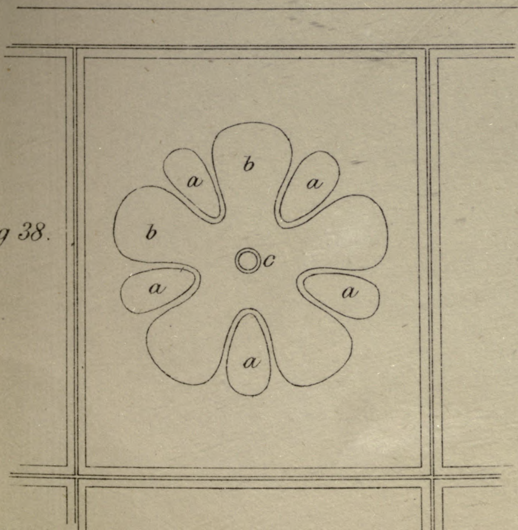


Fig. 39.

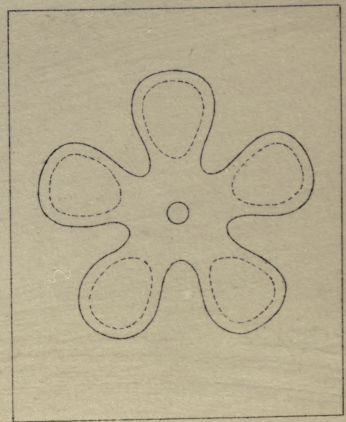


Fig. 40. Sheringham's ventilator, as seen from within a building, with the door *a*, and rod *b*, to regulate or close the opening.

Fig. 41. Section of Sheringham's ventilator.
a, door.

Fig. 42. Section of Sheringham's ventilator, fixed below the cornice.
a, Sheringham's ventilator.
b, air-brick fixed in an external wall.

Fig. 43. Window sash, showing Mr. William Cooke's expanding ventilator of wire gauze, on Mr. Stephen Flexen's system of using perforated tin.

Fig. 44. Section showing the perforated material fitted with joints and made to double up, so as to exclude air.

Fig. 45. Mr. Obed. Blake's perforated apertures, filled with pieces of wire gauze, *a*, *a*, at the top of a window sash, and *b*, handle to admit or exclude air.

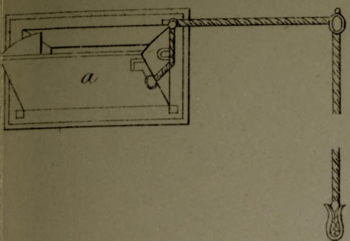
Fig. 46. Horizontal section of a portion of a window sash.
a, *a*, *a*, perforated gauze outside the sash.
b, *b*, *b*, perforated gauze facing the room.
c, *c*, *c*, regulator, with handle *d*, to control the admission of air.

Fig. 47. Messrs. Boyle and Co.'s window ventilator.
a, ornamental disc of glass, covering the wire gauze by which the air is admitted.

Fig. 48. Section of a portion of a window sash.
a, disc of glass as pulled forward to allow air to enter.
b, wire gauze fitted in window frame.
c, *c*, jointed rods to hold disc of glass to window.

Fig. 48.* Messrs. Boyle and Co.'s draughtless inlet for fixing to the skirting of a room.
a, ring of metal filled with wire gauze.
b, cover connected with *a*, by a screw in the middle. The cover can be screwed close up to the gauze *a*, so as to exclude air, by simply turning it with the fingers.

Fig. 40.



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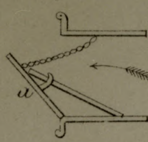

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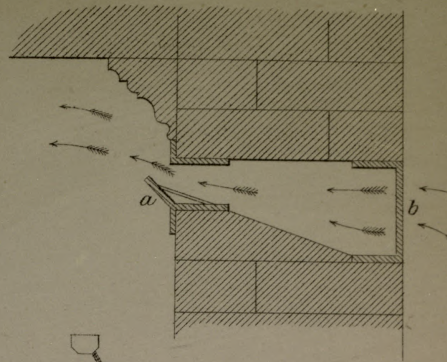
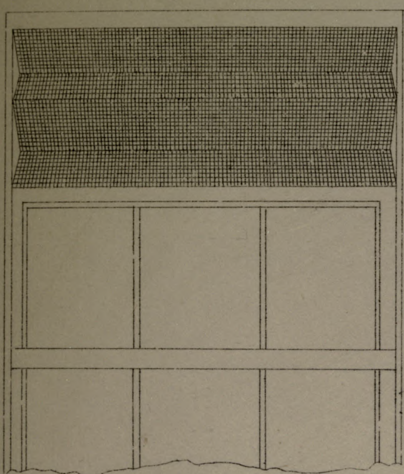


Fig. 43.



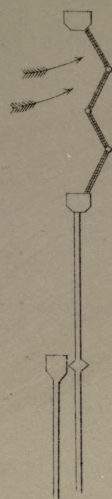
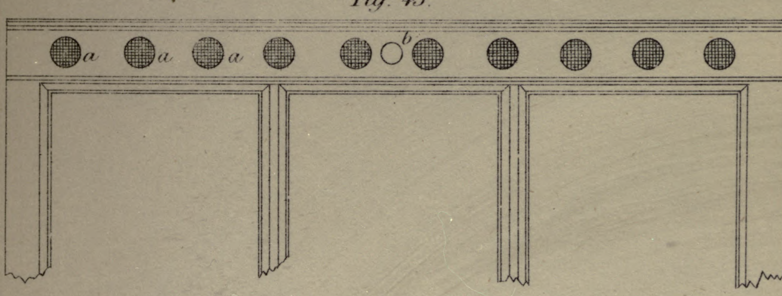


Fig. 44.

Fig. 45.



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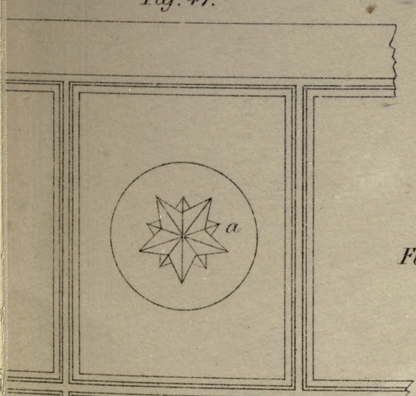


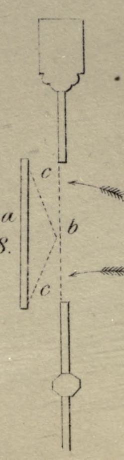
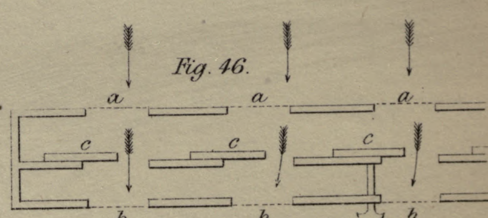


Fig. 48.

Fig. 46.



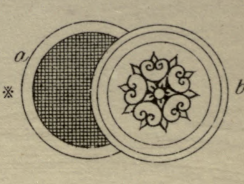


Fig. 48*

Fig. 49. Gammon's ventilators.

a, *a*, *a*, &c., perforated brass through which air is admitted; *c*, cover made to turn back for cleaning.

b, contrivance to which a piece of cord is attached, which enables a perforated plate of brass to be so moved over the apertures as to exclude air, or regulate its admission.

Fig. 50. Gammon's ventilator when closed.

Fig. 51. Horizontal section of Gammon's ventilator.

a, perforated face with sliding valve, fixed even with the window sash.

b, perforated back of zinc exposed to the external air.

c, *c*, *c*, &c., perforated pieces of zinc to check the impetus of the air, and assist in excluding dust.

Fig. 52. Gammon's ventilator as fixed to a window sash with a cord to control the admission of air.

Fig. 53. Doorway, showing louvre boards, *a*, *a*, *a*, fixed above for the admission or exit of air.

Fig. 54. Section of doorway and louvre boards.

Fig. 55. Chimney ventilator of perforated zinc, used by the late Mr. Joseph Toynbee.

a, valve of oiled silk.

Fig. 56. Boyle and Co.'s chimney ventilator.

a, *a*, *a*, &c., valves of mica, to open by the pressure of the air.

Fig. 49.

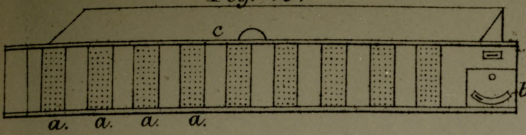
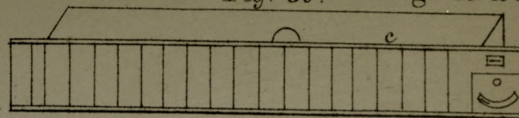


Fig. 50.



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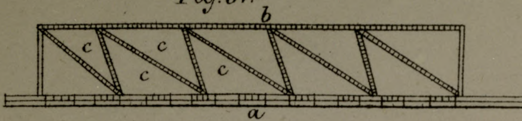

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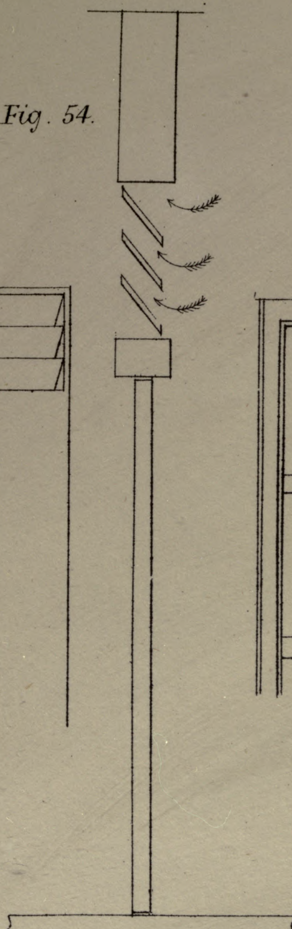

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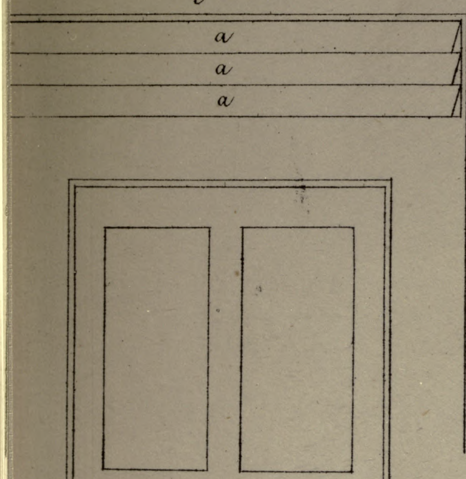

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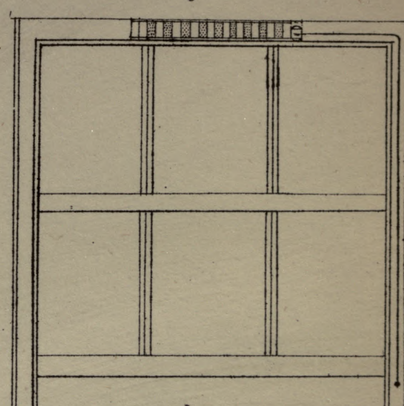

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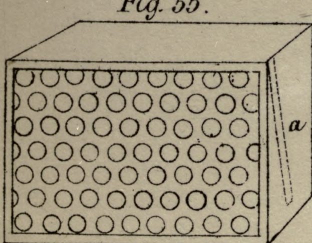

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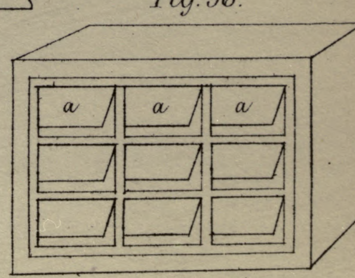


Fig. 57. A plan of ventilating gas-burners, mentioned in a pamphlet published in 1846, by Mr. J. O. N. Rutter, F.R.A.S.

a, gas-burner.

b, glass globe, open above and closed below.

c, *c*, tube to convey gas.

d, tube to remove products of combustion.

Fig. 58. External view of Mr. Rutter's ventilating gas-light.

Fig. 59. Section showing.

a, gas-burner.

b, *b*, aperture by which air enters to support combustion.

c, gas-pipe contained within the ventilating tube.

d, ventilating tube.

e, *e*, passage for the escape of air from the room.

f, main channel of escape to the chimney.

Fig. 60. Ventilating bracket gas-light, to be attached to a wall. The ventilating tube, or a ventilating flue from it, should pass up horizontally to the roof, and be sheltered.

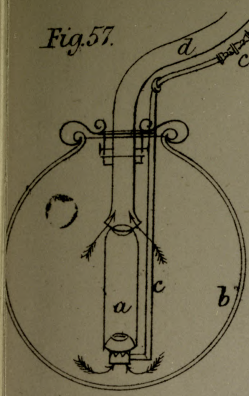
Fig. 61. Ventilating flue for use in a kitchen, with close kitchener.

Fig. 62. Section of a kitchener fixed in fire-place, with the ventilating flue *a*, *a*.

Fig. 63. A ventilator with a face of perforated zinc, and a sliding valve at back to fix below the cornice over a doorway.

Fig. 63*. Back view of fig. 63.

Fig. 57.



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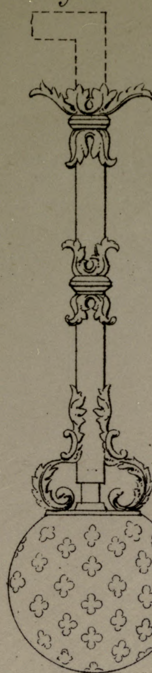

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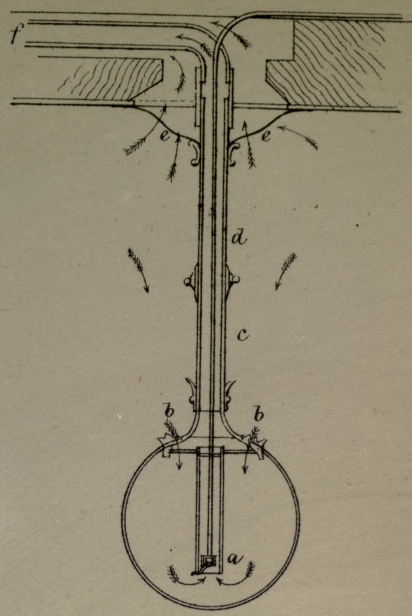


Fig. 60.

Fig. 61.

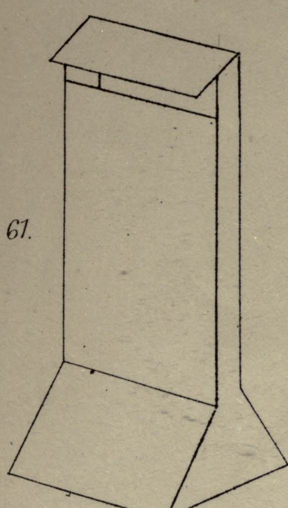


Fig. 62.

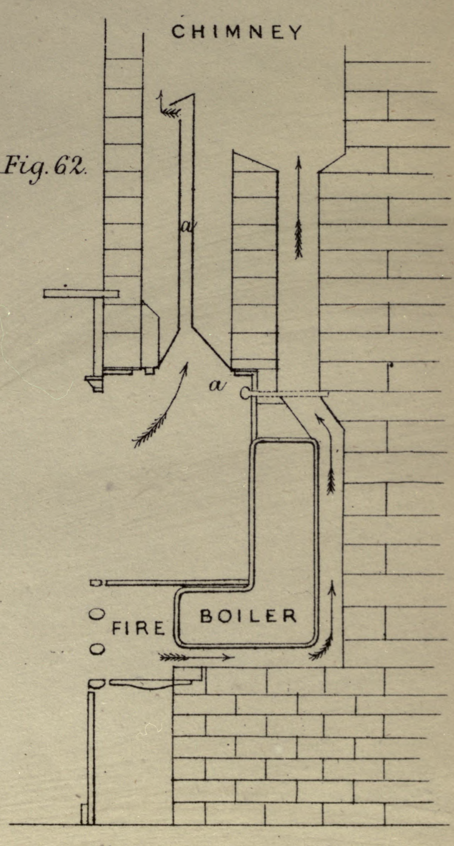


Fig. 63.

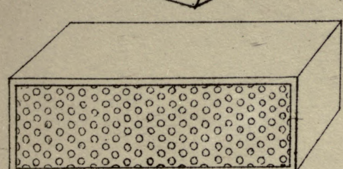


*Fig 63**

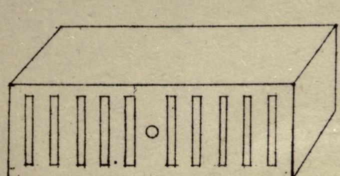


Fig. 64. Section showing a system of ventilation from the ceiling. A modification of a sketch given in Mr. Tredgold's treatise.

a, passage for air to escape to the chimney.

b, central ornament, suspended by the cord or chain *c*, and a balance weight.

Fig. 65. Perforated zinc ventilator, for the admission of air, adapted to form part of a cornice.

a, under part of cornice facing the room.

b, perforated zinc.

c, portion of cornice over the aperture by which air is admitted from without.

d, cord to regulate the quantity of air admitted.

e. dotted lines, representing position of door or valve.

Fig. 66. Section showing how the inlet ventilator, fig. 65, is applied to a room. Letters of reference, *a*, *c*, *d*, *e*, correspond. The perforated zinc, *b*, is at each side of upper part of cornice, *c*.

f, air brick fixed in external wall.

This system was recommended in the report of the Commissioners for Improving the Sanitary Condition of Barracks and Hospitals, issued in 1861, from which these sketches are taken.

Fig. 67. Grate with valves, *a*, *a*, to admit cold air in proximity to the fire.

b, channel formed below the floor, to provide air from an external source.

Fig. 68. Grate constructed to admit fresh air through open spandrils, *a*, *a*, the air passing from an external source along a channel to the back of the grate, and becoming warm by contact with the heated surface before it enters the room.

Fig. 69. Horizontal section taken across the upper part of the grate.

Fig. 64.

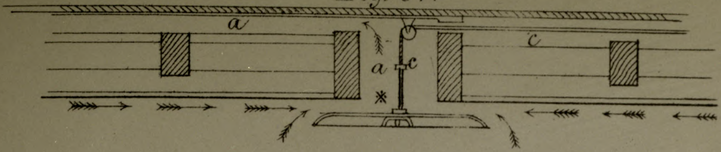


Fig. 65.

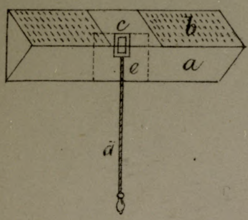


Fig. 66.

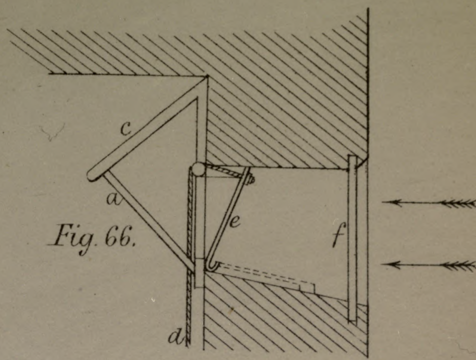
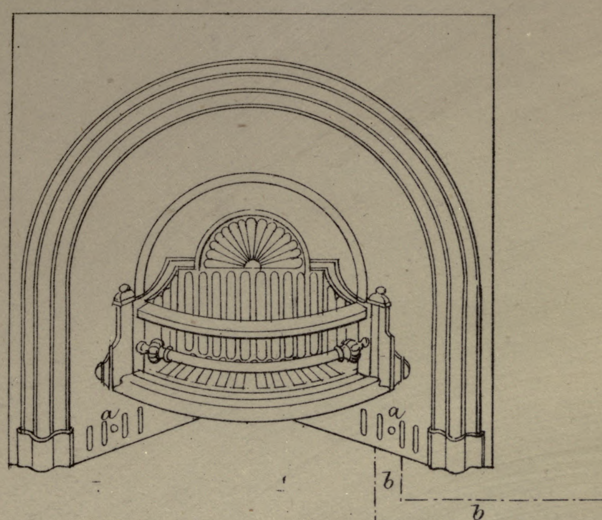


Fig. 67.



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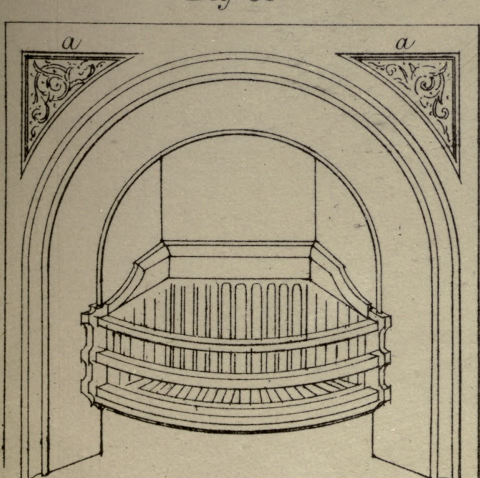


Fig 69.

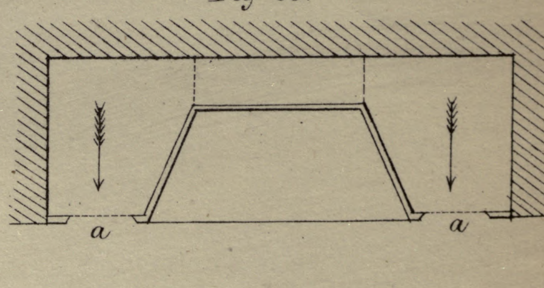


Fig. 70. Section showing Mr. D. O. Boyd's system of ventilating flues in conjunction with smoke flues.

a, *a*, *a*, three fire-places.

c, *c*, *c*, ventilating flues.

b, *b*, *b*, chimneys from the three fire-places.

d, *d*, *d*, valves by which air passes from the rooms to the ventilaing flues.

Fig. 71. Perspective view of portion of flues in course of formation.

a, chimney.

b, *b*, plates of iron dividing the chimneys, the space between forming the ventilating flue.

Fig. 72. Henry Doulton & Co.'s earthenware smoke and ventilating flue.

a, smoke flue.

b, aperture to ventilating flue.

Fig. 73. Horizontal section.

a, smoke flue.

b, ventilating flue.

Fig. 74. Mr. George Jennings' arrangement of smoke and ventilating flues,

a, smoke flue.

b, *b*, *b*, *b*, channels by which air descends, becomes warm, and enters the rooms through open gratings when there are fires burning, and air is prevented from entering by other means.

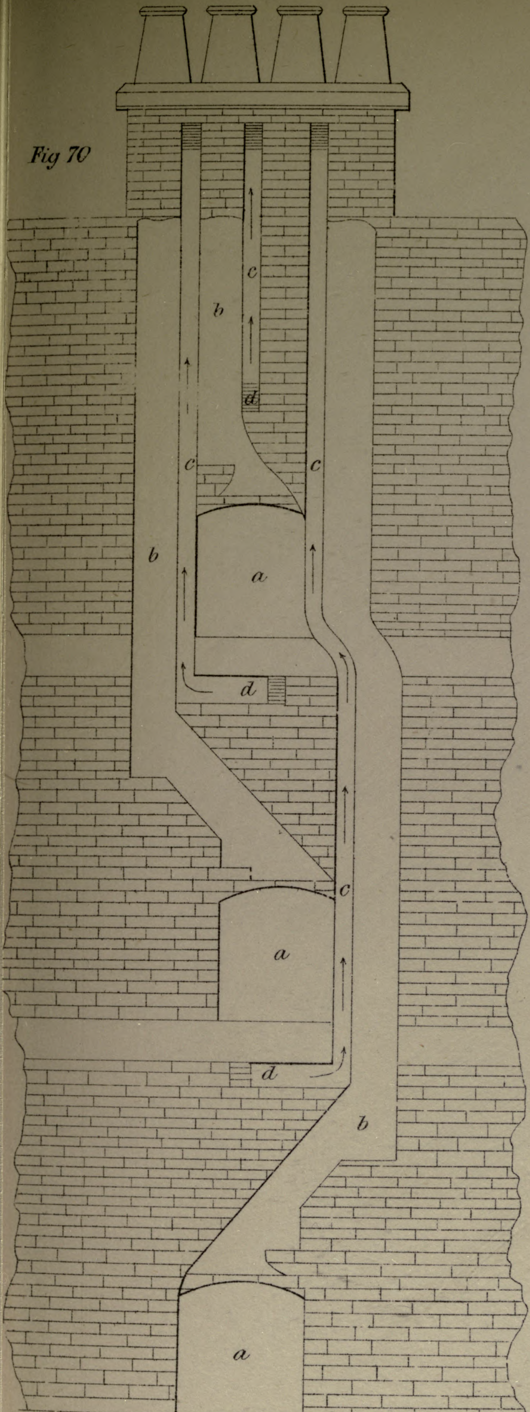
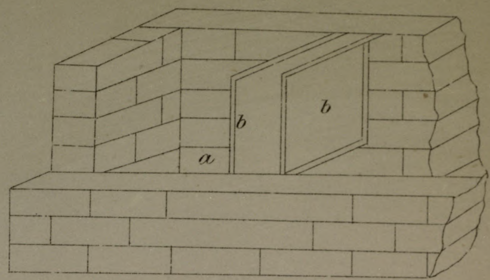


Fig 70

Fig. 71



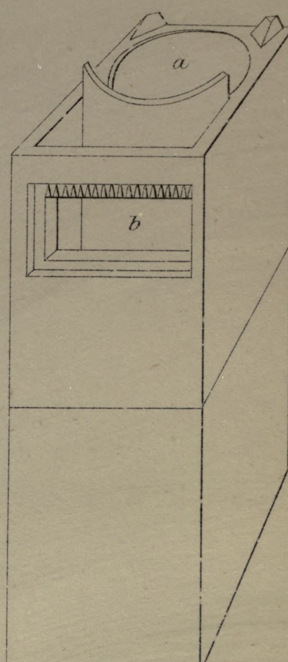


Fig. 72

Fig 73.

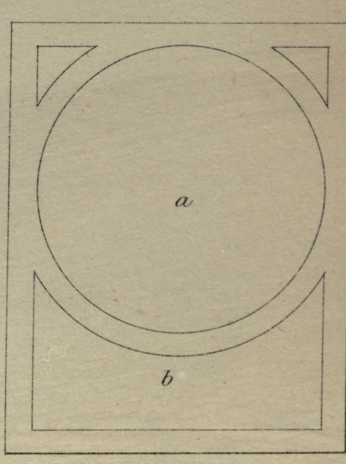


Fig 74.

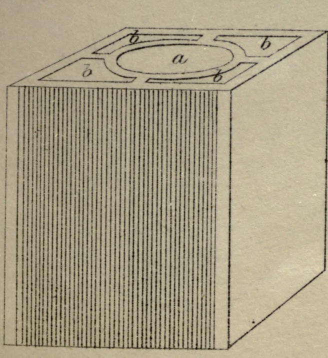


Fig. 75. Sketch of Dr. Arnott's smoke consuming grate, showing the plate below the bars which covers the supply of coal intended for the day's consumption. Section of fig. 75, showing the ash pit, the rising bottom, the lifting machinery and the improved register with handle facing the room.

Fig. 76. The author's smoke consuming grate, showing a moveable door or blind in front of the body of coal, a sunk ash pit and improved register, same as to fig. 75.

Fig. 77. The same grate as No. 76, but without the sunk ash pit, the bars being raised in order to avoid it.

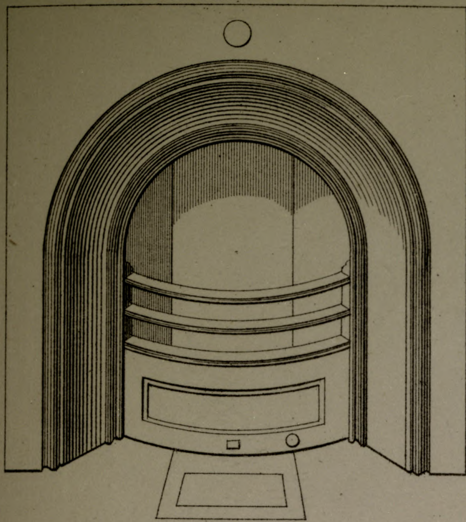
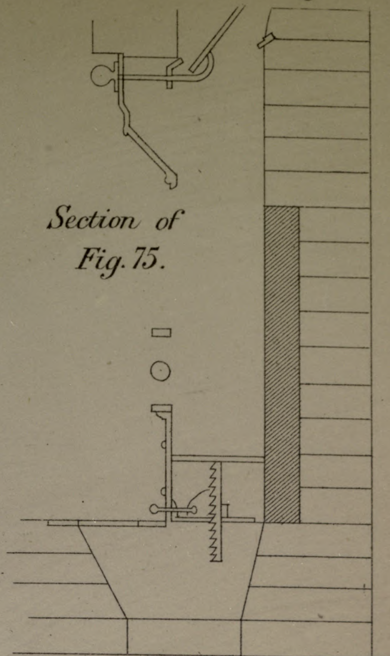


Fig. 75.



Section of Fig. 75.

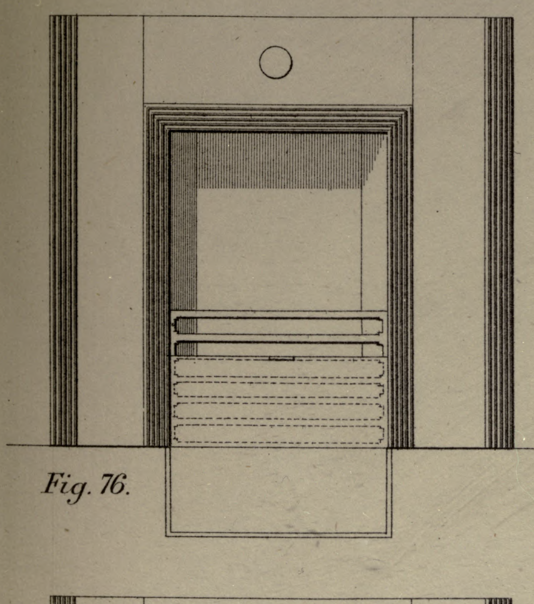
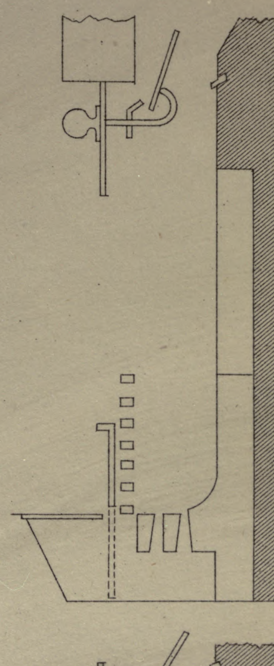


Fig. 76.



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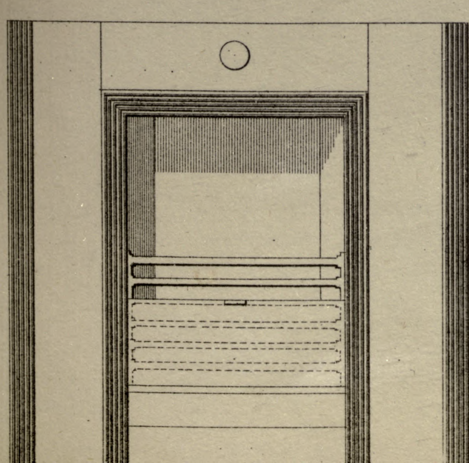
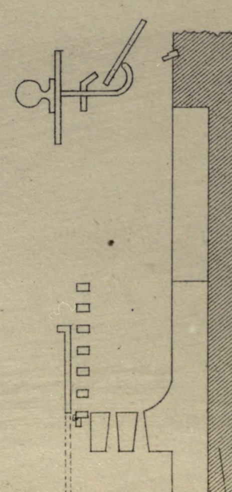




Section of Fig. 77.

Fig. 78. Captain Galton's grate, showing the warm-air flue, the smoke flue, and the grating below the ceiling for the admission of fresh warm air.

Vertical section of fig. 78, showing the warm-air chamber at back of grate.

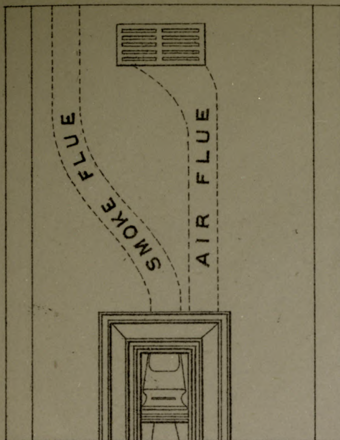
Fig. 79. Vertical section of an apartment, showing fresh air admitted from an external source to the chamber at back of grate, and by means of the ascending air flue into the room.

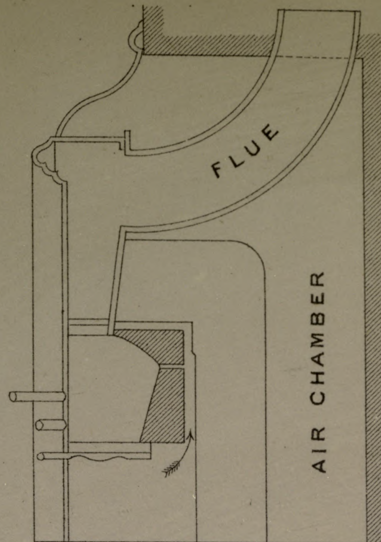
Plan of fire-place, showing iron "gills" for warming the fresh air in the air chamber.

Fig. 80. "The Country Parson's Grate," as minutely described by "S. G. O.," writing under the signature of "Another Country Parson," and Mr. Mechi.

Section of fig. 80, showing the size and shape of the fire-place insisted upon by Mr. Mechi.

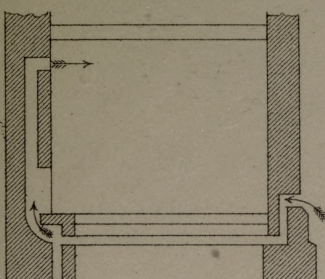
Fig. 78.

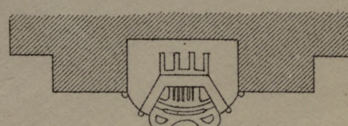




Vertical Section of Fig. 78.

Fig. 79.





Plan of Fire Place.

Captn. Douglas Galton's Grate.

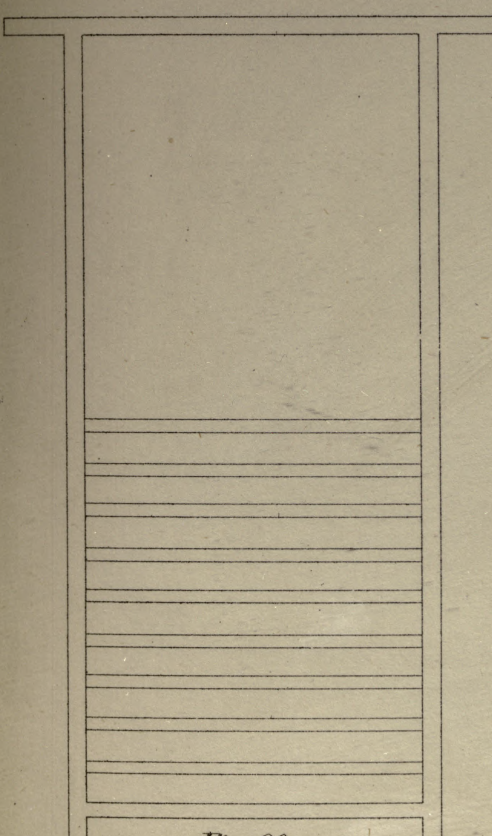
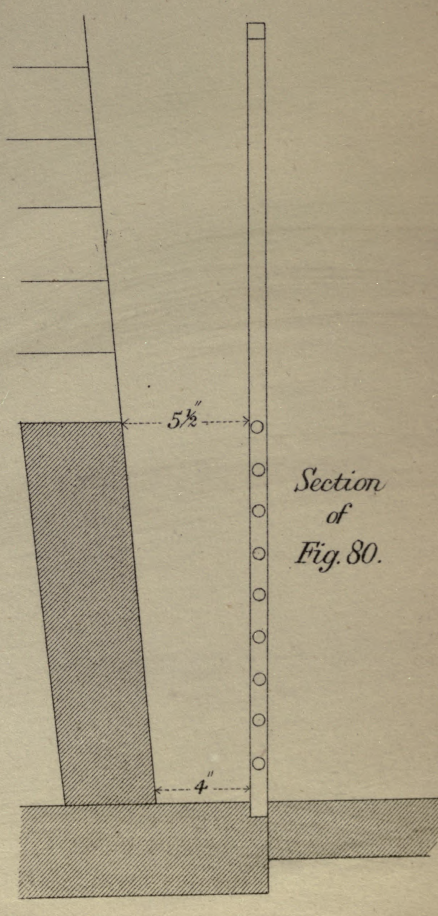


Fig. 80.

The Country Parson's Grate.



Section of Fig. 80.

Fig. 81. The Abbotsford grate, with solid brick bottom.

Fig. 82. The Author's grate for burning coal in the ordinary way, showing a basket of the fire lump, having perforations at bottom, and a simple ash pan with regulator.

Section of Fig. 82, showing the fire lump basket, the ash pan and the improved register in the chimney with handle exposed in the room.

Fig. 83. The brick basket of fig. 82.

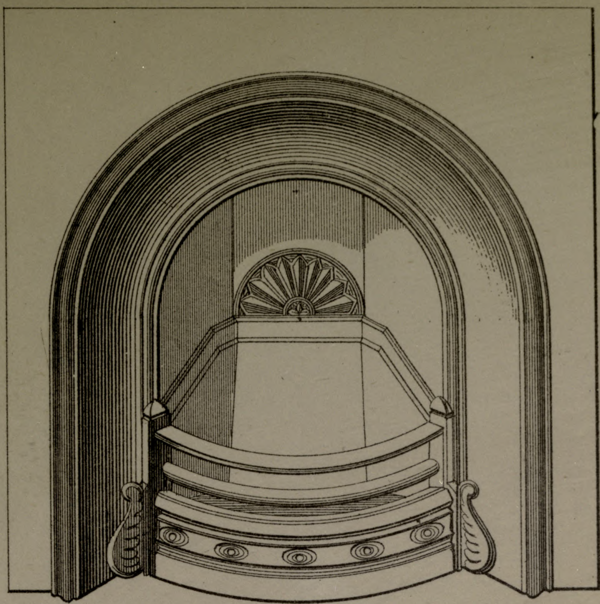


Fig. 81. The Abbotsford Grate.

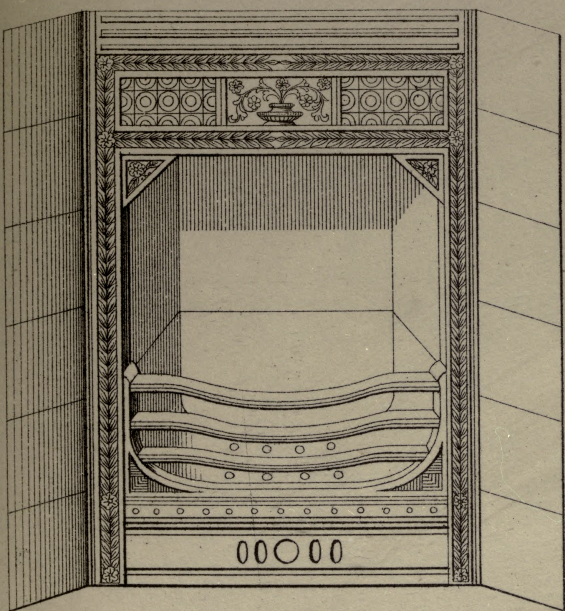
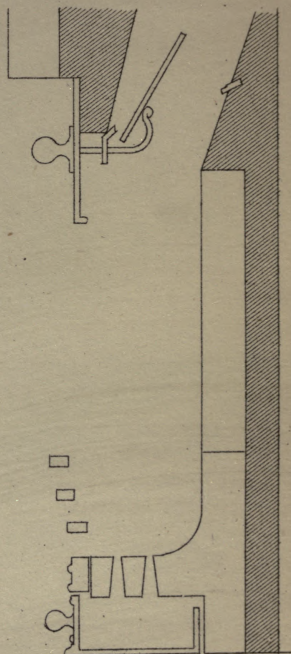


Fig. 82. The Author's Grate.



Section of Fig. 82.

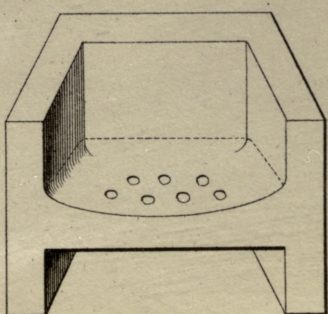


Fig. 83. Brick Basket.

Fig. 84. Ventilating grate with open brass grating at top for admission of fresh warm air.

Section of fig. 84, showing warm air chamber at back of grate, grating at top and improved register.

Fig. 85. The late William Peirce's Pyro-pneumatic stove for which the Society of Arts awarded their silver medal in 1849.

Fig. 86. Vertical section showing fresh air flue, smoke flue and internal passages, by which the fresh air becomes warmed before entering the building or chamber at top of stove.

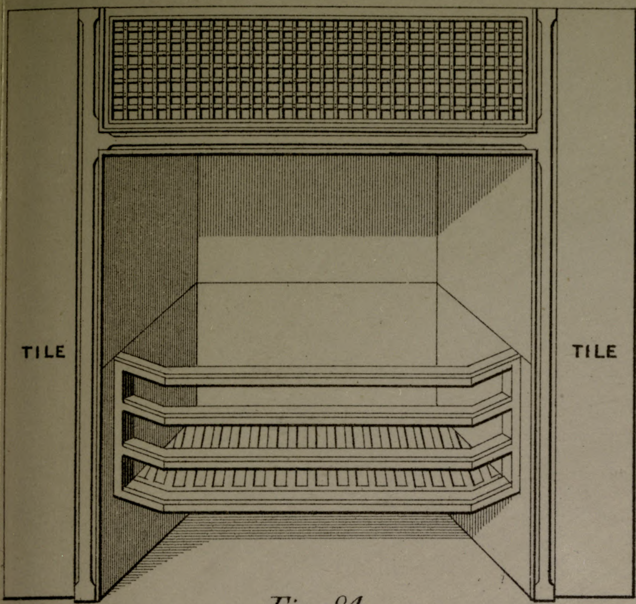
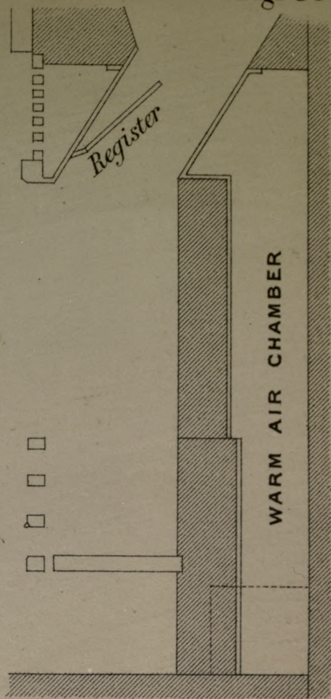


Fig. 84.

Ventilating Grate with open grating at top for admission of fresh warm air.



Section of Fig. 84.

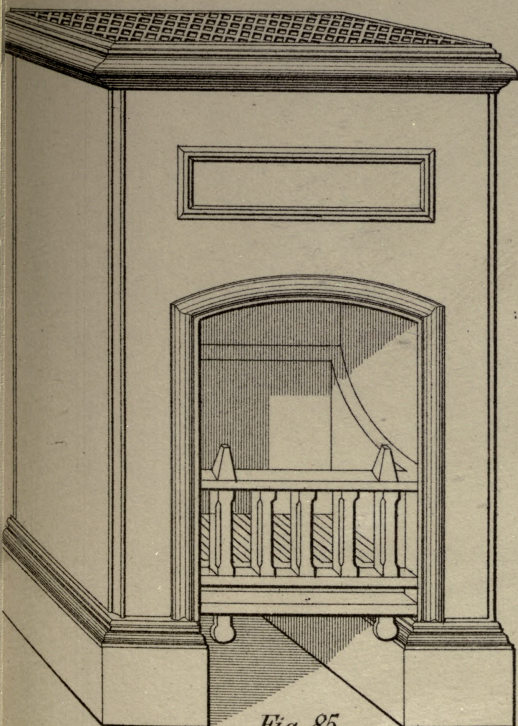


Fig. 85.

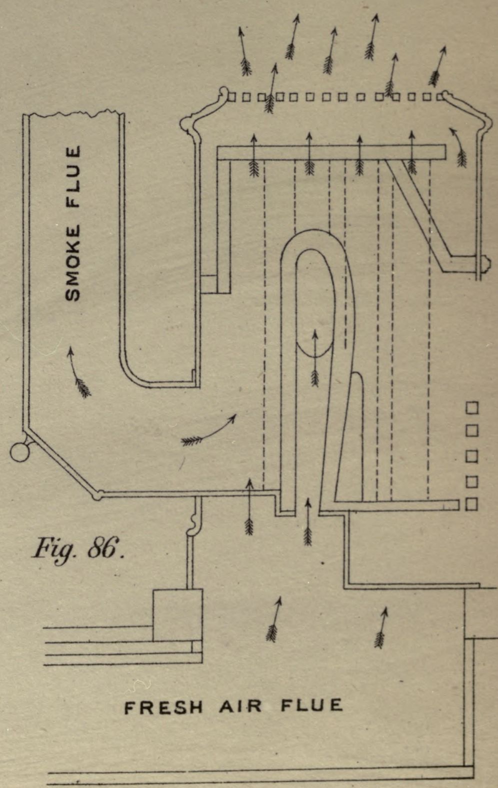


Fig. 86.

Pierce's Pyro-Pneumatic Stove for admission of fresh warm air.

Fig. 87. Vertical section showing an arrangement for supplying fresh air at the top part of a window.

a, perforated apertures facing without.

b, perforated zinc or wire gauze facing the room.

c, perforated plate of zinc, fig. 88, to reduce the quantity of air admitted.

d, window sash, slightly lowered.

e, cord to move plate *c*.

Fig. 88. Finely perforated plate of zinc, *c*, fig. 87, with some simple machinery for moving it.

Fig. 89. View of ventilating arrangement from the room, the window sash lowered.

Fig. 90. Apertures as seen from without.

Fig. 91. Another arrangement for admitting air at the top of a window opening.

a, cylinder formed of wire gauze in slips of different texture.

b, cord to move cylinder, so that a coarser or finer description of gauze may face the room as desired.

Fig. 92. Cylinder *a*, of fig. 91, as seen separately.

Fig. 92.* View of the arrangement shown in fig. 91, as seen from the room. The wire gauze seen is of course a part of the cylinder, fig. 92.

Fig. 87.

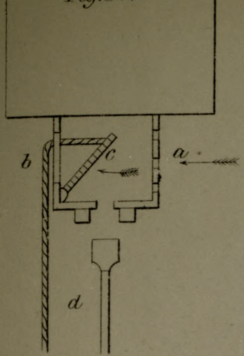


Fig. 88.

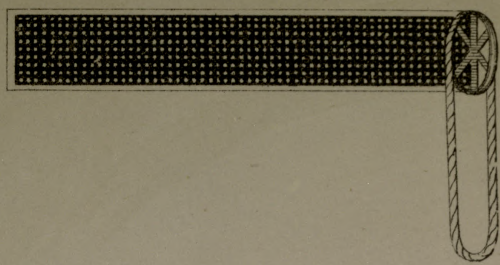


Fig. 89.

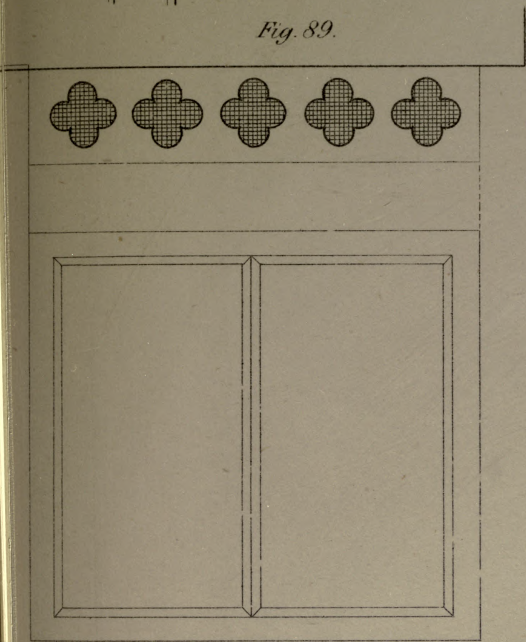


Fig. 90.

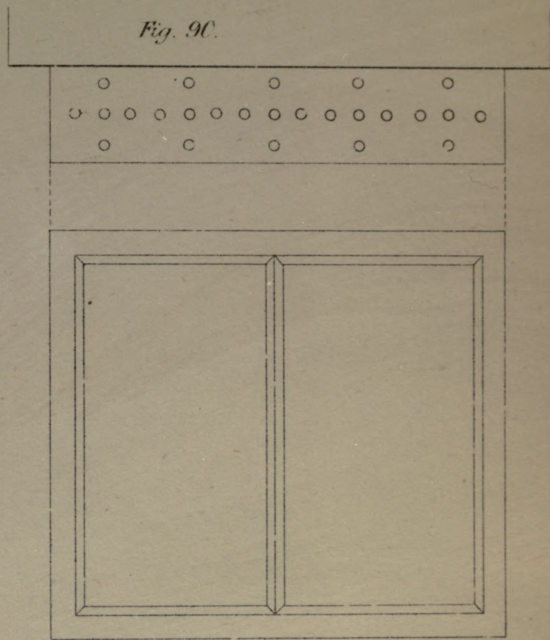


Fig. 91.

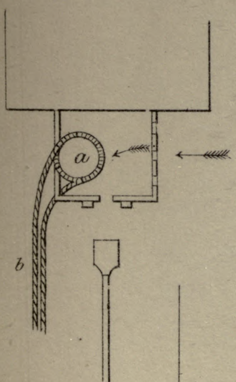


Fig. 92.

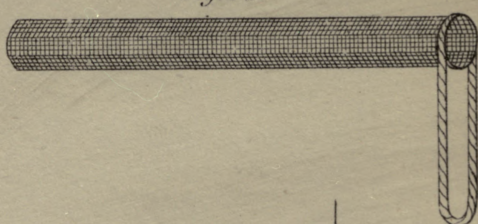


Fig. 92.*

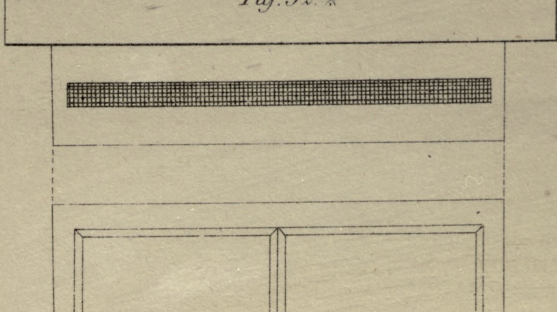


Fig. 93. Vertical section, showing Mr. McKinnell's ventilator applied to the roof of a building with the ascending current of air escaping by he inner tube, and fresh air entering between the inner and outer tube.

Fig. 94. Chadwick's Archimedean ventilator kept in motion by the wind, the blades below serving to propel air upwards.

Fig. 95. Muir's ventilator, intended to operate in a similar manner to fig. 93.

Fig. 96. Horizontal section of Muir's ventilator, showing four channels by which air either ascends or descends.

Fig. 97. Section of Watson's ventilator, intended to operate in a similar manner to fig. 93.

Fig. 98. External view of one of Mr. Watson's ventilators.

Fig. 99. Mr. Thomas Harris's double current ventilator for school-rooms, work-rooms, &c., fixed in an external wall. View facing the room.

Fig. 100. Vertical section showing air entering the room through the lower apertures, and air escaping by the upper apertures.

a, *a*, certain valves of oiled silk.

b, *b*, valves of metal carefully poised.

Fig. 101. External view.

Fig. 93.

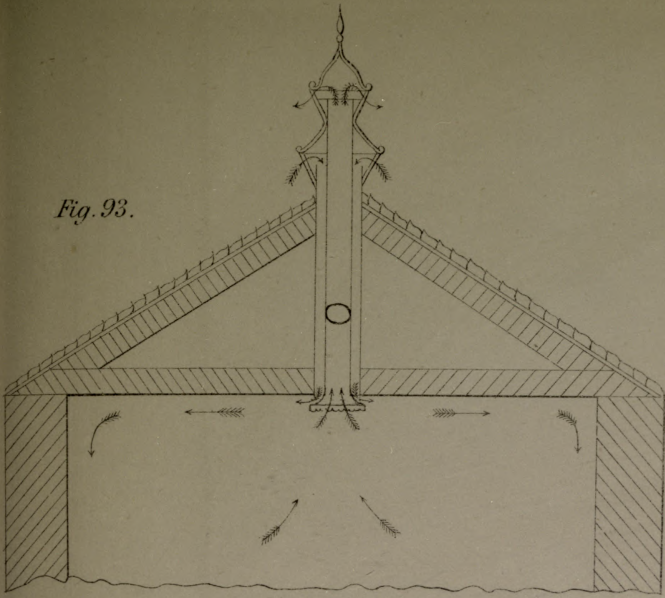


Fig. 94.

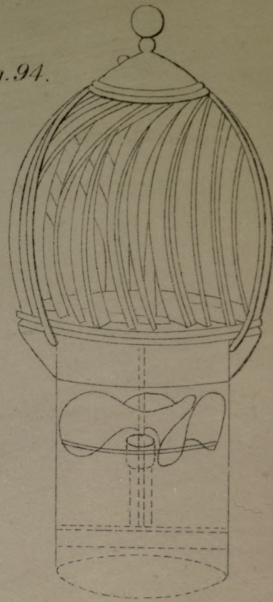


Fig. 95.

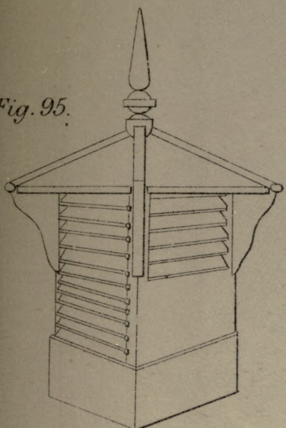


Fig. 97.

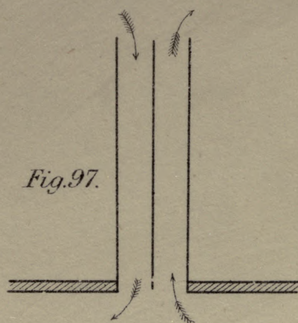


Fig. 98.

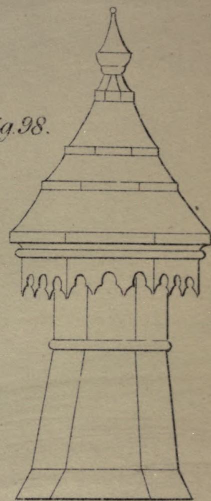


Fig. 96.

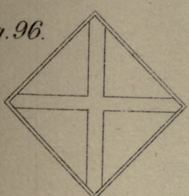
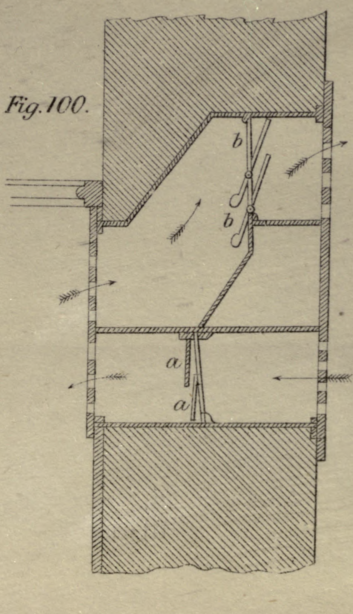


Fig. 100.



g. 99.

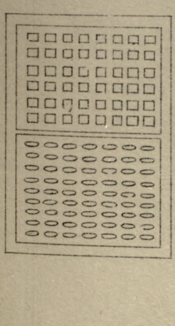


Fig. 101.

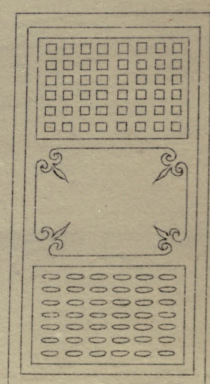


Fig. 102. Vertical section, showing the communication of one fire-place with a main smoke flue and a large main air channel, in which the smoke flue is enclosed for the supply of warm air to upper chambers.

a, *a*, main smoke flue.

b, *b*, *b*, main air channel.

Fig. 103. Section of smoke flue and warm air channel above the mantel-piece.

Fig. 104. Section of smoke flue and main air channel just above the level of the floor.

a, smoke flue.

b, *b*, warm air channel.

c, *c*, perforated gratings and regulators for the admission of warm air to the room.

d, position of fire grate.

e, *e*, chimney jambs.

Figs. 102 to 104

Fig. 102.

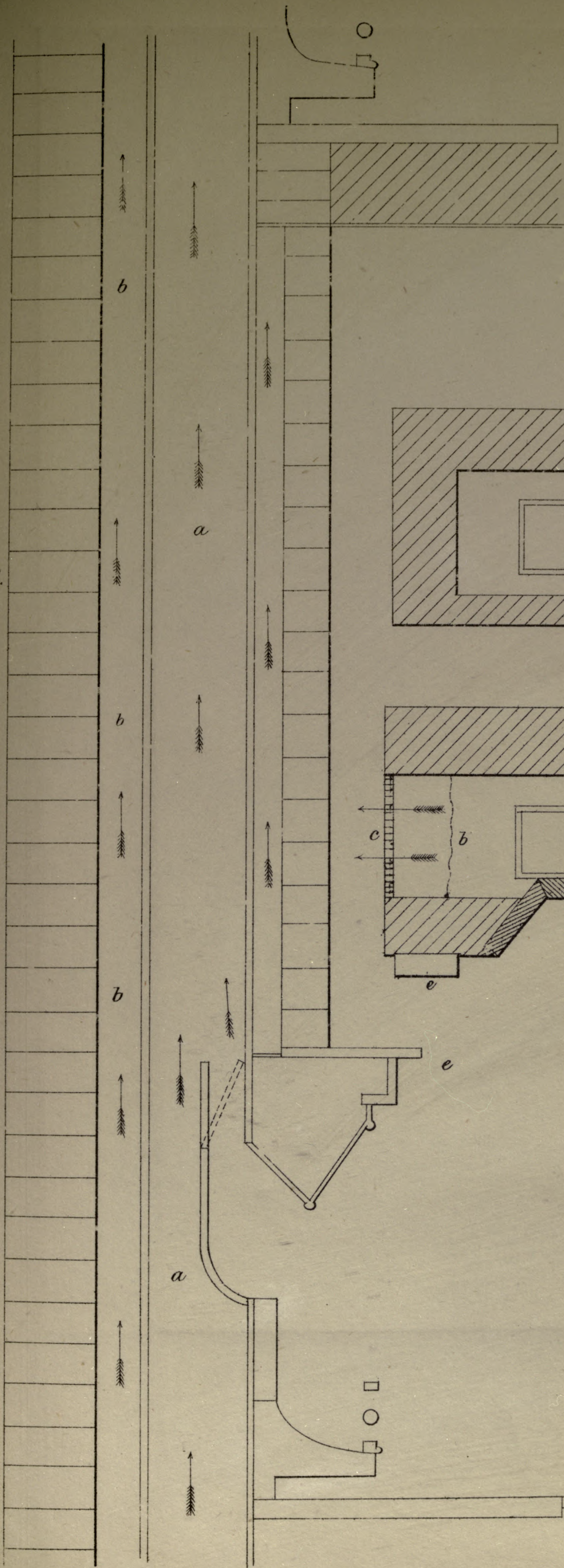


Fig. 103.

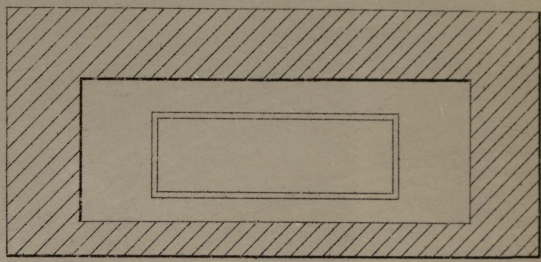


Fig. 104.

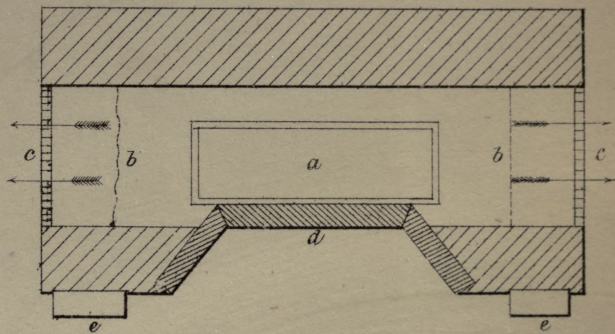


Fig. 106. Longitudinal and vertical section, showing a number of houses heated by warm-air ascending from a warm-air channel up shafts in the party-walls, and entering the various rooms, and on landings at openings provided.

a, a powerful furnace.

b, *b*, *b*, &c., large channel heated by the furnace.

c, large chimney shaft flanking the houses.

d, *d*, *d*, &c., horizontal main air channel, supplied with air, as shown in fig. 107.

e, *e*, *e*, &c., minor warm-air channels passing through the main flue.

f, *f*, *f*, &c., main air shafts in party walls, with openings into the rooms, &c., as shown by the arrows.

g, *g*, *g*, &c., dotted lines showing circulating pipes for supply of hot water from a furnace boiler.

h, *h*, *h*, &c., dotted lines showing vertical circulating pipes.

i, *i*, *i*, &c., hot-water cisterns for supply of warm bath, &c.