HEALTH & COMFORT IN HOUSE BUILDING

J. DRYSDALE & J. W. HAYWARD.

HEALTH AND COMFORT

IN

HOUSE BUILDING;

OR,

VENTILATION WITH WARM AIR BY SELF-ACTING SUCTION POWER;

WITH

REVIEW OF THE MODE OF CALCULATING THE DRAUGHT IN HOT-AIR FLUES; AND WITH SOME ACTUAL EXPERIMENTS.

BY

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AND

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" *Warmth* and comfort with regard to domestic homes have long been terms almost synonymous." In regard to our domestic homes, " *Ventilation* is scarcely second in importance to a due degree of warmth."—*Gov. Blue Book*, pp. 6, 7.

" The science or art of ventilation of buildings has never been reduced to system."—*Blue Book*, 1857.

" The art of warming and ventilating is extremely difficult, and cannot be said to have attained to anything like perfection."—*Cyc. Useful Arts*, 1868.

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PREFACE.

FROM his daily occupation the physician has more opportunities, than almost any other member of the community, of studying the interior arrangements of a great variety of houses. And no one realises as he does the true nature of any defects of construction, warming, or ventilation which bear upon the health and comfort of the inhabitants.

The writers have devoted much time and thought to the subject of house building; and, in the hope that the fruits of their reflections may afford some suggestions of practical value, they offer the following pages to the public.

The writers have not merely theorised, but have also put theory to the test of practical experience. In 1861, Dr. DRYSDALE built a house in the suburbs of Liverpool, in which many of the defects of ordinary houses were met in the way described in Chapter II., House No. 1. In particular he invented the scheme of ventilating the whole house through the kitchen chimney, by means of a syphon shaft, and a foul-air chamber communicating with each room by a separate pipe. This and other arrangements of the house attracted the attention, and met with the approval of, several competent judges. In 1867, Dr. HAYWARD also built a house in which the same principles were followed, with certain important variations adapted to the more difficult situation of a town-house: House No. 2, Chapter II.

In 1868, a paper was read on this subject by Dr. HAYWARD before the Architectural Society of Liverpool: it was received with approbation, and subsequently published in their proceedings. Some extra copies of this paper were issued in the form of a pamphlet, which is now out of print. This having been favouably noticed by the press, especially the medical journals, and deputations from several public bodies, who have visited the house in question, having expressed a wish for further information respecting it, there is a demand for either a re-issue of the above pamphlet, or for a more complete explanatory treatise on the subject. This demand, we think, can be best met by publishing a joint essay on the general principles and some of the practical details of the question; and by giving the plans of both houses, which, being very different in detail, will serve better to exemplify the principles which are followed equally in both. We also add, in an Appendix, a review of the methods of calculating the draughts in hot-air flues, some simple formulæ for this purpose, a ready-reckoner of velocities, and a record of some original experiments performed in House No. 2.

Liverpool, March, 1872.

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CHAPTER I.

GENERAL PRINCIPLES.

§ 1. We shall not enlarge on the necessity of an abundant supply of fresh air in our houses, for comfort as well as health, because this is now fully admitted. Our endeavour will be to show how it should be obtained.

To procure a sufficient supply of fresh air in our houses may, at first sight, appear a very simple and easy matter—we have apparently only to make as large an opening as is necessary for the admission of the outer air and it will come in. This is, however, a misconception, for the outer air will not come in unless at the same time the inner air go out; and these two currents will not readily take place through one aperture; there must therefore be two openings—an inlet and an outlet.

We need not insist on the above fact, because it is recognised by most persons of experience in the art of ventilation, and they generally provide two apertures. But here they stop, as though the making of a sufficiently capacious inlet and outlet were all that is necessary. Messrs. POTTS, MACKINNELL, MUIR, and WATSON indeed strongly contend that nothing more is requisite. And this is really all that is generally done in the way of ventilation; in fact it forms the basis of nearly all the plans of ventilation at present in use. But this is not enough; and it does not, will not, and cannot answer for house-ventilation in this country; because there is at least one circumstance that forms a fatal objection to all these schemes, and that is that nearly always the outer air is *cold* air; and cold air cannot with safety be admitted into our rooms at all times; nor indeed will it be, for in cold weather the inmates will stop up the holes in order to keep it out. Of this we have had ample evidence, and observation in this direction will quickly convince any one of the fact, as it did the GOVERNMENT COMMISSIONERS; the results of whose investigation are given in the following words:—"The science or art of ventilation of buildings has never been reduced to system. Openings are made from the open air outside a building, below for the admission of fresh air, and above for the escape of the foul, in various fanciful ways; but the cold draughts are so inconvenient that every endeavour is practised to obstruct the inlet." (*Government Blue Book on Warming and Ventilation of Dwellings*, p. 126.) The writer of the most recent summary of this question says:—"The art of warming *or* ventilating a building is not a difficult one; but the art of warming *and* ventilating is extremely difficult, and cannot be said to have attained to anything like perfection." (*Cyclopædia of Useful Arts*, published

1868, Art: "Warming and Ventilation.") The air must then be *warmed* before it is admitted. How this is to be done will be explained presently. But the entrance of cold air through these inlets is not the only evil connected with this crude method of ventilation, for it will also frequently come in through the openings intended for outlets. Speaking of these latter the GOVERNMENT COMMISSIONERS say:—"At no examination of these was it found that the air was escaping through them. On the contrary, flame was bent inwards, and fumes of partially consumed substances were driven into the room" (p. 91). This ought to be remedied; by what means will be shown in the progress of this essay.

§ 1a. In our climate permanent openings from the outer air cannot be endured; nor can the doors or windows, except on rare occasions, be left open even in the day, and never in the night without risk. After advocating the admission of plenty of fresh air into our houses, Dr. INMAN says:—"When speaking of airiness, I do not mean individuals to encourage draughts of cold air about their persons, nor can I recommend them to do as a medical friend of mine is said to do, viz., open the windows of the bedroom at night, to get the fresh country air, which the town smoke vitiates during the day so as to make it too impure. There may be difference of opinion on the subject amongst those who observe little, but amongst those who observe much the belief is entertained that warm air moderately impure (as in a closed bedroom where two or more are sleeping) is less noxious to the invalid and those whose health is shaky, than is cold air and absolute purity. The purity does not counterbalance the effect of the chill."—*The Preservation of Health*, p. 30.

No direct admission of the external air into the rooms *of a house can be borne during at least eight months of the year.* Hence *no* kind of arrangement of openings directly to the external air, such as perforated bricks, gratings in the outer walls, perforated or louvered panes in the windows, the wire-gauze apparatus at the top of the window sash, POTTS's perforated cornice, MACKINNELL's, MUIR's, or WATSON's ventilators, or *any* other contrivance that communicates directly with the outer air, can possibly be maintained as a plan of house ventilation in this country. In a climate like ours, houses should be built with reference to the winter, not to the summer; and they should be planned with the object of *keeping out* the cold air and not with the object of letting it in: ventilation should be provided for by special arrangement, which must include some means of continually warming the incoming air. When the air admitted into the rooms is perceptibly *cold* every effort is made to arrest its entrance, by stopping up all modes of ingress, even those of the best-contrived ventilating systems; these are thus rendered nugatory, and the whole art of ventilation is decried as a nuisance, the assurances of Messrs. POTTS, EDWARDS, WATSON, &c., to the contrary, notwithstanding. On the other hand, if anything like success be attained in keeping out the draughts by close-fitting doors and windows, thick carpets and mats, or by listing, sand-bags, &c. &c., the room becomes close and oppressive; and if several persons be in it, as at a dinner or supper party, the want of fresh air cannot be borne, and it soon compels the opening of the door or window; thus subjecting some one to a cold draught and the risk of rheumatism, sore-throat, bronchitis, or neuralgia. If only a few persons occupy a room protected from draughts, as above described, it may be borne for a time; but then the chimney begins to smoke, if not continuously at least occasionally, from slight disturbances of the atmosphere, such as gusts of wind, slamming of doors, or even the sweep of a lady's dress in the room. Hence, even in the best houses, the smoke and dust of the fire begin to gather on the ceiling, walls, windows, and furniture, rendering continuous washing and cleaning necessary; and where these are not done, as in houses of the less opulent classes, the rooms soon acquire that dingy look and fusty smell so commonly met with in such dwellings. Of course we do not mean that defective ventilation and smoky chimneys are the only causes of the dirty, dingy appearance of rooms, nor do we approve of continual washings and cleanings; indeed, we are sure that much evil would result from such a practice; and we agree with what Dr. INMAN says in the following extract:— "Dr. COPELAND," he says, "tells us he was consulted by a lady respecting the prevalence of scrofula in her school. She had been very successful as a teacher, and was particularly anxious to do her duty, as a mother, to those under her care. She fed her flock on the best, and lodged them in the cleanest and airiest of beds and chambers. The doctor inspected everything, and was at a loss to account for the frequency of the complaint, or suggest a remedy. Everything inside and out seemed *en règle*. A casual remark of his on the whiteness of the boards, where they were visible, elicited the information that all in the house were washed daily. The sagacious physician at once detected the flaw, and recommended an almost total abstinence from the use of the pail. His advice was followed, and the scholars became as conspicuous for their health as they had previously been for the reverse. Two or three days ago I was myself consulted in a bad case of scrofula in a fine-looking young woman of twenty-one, who had suffered from it for many years, and I could trace it to no other cause than her mother's strong propensity to have the music of scouring daily in her ears." (*Preservation of Health*, p. 29.) Even worse evils have been found to attend the daily washing of the decks of the ships of the Royal Navy: these at length became so manifest as to cause its relinquishment and the adoption of dry scrubbing.

§ 2. To obviate the evils of cold draughts and smoky chimneys several plans have been proposed: one, to supply the fire separately and specially by means of a pipe or flue directly from the outer air, opening near the fire. This plan is effectual so far as it goes, that is, in supplying the fire and so preventing the chimney from smoking; but it does nothing towards ventilation, on the contrary, it rather impedes it. Another plan is to have a double-backed grate; in this case the outer air is brought in at the back of the fireplace, and after being heated there is turned into the room through open work in the front of the grate, or chimney-piece, or through openings in the chimney breast, whence it rises into the room; and so, besides supplying the fire, preventing the chimney from smoking and checking cold draughts, it does really assist ventilation to a certain extent. (*Blue Book*, pp. 109, 110, 114, 115.)

§ 2a. A still more complete plan is that invented by Captain GALTON, of the Royal Engineers, and improved by General MORIN, head of the *Conservatoire des Arts et Métiers*, in Paris; and which Mr. EDWIN CHADWICK characterises as—" Simple and inexpensive; and the principle of which," he continues, " consists in surrounding the smoke flue, which may be of stoneware or iron, with a fresh-air flue: the fresh air being taken from the outer air. The heat of the smoke flue expands the air in the fresh-air flue and causes it to rise in a current, which is discharged—warm—near the ceiling of the room, across which it spreads. It then descends and mixes with the colder and heavier air beneath, and it is carried with the current into the open fireplace, and is thence discharged as vitiated air through the smoke flue. The smoke flue, surrounded by a fresh-air flue, constitutes a pump—pumping into the room warmed fresh air, in quantities proportioned to the warming power of the smoke flue, and the adjustment of the size and length of the fresh-air flue." (*Sanitary Specifications for House Construction*, read before the Medical Officers of Health, London, May 15, 1868. *Medical Mirror*, vol. v. p. 398.) According to Mr. CHADWICK, Captain GALTON'S first experiments were with a fresh-air flue parallel to the smoke flue, and warmed by it; but in General MORIN'S improvement of this the fresh-air flue was made to surround the smoke flue, and thus become more completely warmed by it: and it was found that by a proper adjustment of the flues the air of a room may be changed more frequently than the theoretically requisite number of "three times in the hour;"* and that "whilst in the common arrangement of a fireplace only one-eighth part of the chimney-heat is gained, with the ventilating chimney at least one-third is gained."† "There are objections," Mr. CHADWICK continues, "to ventilating with dry heated air; but Dr. PARKES, of Netley, has made experiments which show that at the rate which the air passes through the fresh-air flue and the short time of its contact with the heated surface it is carried into the room with its hygrometric condition very little altered. Another effect produced by the above invention," he continues,

* CHADWICK and REID say it is necessary the air of a room should be changed three times in the hour, Captain GALTON says twice, General MORIN five times, the GOVERNMENT COMMISSIONERS say twice; see also § 7a, p. 42.

† This last sentence is repeated by Captain GALTON in his essay on *The Construction of Hospitals*, p. 94.

"is the maintenance of an equable temperature in all parts of the room, and the prevention of draughts. . . . It also largely economises fuel, by making use of the spare heat which would otherwise be carried up the chimney." (*loc. cit.*) Mr. Chadwick also referred to a somewhat similar plan in his *Sanitary Reports* in 1862. The principle of these plans was, however, already known to us through the *Blue Book*, published in 1857, and was rejected by us in 1860 as an unsatisfactory method of house ventilation; and for the following amongst other reasons, viz.:

§ 3. Even the best of these plans (§ 2a) is applicable only to single rooms; and mere single-room ventilation is necessarily incomplete and unsatisfactory. Moreover, as regards the room itself, the above plan is objectionable, inasmuch as it can act only when the fire is burning, and when the fire is not burning it is apt to let in *cold* air; and because the sole means of abstraction of the vitiated air is through the fireplace. The vitiated air naturally collects near the ceiling of the room, and having no means of escape there becomes mixed with the incoming fresh air, pollutes it, and with it is again diffused through the room, and only then gets away by passing up the chimney along with the fresh air with which it is mixed. The vitiated air has, therefore, to be respired over again, which it never ought to be. It must also be remembered that this method can only act properly when the doors and windows of the room are closely shut; for the ingress is caused not altogether nor principally by the pumping in of the fresh air by the flue, but by the suction of the fire; and that the draught of the fire is much more easily supplied by the windows and doors, when these are open. There are also the objections which are applicable to all plans of ventilating with air passed over highly heated surfaces, viz., that it is liable to get dried, burned, spoiled, and disagreeable. The GOVERNMENT COMMISSIONERS also object to ventilation through the fireplace; they say: "The commission strongly recommend that the fire-grate should be studied in its construction with a view to its effecting a better and more economical consumption of fuel, and a more equable distribution of heat, and *not as a contrivance for the ventilation of rooms.* The commission is decidedly of opinion that so long as the fire-grate is studied with a view to this twofold application it will not succeed well in the performance of either." (*Blue Book*, p. 95.) Nevertheless, Captain GALTON's plan has the advantages, before referred to, of not only supplying the fire and assisting ventilation, but also of saving a considerable amount of the chimney heat; this latter being a matter of great importance; and as the objections given above do not counterbalance its utility in single rooms, we would advise its being kept in mind wherever, from isolation or other causes, the complete plan presently to be described cannot be carried out, or must be supplemented: *vide* § 6.

§ 3a. *No plan of ventilation by fire-suction applicable only to single rooms can possibly supersede the necessity of a general plan for the whole house*, because it can act only for single rooms, and of course only when there is a fire burning in them. In many houses there are rooms, at least bedrooms, which have not even a fireplace; and in many bedrooms the fire is seldom or never lighted, although bedrooms especially require ventilation; and with these double-backed grates or double-flued chimneys, when the fire is not burning, only *cold* air can by this means gain entrance, whilst the admission of cold air is particularly dangerous during sleep. For a great part of the year only a few rooms have fires burning in them; and for some months in summer there is positively no fire burning in the house except the kitchen fire. If, therefore, a general system of ventilation is required, it must be effected by some other means than the fires of the rooms; and indeed, if at all, this is to be done by fire-suction, without a special fire for the purpose, it must be by means of the kitchen fire, which alone, in every house, is lighted daily throughout the year. A general plan that includes the whole house is then absolutely necessary; and this, of course, involves the maintenance of an agreeable warmth in all the central thoroughfares and passages, in order that the air which enters the rooms from them may be warm. And this warmth of the passages is of itself a great advantage to the inmates, by enabling them to move about through the whole house; and thus get much fresh air without going out of doors.

§ 3b. We hope it is quite superfluous for us to say that, as medical men, we are fully alive to the benefit and even necessity of being as much as possible in the open air. No attention to warmth and ventilation can supply the place of this, as is proved by the comparative unhealthiness of workmen and others who pass the whole day in closed rooms and manufactories, however well ventilated, and those of the same class who work in the open air. The latter are, on the average, much worse off as to food and the comforts of their dwellings than the former, yet their state of health and strength is greatly superior. This, though it may be partly due to the presence or absence of sun-light, is not yet fully to be explained; but the fact is so; and it applies to all ranks of life. It must, therefore, be admitted, as practically established, that unless a certain portion of the daily life of all persons, especially children, is passed in the open air, the health will surely, though slowly, deteriorate. We must also admit that the chief benefit of change to a milder climate is owing to the possibility of the invalid being more in the open air without risk of taking cold; and we do not pretend that any kind of house or sanatorium, where a mild uniform temperature is secured in-doors, can equal the good effects of a naturally warm climate. Nevertheless, we must not fall into the error of supposing that a badly ventilated and draughty house possesses any of the advantages of the open air, or escapes any of the evils of in-door life: on the contrary, whilst destitute of the former it possesses the latter in an aggravated degree. We do not hesitate to say that a properly warmed and ventilated house is of the very greatest consequence to health and comfort, and in many cases to life itself. Such a house is by no means prejudicial to healthy persons, as making them less able to bear the open air, or less disposed to seek it; on the contrary, it is less prejudicial in these respects than an ordinary house. We find a considerable proportion of the inhabitants of this country, though not actually ill, remain in the house the whole day during the winter, and at times for days together: and in houses of the ordinary construction we see them crouching over the fire, covered with shawls and protected with screens, hesitating to go even from one room to another for fear of the cold. These persons naturally get such a languid circulation and become so chilly that they dread more and more the natural remedy, viz., the open air; and they will not go out. Whereas, if the house were properly warmed and supplied with fresh air, so that they could move about freely in it and sit in any part of the rooms just as in summer, the circulation would be so much better that they would not fear a walk in the open air, even on a winter day. The idea that with healthy men it would dispose to a relaxed and effeminate state of the system is equally groundless: as a proof of this we may notice that one of us who has lived four years in House No. 2, is a general practitioner of medicine, including surgery and midwifery, which involves being frequently called out at all hours of the day and night; yet no increased liability to cold, or delicacy of any kind, has been observed; on the contrary, whereas previously, when living in ordinary houses, he frequently suffered from bronchitis and quinsy, he has never had either disease since living in his present house: and a member of his family who had previously to spend several winters in a warm climate, is now able to remain at home and go about in the open air all the year round. For the prevention of disease we hold such a house to be a most important auxiliary. We could bring forward numberless instances of disease brought on by colds caught within ordinary dwelling-houses, both from medical literature and our own observation; but such would be superfluous, as it is a matter of common experience. It is also superfluous to insist on the advantage of such a house during actual illness and the period of convalescence, as the difficulties of securing the necessary warmth and ventilation in such cases in ordinary houses are keenly felt and deplored by all medical men. "Mrs. ——, a lady," says Dr. Inman, "living in the country, in a comfortable old-fashioned house, of active habits, and surrounded with luxuries, began to suffer from sneezing. As soon as she left the bedroom the fits began and continued with scarcely two minutes interval throughout the day. Her doctors could not cure her, nor did she find any relief until she reached a warmer atmosphere than that she had been breath-ing. Warned by a recurrence of the attack, the following winter the husband introduced a heating apparatus into the dwelling, and, with its aid, he was able to enjoy his wife's presence in person rather than through the medium of the Post-office."—*Preservation of Health*, p. 30.

"We submit, then, that an adequate amount of heat around us is one of the greatest luxuries which mankind can enjoy."—*Ibid.*, p. 107.

To illustrate the advantages of a properly warmed and ventilated house in the debateable ground between health and sickness which is constituted by the slighter ailments from cold, and during the convalescence from ordinary catarrhal diseases, we will simply allude to *consumption*, the mortality from which we think might be notably diminished by improving our houses in the way we are advocating. A great change of medical opinion is at present taking place in respect to this disease. For nearly fifty years the theory of LAENNEC had been dominant in the medical world, viz., that almost all cases of pulmonary consumption depend on the spontaneous development of tubercles, which run their course to destruction of the lung, little, if at all, influenced by the art of medicine; and the popular opinion that neglected colds lead to consumption, was said to be nothing but a vulgar error. It is now, however, held that in a large proportion of the cases of consumption no tubercles are present, at least until nearly the end; and that such cases are nothing more than the results of inflammation within the chest, imperfectly cured, or continually renewed by fresh cold brought on, doubtless often by imprudent exposure out of doors, but also, in accordance with what has been said, by the draughts and cold lobbies of our badly-constructed houses. These relapses and imperfect cures may happen even in the strongest individuals; but they are, of course, more liable to occur in delicate persons. The popular opinion is thus justified; and the importance of due care in the prevention and treatment, by all possible means, of the ordinary and slight forms of cold in the chest is rendered obvious. Amongst these means the advantage of a properly warmed and ventilated house is too evident to require any argument. All writers who have given much attention to this subject insist on the necessity of warmth as well as ventilation: in the work already referred to, Dr. INMAN devotes a whole chapter, XVI., to arguments and illustrations of the "Value of Heat," and another, XVII., to the evil "Effects of Cold." BERNAN, also, devotes two whole essays to the same subject in his *History and Art of Warming and Ventilating Rooms and Buildings, and Notices of Personal and Fireside Comfort.**

§ 4. In all our attempts to ventilate houses, and at the same time preserve a uniform temperature throughout, we must bear in mind that we are living at the bottom of an ocean of air, which presses equally every way, and whose weight and pressure and their laws are accurately known. Any portion of this air on being heated expands in volume and becomes specifically lighter than the neighbouring portions, which have therefore a greater tendency to fall towards the earth and thus push the lighter portion upwards. Heated air has thus a tendency to ascend, not however from any such power within itself, but solely because it is pushed upwards by the fall of the colder, denser, and therefore heavier air taking its place; just as the lighter scale of a balance ascends because it is pushed up by

* By WALTER BERNAN, C.E., 2 vols. 1845.

the descent of the heavier scale, and not because of any power of its own to ascend. These simple truths are frequently overlooked by amateur contrivers of ventilating schemes; they know the fact that hot air rises, and they think, therefore, nothing more is necessary than to make an aperture at the top of the room, and through it the foul heated air will naturally go out! But it will not do so, unless an exactly equivalent volume of colder air find entrance at the same time to push it out. In an air-tight chamber with a single aperture at the top, a lighted candle will go out, even though the aperture is quite large enough to supply an ample change of air. Where a candle will go out a human being will die. The reason why one moderate sized opening fails is, that the incoming cold and the outgoing hot currents of air meeting in one small space, oppose and counteract each other to such an extent that the passage is practically choked. That this is really the case, and not that the opening is absolutely too small, is easily shown by inserting a septum into the tube or making it double, one side reaching a little lower down than the other: immediately the currents are separated, the colder one going down the longer tube and the hot one up the shorter, inducing directly a full supply of fresh air. This is the principle of MacKinnel's, Muir's, and Watson's ventilators, and Mr. Potts's plan of letting the *cold* air *in* through the lower part of the cornice and the heated air *out* through the upper part (*A System of Ventilation*, by William Potts, 1868), and is strikingly illustrated by the travellers for Mr. Watson's invention, who carry about with them a little glass chamber with a small tubular aperture at the top. Into this chamber a piece of lighted candle is put, and in a short time the light becomes dim, and eventually it goes out altogether.

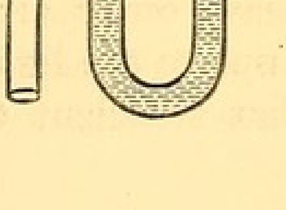
The candle is then lighted again, but at the same time a septum is inserted into the aperture dividing it into two tubes of unequal lengths: although the aperture is not enlarged, but in fact diminished in size, the candle now burns on with undiminished lustre until quite consumed. In this experiment the change of air is produced by the simple process of self-acting heat-suction, and it shows palpably the necessity for *two* openings—an inlet and an outlet, and demonstrates the necessity of ingress of an equivalent volume of colder air before any air can be taken out by any self-acting process of heat-suction. As a contrivance for ventilating a confined space through one spot by the difference between its heat and the heat of the external air, this invention must be pronounced perfect; and, therefore, as a practical apparatus, it may be recommended wherever the object is to have *fresh* air, while at the same time it is either immaterial whether the air be *cold*, or it is desirable that it should be so. It may therefore be used in out-houses, barns, foundries, and other large buildings where the incoming air may be cool as well as fresh without disadvantage; and it may be fixed even in theatres and churches, though probably usable in these only in summer. For ventilating houses it is quite inadmissible, and has had to be abandoned in almost all cases where, from a misapprehension of its real mode of action, it had been adopted. It is quite true that it brings in a sufficient supply of oxygen for the candle to burn where it went out without it; and that under similar circumstances it would enable an animal to live that would perish without it, that is so far as oxygen is concerned; but there is an important difference between a candle and an animal. A candle will burn quite well however cold the incoming air may be, and perhaps the colder the better, whereas an animal can live only within a comparatively limited range of temperature. To us likewise are given *feelings*, which inform us pretty quickly when the limit of health and comfort as to cold is reached. Many a worthy *paterfamilias* has been captivated by the candle experiment of the traveller for WATSON'S ventilator, and immediately ordered one to be put up in his house. On coming home to dinner, after a sharp walk, he has been delighted with the fresh cool air which met him in the lobby, instead of the close stuffy air, loaded with kitchen smells, to which he had been accustomed; and so, for a time, he has been loud in praises of the new machine; but his triumph has been short-lived, for as the colder weather came on the prudent *materfamilias* has begun to shut the ventilator as soon as his back was turned, dreading with good reason the colds, coughs, neuralgias, rheumatisms, and the numberless ills of which cold may be the exciting cause, much more than the ordinary evils of defective ventilation; and the upshot generally is, that the ventilator is either removed or is kept shut for three-fourths of the year; and we think rightly so. The principle made use of by these inventors is that of "spontaneous" ventilation; but it is not at all necessary that the inlet and outlet should be at the same place. The inlet for the colder air may be anywhere, provided it is a little below the level of the outlet. It must be remembered that in all mere spontaneous ventilation the suction power is obtained solely by the heat of the air in the apartment; and that the incoming stream of air *must* therefore be *cold*, at least comparatively so, for the suction power is gained solely by the *difference of temperature* between the air within and that without the chamber; the heated foul air being simply pressed upwards by the incoming cold air. Does not this, though, militate against *our* first requirement of house-ventilation, viz., that the incoming air must not be cold? By no means, for the plan to be presently described is not "spontaneous" but "self-acting," and the suction power is gained not only by the warmth of the air in the house, but also, and principally, by the intense heat of the kitchen fire and the long warm syphon, which give such a powerful draught that air sufficiently warmed can be drawn into and through the rooms, up the flues, through the foul-air chamber, and even down the downcast shaft, in opposition to gravity.

If no properly devised method of ventilation be adopted by which an ample supply of fresh warmed air is provided, the principle of spontaneous ventilation *will* come into operation in every house, and cold air will gain admission; for it must be remembered that the fires, and even human beings (who likewise produce heat by the consumption of oxygen) convert the house or apartment into a kind of vacuum or suction-pump, the draught of which is everywhere inwards; so the tendency must be for the outer air to enter at all possible apertures; if legitimate ones sufficient are not provided, it will come in through all others to be found, such as ill-fitting windows and doors, crannies in the skirting-boards and floors of the rooms, &c.; if these are insufficient it will come down the chimney, which will thus be made to smoke; should the door then be opened, or a permanent opening be made through it or over it into the lobby, without a suitable provision for supply into the lobby itself, then air will be sucked in from other rooms, down other chimneys whose draught is not so strong, causing them to smoke if lighted, or bringing down cold air or back smoke, if not lighted. If these are closed with valves, then air will be sucked in from worse places, viz., sinks, water-closets, drains, cesspools, and cellars, and empty spaces near the foundation; from all of which foul and dangerous gases are liable to be drawn in; and, not a pleasant reflection, one's house is converted into a ventilating shaft for those noisome places, for the sole benefit of the rats and other vermin that may inhabit them.* The same principle enables us to understand why merely making a hole in the top of a room is not enough for ventila-

* The risk of dangerous effluvia being drawn in from water-closets and drains would be, to some extent, obviated by frequent and regular flushings of the drains and sewers, and by a proper ventilation of the main sewers of the town and the drains of the house; particularly the ventilation of the house drains,

Sewers and drains contain the excreta and infectious particles or disease germs generated, and thrown off by diseased individuals, as well as other matters in a state of putrefaction: these latter are continually giving off offensive gases, which must and will escape somewhere and carry with them the disease germs: they will, indeed, force their way out of the drains in spite of any system of trapping, and through the best description of traps, even without the assistance of suction, though they will be particularly likely to escape where there is suction. These gases, being light, naturally tend to rise, and therefore to pass *up* the sewers and drains; and thus they exert their greatest force in the highest parts of a town; and by escaping there they carry disease from the worse to the better parts of a town. This is one explanation of the occurrence of infectious diseases in the better parts of towns, and is one cause of the spread of epidemics.

Main sewers should be ventilated by openings at short intervals up into the streets, and covered only with strong gratings; for there would be very little offensive emanation, and very little risk of the disease germs taking effect when so diluted as they would be when mixed with the whole air of the street, though there would be but little chance of escape from their deadly influence when escaping into a warm ill-ventilated house. All the drains of every house should be ventilated; and this may be done easily and at little cost by running up from the top of every water-closet soil pipe, and from the top of every bend and trap of every waste and sink pipe, a small pipe (say gas pipe) to the top of the house, as suggested in 1861 by Mr. MORRIS, M.I.B.A., thus:



And the sewer in the street should be cut off from the drains of the house by traps, ventilated in the same way by means of the down spouts, or by traps open to the air just outside the house. So long ago as 1845, ALFRED HIGGINSON, M.R.C.S., of this town, proposed to ventilate the sewers by connecting them with furnaces, in order to suck in air through the branches. An objection has been raised to this plan that the suction would probably not reach the house drains, because plenty of air might be drawn in through the street gutter traps.

tion: without proper provision, as above explained, not only will the vitiated air refuse to go out, but the cold air will insist on coming in, to the confusion of the contriver and the discomfort of everybody in the room; because the feeble ascending power of the heated air in the upper part of the room will be overcome by the draught of the fire: a single fire draws in for its own supply from 600 to 1000 cubic feet of air per minute. Referring to this point at p. 91 of the *Blue Book* the GOVERNMENT COMMISSIONERS, speaking of their own experiments, remark: "In the ceiling of every room two or three small gratings were inserted, connected with other gratings of a similar size and form, in the face of the external walls of the building. At no examination of these was it found that the air was escaping from them; on the contrary, flame was bent inwards, and fumes of partially consumed substances were driven into the room." With respect to spontaneous ventilation, independent of the complication induced by the suction of fires, we must remind the reader that the draught must be greater in proportion as the air in the room is warmer, or, which amounts to the same, as the outer air is colder. This is the reason why it is so easy to obtain sufficient change of air in very cold weather, without any special provision for its admission. The tendency for the cold air to rush in is so strong that a few small openings, or even crevices, are enough to change the air of a room rapidly; but at the same time to cool it effectually. So the difficulty is not to get the cold air in but to keep it out. In winter-travelling in cold countries, in spite of all shutting of the carriage windows, the tendency of the cold, dense, heavy outer air to press in through the crevices and displace the lighter warm air in the carriage is so strong that sufficient change of air takes place for the travellers to get to the end of their journey alive, that is, not suffocated, as they certainly would be with a like shutting of the windows in summer weather, or with the outer air at blood heat. The difficulties of spontaneous ventilation begin as the weather gets warmer: as the temperature of the outer air approaches that of the room there is less tendency to change; and if the outer air and the air within the house were of exactly the same temperature the latter would be stagnant, even though the windows were open, unless some driving or suction power were provided. The punkah is therefore not a luxury, but a necessary of life in Indian houses, that is to say, when the general temperature is about 98 deg. Fahr.; in this case the breath does not rise, as it does when the air is cold, but remains near the face of the individual, going only as far as it is blown by expiration. For the same reason in very hot weather in this country, houses such as we propose would be better ventilated with the windows shut than ordinary houses are with them open.

Of course we are aware that ultimately all contamination of the air from gaseous products would be removed, without *ventilation*, by mere *diffusion*, according to GRAHAM'S law of the diffusion of gases; but this process is far too slow to be here taken into account, as it occupies from several hours to many days to accomplish; for example, in GRAHAM'S experiments, in four hours only 31 per cent. of carbonic acid was removed, and in ten hours only 47 per cent.: and we know that in a brewer's vat, open at the top, the production of carbonic acid being quicker than that rate, the part of the vat above the liquor becomes so charged with it as to be fatal to animal life. The air of our rooms is contaminated from much the same cause, and therefore it requires a much more rapid process of removal than mere diffusion, and such as can be got only by "ventilation," in the proper acceptation of the word, which means that one mass of air must be removed, and another introduced into its place. Besides, diffusion is always at work, but is found to be practically ineffectual.

§ 5. Supposing that we have provided for the ingress of a sufficient supply of moderately-warmed fresh air for all the wants of the house; and for a sufficient suction power for drawing off all the vitiated air, *our next care must be to prevent the heat in the general thoroughfares and passages from being wasted;* and unless special attention is paid, in the original planning of the house, to the position of the doors opening from the outer air, the heat will be wasted, and all our endeavours to produce a comfortable house will be thrown away. In the polar regions the necessity for an inner door and intermediate passage is recognised and provided for in the construction of the meanest hut. In fact it is a matter of life and death; for to cool down the whole house to the level of the outer air every time the door is opened would soon kill all the inmates. In this country, of course, this point is not so imperatively forced on our attention; but the same principle is at work here, to the detriment of comfort and health. When we look at those ugly, vulgar, square boxes, put up by mere builders and bricklayers, which form the staple of our suburban villas, we see at a glance that there can be no comfort in such houses for three-fourths of the year. When the front door is in the middle of the front elevation, opening into a lobby that leads between two sets of rooms straight to the stairs, each time the door is opened the cold blast rushes through the whole house, reducing it almost to the temperature of the outer air: and this evil is much aggravated when, as is frequently the case, a back door is placed nearly, or quite opposite, the front door. By such an arrangement of the plan of a house all systems of warming are reduced to that of warming single rooms, and all ventilating plans are crippled accordingly. This defect is at least shared in by nearly all houses, even those of a more careful planning, unless special provision is made for the opening of the outer doors without the attendant passing through the central hall of the house. The usual attempts to counteract this evil by having inner doors are, in nine cases out of ten, practically ineffectual, as the servants leave the inner door open at the very time it is most necessary it should be shut: and sometimes this does not arise from carelessness, but from the inner door being not conveniently enough placed to allow of it being kept shut when more persons than one are entering the house. In some houses the inner door is actually open at the top; so that it is quite useless as a second door; and when so made, it being closed to keep out intruders, the outer door is frequently left open, even in winter, thus allowing a current of cold air to be continually rushing through the house, rendering it little better than an open shop.

§ 5a. *To prevent this waste of heat care should be taken in the original plan of the house to have a central hall, corridor, lobby, fresh-air chamber, or vestibule, separate from the stairs lobby, and into which no outer door should open.* The back door should open into the scullery, or kitchen, or some other room in which it is the interest of the servants for their own comfort to keep it shut. The front door should open into a lobby or vestibule to which there is a separate access from the servants' department, without their going through the central hall of the house proper. As long as the central hall or lobby of the house is the thoroughfare for the servants in attending to the front door, all plans of procuring a central or general warmth in the house will be sure to fail, because the best trained servants will at times neglect to shut the inner door. As a matter of fact we have observed that in about nine out of every ten houses possessing inner doors, as we enter the servant does neglect to shut the inner door. And even when the inner door closes by a spring we very commonly find that it is propped open most carefully by some ignorant or perverse domestic. A double entrance to the front vestibule, or a separate lobby, is, therefore, desirable, if not absolutely essential. To obtain this is comparatively easy in a country house, or a corner house in a street, simply by making the front door at the side, and arranging all the servants' or working department on the one side, and the living rooms on the other. This is the plan of House No. 1, described in Chapter II. In an ordinary street house the problem is much more difficult, and will often tax the ingenuity of the architect to the utmost to solve it properly. The mode adopted in the plan of House No. 2 is probably one of the best. Each plan is, of course, susceptible of numberless variations. For instance, where economy of space is a matter of importance, as in small houses and labourers' dwellings, the central corridor may be dispensed with by having the warming chamber entirely in the basement, and carrying the warmed air directly into the rooms by flues within the walls; and the stairs lobby being also supplied with warmed air the room doors may open out of it. In all good houses, however, we advise the central corridor, because of the many conveniences and comforts it affords: besides checking the direct current and distributing the incoming air, it allows the rooms to be built *en suite*, and may be made useful and ornamental in many ways; for instance, it affords opportunity for remoistening the air; and in House No. 2, on the ground floor it forms a museum, on the first floor a bagatelle-room and picture gallery, on the bedroom floor it would serve for the placing of wardrobes, &c., and on each floor it serves for the reception of furniture when cleaning the rooms. Ventilation directly from the stairs lobby is inadmissible, because, being a common thoroughfare, it is open to servants and other listeners.

§ 6. As much of the heat communicated to the incoming air will be lost by radiation through the windows and outer walls, or abstracted by the contact of the cold outer air (see Chap. III. p. 67), the individual rooms must have some special means of making up for this loss. For this purpose various plans have been tried. Some of these simply radiate heat into the room, others simply heat the air and conduct that into the room, and others do both these. The contrivances for radiation include the open fireplace in all its multitudinous forms; the closed stove, in almost every shape and construction; pipes, containing hot water or steam, arranged in almost every conceivable way; floors made of tiles, and furnace flues underneath them; hollow walls with furnace flues between them; and other such like expedients. The contrivances for simply heating the air include the various forms of chambers, flues, and pipes; which, being heated on the outside, heat the air as it passes through them, and then conduct it into the room either through the floor, the skirting-board, the wall, or the cornice, in various ways. The combined plan includes the various kinds of double-backed grates and double-flued chimneys referred to at §§ 2, 2a.

To the mere heated-air plan there are many and grave objections; and these apply also, in some degree, to the combined plan. It is a bad method of distributing heat, because of the tendency of the heated air to rise upwards, and thus collect the heat in some places whilst others remain cold. Besides, if the air be heated for the purpose of supplying heat, in order to compensate for the loss by conduction and radiation by the windows and walls, as well as that escaping up the chimneys, and other voluntary or involuntary modes of ventilation, it must be heated to a higher degree than is comfortable or healthy, and is liable to be too much dried, and to get that burnt, disagreeable smell, from the deficiency of its moisture and the destruction of the organic particles which are suspended in all air. Simple radiation is decidedly the most pleasant and wholesome, as well as the most effectual. The heated floors, double walls, and hot-water pipes, have the recommendation of cleanliness and more general distribution of heat, but the open fireplace is the most generally acceptable, and certainly the most cheerful: and in this country, where fuel is comparatively cheap and the cold hardly ever intense, we can, as a rule, have the open grate; though in some parts of Europe, and in North America, where the cold of winter is intense, stoves, flues, or pipes may be necessary. Since the time Count Rumford first took up the subject of fire-grates, they have been brought to great perfection as to economy of fuel by their form, radiation of heat by their surface, and prevention of loss of heat up the chimney by contraction of the chimney throat. There are many good kinds: we approve of the smokeless plan of Cutler, improved by Dr. Arnott, in which the fire is replenished from below: they give a steady, red fire, are cleanly, and require but little attention: there are two of them in House No. 1: though more expensive in first cost, they are eventually much cheaper, because of the economy in fuel; still many people prefer the sparkling bright fire of the common form of grate: of these perhaps Stephens's are the best: these are the kind used in House No. 2.

Having now secured a method of preserving the heat of the central hall and general passages of the house, of warming the individual rooms, and compensating for the loss by radiation, the next point is *the mode of warming the incoming air.*

§ 6a. We are no advocates of warming the house by means of heated air. All we recommend here is the heating of the incoming air that is requisite for ventilation; and for this purpose it need not be heated above 65 deg., unless the velocity be great, for the comfortable supply of rooms otherwise warmed: and the best way of doing this is by passing it over or through coils of hot-water pipes, which avoids the danger of burning it or interfering with its moisture. It may often be sufficient to cause the whole of the incoming air to pass through a shaft containing the coils, and then discharge it into the central hall or lobby; but if this be large, or the passages be long, or on different floors, it will be necessary to have the pipes to extend round or along them; otherwise the air would be too much cooled again before entering the rooms, if only heated to 65 deg. at its first entrance. These circumstances, often requiring small bore pipes, may necessitate the employment of steam, or the "high-pressure" water system. In House No. 1, the incoming air is warmed by hot water on the "low-pressure" system with large pipes; in House No. 2, with small pipes on the high-pressure system. Some observations on the comparative merits of the two systems will be found in the Appendix, p. 111.

The objection that artificially warmed air is dry and disagreeable may be obviated by supplying water, either by evaporation or spray, to the air after it has been warmed. Air to be pleasant for respiration must contain a proper proportion of moisture, that is, near to the point of saturation, or what it usually contains out of doors. The quantity of water air requires for saturation differs with the temperature: air at 66 deg. requires 6 grains of water in each cubic foot, but air at 30 deg. requires only 2 grains; that is, air at 66 deg. holds in suspension 6 grains of water per cubic foot, whilst air at 30 deg. holds only 2 grains; consequently, if air be reduced from 66 deg. to 30 deg. it parts with 4 grains of its moisture per cubic foot, in the form of dew; if then it be afterwards raised again to 65 deg., without more water being supplied, it must necessarily feel dry and harsh; hence if in winter, by the warming apparatus, we raise the temperature of the air from 32 deg. to 65 deg., we must supply it with water, otherwise it must necessarily be disagreeable and unhealthy, because of its rapid abstraction of moisture from the lungs and skin. This is a natural result of re-supplying the heat without re-supplying the moisture; it is not "drying" in the proper sense of that word; and it will follow however the warming is done, whether by open fire, closed stove, hot flues, or hot-water pipes; and whether this latter be on the low or high-pressure system—all alike produce the same result in proportion to the elevation of temperature they effect. Of course, it is possible also to burn the air, that is, to decompose its moisture and burn the organic particles floating in it; and this may be done by keeping it too long in contact with very hot surfaces, flues, pipes, or stoves, but it will not happen if the air be passed over the warming apparatus at a proper speed, even when the apparatus is very hot, as has been shown by practical experience with PERKINS's apparatus in House No. 2, and with the double-backed grate and doubled-flued chimney in the Netley Hospital, § 2a, p. 7. The heating surface should be proportioned to the quantity of air required to be warmed, and its exact amount had better be left to the engineer supplying the apparatus, or to the architect superintending the erection of the house.

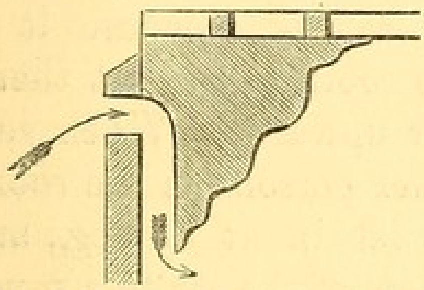
The cost of this warming of the incoming air must not be considered an extra expense, for it is, theoretically, saved in the smaller fires that are necessary in the rooms, and, practically, it is much more than compensated for, because on very many days in the year it makes all the difference between having fires in the rooms and not.

§ 6b. The first opening or *primary inlet* into the house for this incoming air may be in the basement, through the wall towards the region where the atmosphere is generally the least loaded with effluvia, blacks, and dust; but probably a better plan, as likely to obtain purer air, would be to have a shaft or flue leading down the wall from the level of the top of the house. This should lead, by means of a flue, passage, or cellar, to the secondary inlet opening into the central hall or corridor. Between this primary and secondary inlet the air will naturally deposit much of the dust and dirt it may contain, and thus it will carry less to the rooms and furniture than it does when let in in the ordinary way through the windows and doors; and here, also, the incoming air might be made to pass through a canvas screen, and, if necessary, be washed, disinfected, or perfumed, &c. &c. The best position for the warming apparatus is the basement of the central hall, so that the air may be warmed as it enters the house.

Of course, this passage, the coils, and everything connected with the inlets, should be kept scrupulously clean.

§ 6c. In the general plan of the house it is necessary to provide not only a central hall separated from the common thoroughfares, and kept permanently warm, but also *to arrange that the doors of all the rooms shall open out of this*, in order to avoid the cold draughts which otherwise always rush into the rooms every time the doors are opened. As a matter of fact in the houses already referred to, no cold draughts are felt on leaving the doors open, and thus it matters little in them in this respect whether the doors are open or shut; which goes far towards rendering one of the cardinal virtues instilled into children and servants, "Shut the door after you," out of date and superfluous. Nevertheless, although not for the avoidance of draughts, yet for other reasons, the doors should be shut, the permanent provisions of the house must presume that they are so.

§ 6d. The next points to be considered are: *Where and how shall the fresh warm air from the central hall be conducted into the rooms?* Of course it should not be left to find its own way in through the doors or crevices, but it must have a special and ample inlet into each room. If it were a question of warming the rooms by means of heated air, which would then be warmer in the corridor than in the rooms, it should, of course, be brought in through the skirting-board, or at the bottom of the room; but as this is not our method, and the air is merely for the purpose of ventilation just sufficiently warmed not to cool the air of the room, we prefer that it should be brought in near the top, through the cornice, concealed, if necessary, by an ornamental open-work; it should, however, enter through or below the lowest member of the cornice, thus:



in order to prevent any possibility of its passing back into the fresh air lobby. This inlet should be split up into numerous small openings, as by the use of perforated or air bricks in building the wall just behind the cornice, and the air should be let into the room through a slit along the whole length of the wall, so as to distribute it as much as possible throughout the room, and the fireplace should, if possible, be on the opposite side. (*Cyclopædia of Useful Knowledge*, pp. 824, 825.) Through the skirting-board has the advantage of less easy travel of sound from the rooms, but this is not a matter of much importance when the inlets are from the private corridor; and it has the great disadvantage of conducting the cooler air directly to the feet of the occupants. The air is generally rather cooler in the corridors than in the rooms, even when the heating apparatus is working; and there are about two Spring months and two Autumn months when, though it is scarcely necessary to have the heating apparatus working, the air is too cold to be admitted directly to the feet, but it is not too cold to be admitted through the cornice, because, by slowly falling through the warmer air of the room, it becomes tempered before reaching the occupants: practically, we have found this to be the case. And, besides, there are now and then days in winter when it is not necessary to have the heating apparatus working. This is also the position recommended by the GOVERNMENT COMMISSIONERS, by the *Encyclopædia of Useful Arts* (p. 824), by EDWARDS, and by POTTS. There is no risk of the air, coming in through the cornice, passing directly to the outlet in the ceiling, because it is heavier than the air within the room, and must therefore fall, pushing the lighter air upwards. When ventilation is required there are either persons in the room, or a fire, or both. The air is let in at 65 deg., and when there is a fire, that raises some of the air to a much higher degree; this, therefore, being lighter, is pushed upwards by the incoming air, which necessarily then descends; and, being heated in its turn, is pushed up, carrying with it the carbonic acid and other impurities within the room. So when there are only living beings in the room, their bodies and expired breath being at 98 deg., the same process takes place, and with the same effect. Though carbonic acid is of itself heavier than air, there is no risk of its settling near the floor, because of its small proportion admitting speedy diffusion, and of its being carried up by the warmer upward currents within the room.

Of course, all other ingress must be prevented, by such means as valves in the chimney throats, close-fitting windows, &c. In houses built according to the plan herein advocated, close-fitting windows, &c., may be insisted on, as in House No. 1; in fact, the windows may be hermetically closed, as in House No. 2; whereas, in ordinary houses, having no special provision for the admission of air into the rooms, badly fitting windows and doors are an absolute necessity, because if the doors and windows did really shut in the complete sense of the word no fire would burn, at least up the chimney; and no human beings could exist in the rooms. Indeed, we might apply to ordinary house building a paraphrase of the well-known epigram, and characterise it as "bad architecture tempered by bad workmanship." § 5.

§ 6e. The next question is that of the vitiated air *outlets from the rooms*. These should be in or near the ceiling. From the central ornament over the gas, or other ornamental open-work in the ceiling at a distance from the inlet, a zinc tube should lead to a flue within the brickwork of the inner wall; this flue should lead directly to the foul-air chamber; each room having a separate flue; and all the flues should, if possible, open into the foul-air chamber on the same level, and in the direction of the downcast shaft.

§ 7. *The suction power*. This should be ample, self-acting, in operation day and night, and winter and summer alike; and it should be uncostly. Various methods have been suggested for the obtaining of this. In some ventilating schemes it has been thought sufficient to leave the suction to the power of the fires of the individual rooms: in others a tube from the upper part of the room is taken down so as to deliver the foul air through the fire, or up the smoke flue: in others a tube is taken down behind the fire-grate so that, by becoming heated, it may suck down the foul air and deliver it up the smoke flue, or through the fire: in others a tube is carried from the upper part of the room *directly* into the smoke flue. (*Blue Book*, pp. 15, 16.) And in the *Blue Book* the plan recommended is, to have two flues, one within the other, up the whole length of the chimney stack from the basement to the chimney top. The inner or central flue to be for the smoke; and the outer or surrounding flue, which will of course be warmed by the smoke and heat when the fire is burning, to be for the foul air; into this latter, as it passes up through the different stories of the house, there runs a foul-air flue from each room, from near the ceiling (p. 97). Now all these plans are partial, uncertain, and intermittent, and obnoxious to the objections already given at §§ 3 and 3a, when noticing single room ventilation, and which have driven us to the kitchen chimney alone as the only source of suction power by fire heat, which is not subject to these objections, and which is general, certain, and always in operation; which needs no special attention, being self-acting; and which, if served by the waste heat only, as in some cases it can be, costs nothing. Whereas every other method of providing a special and permanent ventilating shaft for the whole house must have a separate fire for itself, or fanners driven by steam or water, or some other power which is not only costly in itself, but which requires special attention to keep it in action.

Perhaps the statement that the suction power would cost nothing requires some explanation; of course, we are perfectly aware that the rule "nothing for nothing" is absolute in physics, and that the whole of the suction power of the kitchen chimney is derived from the fire, and must be paid for in the cost of the fuel. And when we assert that it would cost nothing it is on the presumption that it is produced solely by the *waste* heat of the smoke flue; which, according to Messrs. GALTON and CHADWICK, amounts to about seven-eighths of the total result of combustion;* to insure this it is necessary that the upcast foul-air flue shall be separated

* *San. Spec. Med. Mir.*, vol. v. p. 398. *Construction of Hospitals*, p. 94, see § 2a, p. 7.

from the back of the kitchen fire by a sufficient thickness of brickwork; otherwise some of the heat required for cooking or heating the boiler, &c., will be abstracted.

In order to obviate the risk of this heat being lost by being carried out at the chimney top before it can be utilised in the production of draught, it will be necessary to have a kitchen chimney of considerable length; the smoke flue must be made of cast iron, the kitchen chimney throat must be contracted by having the close kitchen range, and the top of the chimney must be diminished by having a properly proportioned chimney-pot. The chief cause of loss of heat with common fireplaces, is the excess of air that passes up the chimney carrying the heat with it—frequently many times as much as is required for the combustion in the fireplace. Different means have been proposed for preventing this loss; the three principal are: *first*, to have a small and circular smoke flue; *second*, to contract the chimney throat just above the fire, as by register grates, or as in Arnott's smokeless grate, in which the opening into the chimney is only about thirty-six square inches, or in the kitchen by a close kitchen range; and *third*, by contracting the outlet at the chimney top by means of one of the various chimney-pots. The varying requirements of the ever-changing quantities of fire and smoke, and the accumulation of soot, cause the *first* to be a source of a smoky chimney; the *second* prevents smoky chimney at the expense of an increased consumption of fuel by too great draught, unless controlled by a throat-valve. If properly calculated, the *third* is free from both these objections; and it should be adopted in all cases, and especially in the kitchen chimney used as a ventilating shaft. Tredgold says that for each three inches of length of grate we may estimate an average consumption of 1 lb. of coal per hour; and for this quantity of fuel there is an effective excess of temperature in the chimney of 16 deg. To prevent this from being wasted by escaping into the air, the top of the chimney should be contracted ; and he gives the following rule for calculating the proper area of the chimney top for this quantity of fuel. Rule: "Let seventeen times the length of the grate in inches be divided by the square root of the height of the chimney in feet, and the quotient will be the area for the aperture at the top of the chimney in inches," p. 220.* This rule being for room chimneys gives an area rather too small for kitchen chimneys. From experiments and observations on House No. 2, we are satisfied that the diameter of a circular kitchen chimney-pot should be about nine inches. Of course, any extra cost for such provisions in the kitchen fireplace must be put to the debit of the ventilating scheme. See Appendix, p. 114, for cost of cast-iron smoke flues.

This waste heat alone is not sufficient in the case of large houses with many large rooms: in this case it will be necessary that the upcast foul-air flue shall be brought up close behind the kitchen fire and boiler, with perhaps only a sheet of iron intervening ; so that it may abstract also some of the fire heat; and this will afford an additional advantage, viz., that the boiler will keep up the draught during the night. If this should not be likely to produce draught enough, a ring of gas-burners, or a few coils of PERKINS's inch-bore hot-water pipes within the upcast, or a separate fire, or some other means of suction, must be provided for the ventilating shaft: this will, of course, depend on circumstances, such as the size of the building, the situation, &c. &c., and must be left to the architect. It is, however, our opinion, based on some experience,

* *Principles of Warming and Ventilating Public Buildings,* by THOMAS TREDGOLD, C.E.

that in ordinary houses of moderate size, the whole of the suction power required may be procured from the waste heat only of the kitchen chimney, especially when provided with an iron smoke flue, a close range, and contracted chimney-pot.

There is perhaps another contingency we should notice. We have said that the suction power is always in operation; we can, however, imagine circumstances under which it may not be sufficiently powerful to overcome certain disturbing causes, or combinations of such causes; for instance, the kitchen fire may be left out, or it may go out in the night, and if at the same time the windows of one or more rooms are open, and a very strong wind blowing against the ultimate outlets in the chimney top, it is possible that under such circumstances, especially if the ultimate outlets be not efficiently protected, the suction power might be checked or overcome, and the current be even partially or to a certain extent reversed. In this case the worst that could happen, however, would merely be to introduce one of the evils of ordinary houses, in which, unless special care is taken, cold wind blows down the chimney, or, if a fire had been lighted, causing its usual draught up the chimney, but had gone out in the night, by the morning the draught would be downwards into the room *directly* through a smoke flue from the outer air, whilst, in our case, the worst evil would be that there would be an *indirect*, *modified*, and very gentle flow of fresh cold air by a clean flue in through the perforated ornament in the ceiling. Practically, however, we can say from the experience of some years that back draught never does occur, but that the whole ventilating arrangement acts completely, unobtrusively, and continuously all the year round, and to a certain extent even when the kitchen fire is not burning. See Experiments, August 17, 18.

To the *Blue Book* scheme, besides the objections given at §§ 3, 3a, there is an additional one; viz., the danger that the foul air may be drawn from one room into another; and besides this, when several flues enter one common shaft at different levels, the draught is so interfered with that it becomes quite irregular and uncertain—some of the flues receiving more than their proper share of the suction, whilst others receive little or none. Hence it is absolutely necessary that all the flues of the house shall be conducted separately to above the level of the ceiling of the top room, and then be carried down again by one common syphon flue to the bottom of the kitchen chimney shaft, so that the full suction power may act upon them all. But if all the flues enter a mere tube on the higher level without further precaution, the same fault will be committed here in this transverse flue that was avoided by discarding the one common upward flue, and again some of the flues would get all or nearly all the suction, and others little or none. Just as in the case of the coal mine where the cross passages are not properly trapped, and the suction power does not penetrate to the farthest extremity. Hence a still further provision is necessary, viz., that instead of a flue there must be a common drum or chamber—that all the exit pipes of the rooms must be conducted separately into one common central air-tight drum or chamber at the top of the house—and from this one common shaft must conduct the foul air down to below the kitchen fireplace, and up behind the fire to the upcast shaft in the kitchen chimney stack. There will thus be a provision for the application of the suction power to the flue of every room equally. This foul air drum or chamber in the top of the house must be so located, and of such a size, that all the foul-air flues of the house can enter it as inlets separately and on the same level; and that one common flue or shaft can so leave it as an outlet that it may draw equally from every inlet. This exit flue from the foul-air chamber, after having been carried down, must be continued up behind the kitchen fireplace, where it will require to be somewhat flat, to the beginning of the smoke flue, where it should assume a square or circular form in surrounding the smoke flue: it must then be continued up to the top of the chimney stack and terminated externally by several openings just below the coping of the chimney; and these must be protected from the direct current of the wind by some suitable wind-guard. For the purpose of providing this upcast shaft, the kitchen chimney stack must be built, not in an outer wall, but in the interior of the house: it must be built straight up, very capacious, and very tall. Its capacity must provide room for the central iron smoke flue from the kitchen fire; and around this a foul-air flue somewhat less* in area than the area of the downcast shaft from the foul-air chamber; and it must be so tall as to reach several feet higher than any other chimney of the house, in order to provide a long syphon for the purpose of increasing the suction from the foul-air chamber, by abstraction of the heat of the smoke.

In consequence of the increased amount of friction incurred by this lengthening of the syphon, the wisdom of thus carrying the foul-air shaft down and round the kitchen fire may be questioned, and it might be thought to be better to turn it directly into the chimney shaft. It is possible this might be so were it made to pass directly into the smoke flue, or were there nothing more than friction to be considered. But unless it opened directly into the smoke flue, the heat of the smoke would not be transmitted quickly enough, and there

* Some little less because of the increased velocity; though not much less, because of the increased friction.

would be great loss of suction power; and entering so high up there would be little or no protection against back draught, which would also then bring smoke along with it. If the outlet from the foul-air chamber opened directly into an air flue in the chimney stack, it would only have the suction power of the heat given from the smoke in the short remainder of the coldest part of the smoke flue; and unless this flue were made of some very rapid conductor of heat, such as iron or copper, very little of that heat would be communicated, and thus a very small suction power would be gained, for even iron or copper would not in this case give off the whole, nor nearly the whole, of the heat of the ascending smoke.

By taking the shaft down and round the fire as we propose, we not only gain the advantage of a long syphon in the interior of the house, but we utilise for the production of suction power the heat that would otherwise be lost by radiation up the whole length of the chimney, and which we think will much more than compensate for the loss by increase of friction, besides absolutely preventing any possibility of back draught. Nevertheless, if additional heat could be given to the current, as it passes out of the foul-air chamber, by means which would at the same time serve some other useful purpose, the downcast shaft and the double kitchen chimney may possibly be dispensed with below, and only begin on a level with the foul-air chamber; for instance, in houses in which the central hall extends to the top, it might be lighted by gas kept constantly burning in the foul-air chamber, or the exit flue, where it would, at the same time, assist to increase the suction, prevent down draught, and light the central hall, through glass in its ceiling or elsewhere.

It will have been observed that in the foregoing scheme of ventilation, endeavour is made to prevent the air from entering the house at all except by the inlet provided for that purpose: that a special inlet is provided in the lowest story of the house, with conditions available for the warming, cleaning, disinfecting, or otherwise improving the quality of the incoming fresh air, and regulating its quantity: that the fresh air is then conducted into the central private hall, which is protected from the intrusion of servants, from kitchen and other smells, and from all other means of pollution: that it is from this private hall the rooms draw their supply, and *that* even when the doors are shut: that having served its purpose in the rooms, the air is drawn off through the ceiling up into the foul-air chamber, and thence down and behind the kitchen fire up the kitchen chimney stack and discharged high up in the open air; all possibility of back draught being prevented by the length and heat of the exhausting syphon.

By the combined use of the above means we attain the desiderata of a healthy and comfortable house, viz., an abundant supply of sufficiently warmed fresh air, and a continual self-acting process of removal of the vitiated air. It must be kept in mind that the system forms one connected whole, all the parts of which are mutually dependent, and that therefore we cannot have the benefit of one part without adopting the other; that we cannot expect success, but must look for failure, if we adopt one part and neglect the rest: just as the absence or failure of one link renders a chain wholly useless or even an encumbrance.

§ 7a. The dimensions of the openings and flues for the passage of the air through the house, must of course bear a proper proportion to the size and requirements of the house, both at its maximum and minimum of use: they must therefore be capacious enough to meet the maximum, and be provided with valves to serve the minimum wants.

INLETS.—The *primary* inlet into the house for the fresh air (§ 6b) must be sufficiently large to transmit an ample supply for the total wants of the house when it is put to its maximum of use, and it must be provided with shutters or valves to regulate the supply for the minimum. In such a house as we have supposed (see p. 43) it must be capable of giving passage to 8087 cubic feet of air per minute, *i.e.*, 1575 cubic feet for the occupants, 512 for the gaslights, and 6000 for the fires (six living rooms at 800 cubic feet and two bedrooms at 600 cubic feet each): in other words, it should be capable of replenishing the whole house three times every hour.*

A good rule is that the inlet should be nearly equal in area to the ultimate outlet, taking together the upcast or foul-air flue and the chimney flues. It need not be quite equal to the total outlet, because it has to give passage to the air previously to its being expanded by the heat of the house, and it has not to supply the bath-room, the water-closets, or the hall lamps, which will draw their supply from the stairs lobby; and because there will scarcely ever be more than two bed-room chimneys in use at the same time, the rest will be

* PECLET, calculating from the quantity of carbonic acid produced, says 5 cubic feet of fresh air should be allowed for each person: calculating from the quantity of fresh air required to carry off all the contaminations resulting from human life, REID says 10 cubic feet; the GOVERNMENT COMMISSIONERS say 10 to 20; MORIN says 15 to 20; and ARNOTT and ROSCOE say 20: we have taken an average of 15 cubic feet per minute. According to the *Blue Book*, an ordinary open fireplace requires 1000 cubic feet of fresh air per minute; and the fireplace with narrowed throat, such as ARNOTT'S, with a good fire requires 800, and with a poor fire 700; we have allowed an average of 800 for the living rooms, and 600 for the bedrooms. And according to the best authorities a full-sized gas-burner requires about 8 cubic feet of fresh air per minute to carry away rapidly enough all the products of combustion; we have allowed this quantity.

shut by register grates and throat valves. For the sake of illustration, let us imagine that we have to provide for the necessities of a good-sized suburban villa, containing drawing-room 28 feet long, 19 wide, and 11 feet high, dining-room $26 \times 19 \times 11$, breakfast-room $16 \times 16 \times 11$, library $13 \times 13 \times 10$, billiard-room $24 \times 20 \times 10$, nursery $15 \times 15 \times 10$, bath-room $12 \times 8 \times 10$, and 12 bedrooms—six $15 \times 15 \times 10$, six $15 \times 15 \times 9$, all having fireplaces; and that the drawing-room is calculated to accommodate thirty persons, and to have ten gaslights and one fire; the dining-room twenty persons, six gaslights, and one fire; the breakfast-room eight persons, three gaslights, and one fire; the library three persons, two gaslights, and one fire; the billiard-room six persons, twelve gaslights, and one fire; the nursery eight persons, two gaslights, and one fire; and the bedrooms each two persons and one fire, and six of them two, and six of them one gaslight; and the bath-room two persons, one gaslight, and one fire; and that there are six hall lamps, and four water-closets. And say we exclude ten bedroom chimneys, and one-eighth of the upcast shaft for the exceptions specified, we shall have eight chimneys to provide for: six living-rooms 9×9 in., and two bedrooms 6×6, which will be equal to 558 square inches, or $3\frac{7}{8}$ square feet.* And say the upcast shaft must be $5\frac{1}{2}$ square feet (§ 7a, p. 47), seven-eights would be about $4\frac{1}{2}$ square feet; the maximum area of the primary inlet will therefore require to be $8\frac{3}{8}$ square feet; that is, supposing we provide for the supply to the fires as well as to the gaslights and living beings: but by providing separately for the supply to the fires (and which of course need not pass through the warming apparatus), by

* The Government Commissioners say no living room chimney should be more than nine inches in its widest part. *Blue Book*, p. 194.

special flues from the outer air, as recommended at § 2, except for bedrooms (because of the fires going out during the night, § 7, p. 37), an opening of five square feet would be ample to supply the air for the upcast shaft and the two bedroom chimneys. It would, however, even in this latter case, be better to have a primary inlet of $8\frac{3}{8}$ square feet, in order to meet the requirements of the house in the hot days of summer, when the velocity of the passage of the air through the house will not be so great; because, in consequence of the high temperature of the external air there will be no pressure from without, and there will be less difference produced in the upcast shaft; the suction, therefore, will be less powerful and less able to overcome the friction in the flues and the want of fall in the downcast shaft. As the warming arrangements of a house in this country should have reference to the cold days of winter, when the outer air is too cold to be admitted, and yet will rush into the house with considerable velocity through every crevice to be found, so the ventilation should have reference to the hot days of summer, when the air within the house is too hot and too stagnant to be endured, and yet will not move unless it be drawn by some suction power. The system of ventilation here advocated, being one more of vacuum than plenum, the size of all the openings and flues must be calculated in reference to the capabilities of the upcast shaft as an exhausting syphon; for although it is found by experience that the passage of the air through the house is, to a certain extent, influenced by the pressure of the air at the primary inlet, still in the hot days of summer it must, of course, be mainly due to the suction power of the upcast shaft; and which, indeed, must theoretically be looked upon as the only cause of the circulation of the air through the house. The *secondary* inlet into the house (§ 6b) should be a little larger than the primary, because it has to give passage to the air after it has been expanded by the heat of the hot-water pipes; but it should not be much larger, because it is desirable rather to retain the air in contact with the hot-water pipes: say, in our illustration, 9 ft.

The *inlets into the rooms* (§ 6a) should be as large as they can conveniently be made, not only because they have to supply the fires and gas-burners as well as the occupants, but in order to increase the supply and diminish the current, and obviate any tendency of direct passage of the air from the inlet to the outlet: and they should be through the cornice and split up into numerous small openings along the whole length of the room, as explained at § 6d; and, if possible, they should be made controllable by valves.

Outlets.—1. There should be a flue leading up into the foul-air chamber from every living room, every water-closet, and from over every gasalier in the house. They should be capacious enough to serve the maximum requirements, and provided with valves somewhere in their course, say behind the cornices, to accommodate them to the minimum wants of the room; that is, the flue from each room should be capable of changing the air of the room three times every hour when the room is put to its full use, and should be diminishable, when necessary, to the requirements of only one or two persons. The sum of the areas of these flues entering the foul-air chamber should considerably exceed the area of the downcast shaft or flue leaving the foul-air chamber, because of the greater amount of friction. And the area of the opening through the ornament in the ceiling, covering the entrance into the tube, should be greater than the tube itself, because of the still further increase of friction. The maximum area of the vitiated air flue from the drawing-room should be such as to meet the necessities of the greatest number of persons the room can accommodate, and to carry off all the products of the gaslights; and in such a house as we have supposed, will require to be about $1\frac{3}{4}$ square feet.* The flue from the dining-room should provide for the full complement of occupants, the steaming of food, any tobacco smoking that may be allowed, and the products of the gaslights; and in our illustration will require to be about $1\frac{1}{4}$ square feet.* The flue from the breakfast-room will require to be about 108 square inches; that from the library, about 48 square inches; that from the billiard-room, having to provide for smoking also, will require to be about 1 square foot; that from the nursery, about 86 square inches; and from each bed-room, about 36 square inches; that from the bath-room, about 36 square inches; from each hall lamp, about 18 square inches, and from each water-closet, about 40 square inches—12 square feet altogether.

2. The *downcast* shaft or outlet from the foul-air chamber (§ 7, p. 38) should be considerably less in area than the sum of the areas of the inlets into it, because of the less amount of friction; but it should slightly exceed the area of the upcast shaft, because of the absence of suction within it, its downward direction, and the high temperature of the air within the foul-air chamber in summer; though this excess should not be much, because there is more friction in the upcast on account of the central smoke flue; say, in our illustration, about $6\frac{1}{4}$ square feet.

The *ultimate* vitiated air outlet, or *upcast* shaft (§ 7), must be of sufficient capacity to carry off all the contaminations resulting from respiration and exhalation when the house contains its maximum of occupants;

* In these cases it may be necessary to have more than one zinc tube.

from the gaslights, the steaming of food, any tobacco smoking that may be allowed; from the bath-room, the hall lamps, the water-closets, and from all irregular and uncertain sources of contamination; as well as to allow for the retarding and obstructing influence of cooling and friction; from the length, roughness, and tortuousness of the passages and flues; in other words, it should be capable of changing the air of the whole house three times every hour. In the case of such a house as we have supposed, in which provision must be made for 105 persons and 64 gaslights, 2087 cubic feet of air must pass up the upcast shaft every minute; and as the experiments carried on in House No. 2 lead us to believe that, when the foul-air flue goes up behind the boiler, and there is a close kitchen range, an iron smoke flue, a sufficiently long chimney stack, and a contracted chimney-pot, the practical velocity in the upcast shaft will be about 400 feet per minute, the area of the upcast shaft will require to be about $5\frac{1}{2}$ square feet. (See Appendix, Experiments, April 22.) These dimensions would provide for the extreme wants of the house, but a much less upcast would be sufficient for all ordinary occasions, and extraordinary occasions might be provided for by the introduction into it of a ring of gas-jets, or a few coils of hot-water pipe, as alluded to at page 36.

The above dimensions are the actual requirements, as proved by practical experiment in House No. 2. They differ considerably from the theoretical dimensions given in the Appendix. It is only by actual experiment in a house erected in accordance with the principles herein advocated that the really necessary dimensions can be ascertained. The theoretical deductions from the flow of air in heated flues must necessarily be of a general character, and only taken as an indication for the guidance of architects and proprietors.

§ 8. When building a house, it will, of course, be necessary to make provision for its probable maximum wants; but as these will occur only on extraordinary occasions, the openings and flues should be made controllable by valves, so as to accommodate them to the ordinary wants of the house; at all events, the primary inlet should be so provided. It would, indeed, be well to have control over the inlets into the different rooms, so as to accommodate each room to its individual wants, especially when the fire and gas-burners have not special supplies. The outlets, also, from the different rooms should be provided with valves, in order to regulate the current according to the number of occupants, and to shut off any particular room or set of rooms altogether, when desirable, to divert the flow of fresh warmed air exclusively elsewhere, by shutting it from those rooms not in use; for instance, to divert it to the bedrooms on a cold winter night. From these remarks it will appear evident that, before determining the permanent size of the primary inlet in the outer wall, the architect must have decided whether or not the fires and gas-burners are to be supplied separately, as recommended at § 2, and as strongly urged by the GOVERNMENT COMMISSIONERS; or even the complete plan of universal double-flued chimney, referred to at § 2a, is to be adopted; or if both these adjuvants are to be utilised. Theoretically, it is undoubtedly best that these extra provisions should be made for all the rooms except bedrooms. In very large houses, such may even be necessary for economy in fuel; but in houses of moderate size, in which there is an average small number of fires generally burning, no such special provision need be made for ordinary occasions; and for extraordinary occasions, their absence will merely involve the heating of a little more inlet air. Of course, all sources of contamination must be carefully excluded from the central hall or ventilating lobby. The products of combustion of the gas lighting this hall, for instance, must be prevented from mixing with the fresh air. This may be secured perfectly by the adoption of the ventilating globe lights of Mr. RUTTER, as patented by Mr. RICKETS, which are so contrived that not only can all the products of combustion be carried away, but a separate supply of air brought to feed the light. It may also be worth consideration, in some cases, whether it would not be desirable to adopt such gasaliers throughout the house, in order to prevent the usual blackening of the ceilings.

§ 8a. The above calculations are given as samples only, and not as being strictly correct for all houses. It is, in fact, impossible to arrive at absolutely correct data, because of the varying conditions of the rooms of a house, however carefully constructed: no house is susceptible of such accurate fittings as to doors, windows, &c., as an apparatus for scientific experiment. Also, the suction power will not always, as a matter of fact, correspond exactly with the above data, on account of the varying condition of the kitchen fire, the uncertain amount to be subtracted for the length of the downcast flue from the foul-air chamber, for the roughness and tortuousness of the flues from the different rooms, and for the modifications induced by cooling and friction, all of which we are unable to allow for exactly. There will also be some of the inlets into the foul-air chamber, such as those from the water-closets, letting in cold air; and there are other necessarily varying circumstances, such as the coldness of the weather, the temperature of the heating apparatus, the number of occupants, the heat of the kitchen chimney, the force of the wind, the pressure of the atmosphere, &c. &c., over which we have no control. But still, in spite of all these contingencies, we have the testimony of practical experience that, in the houses erected in accordance with these data, the whole scheme works with an accuracy quite sufficient for all the requirements of practical utility. In short, the whole house is warm, comfortable, and airy, and free from perceptible draughts. And not only has the upcast shaft a considerable amount of efficiency, however little is the heat of the kitchen fire, but even when the kitchen fire is not in use at all, there is still a sufficient amount of suction to keep up a good circulation of air throughout the house. This is not a matter of theory only, but has been proved by direct observation in House No. 2, in the foul-air chamber of which strips of silk are hung over all the inlets, in order to indicate the current. These have been observed to be always blown in the right direction, even during the summer, when the kitchen fire was not in use, and though all the windows are, for the sake of keeping out the cold air, the blacks, and dust, made fast, and not to be opened. (See Appendix, Experiment, August 17, 18.) This fact may appear at first sight somewhat puzzling; but on reflection we perceive that it must be so, because the whole system then forms a mode of spontaneous ventilation (see § 4). In fact, the whole scheme becomes then simply another form of the WATSON ventilator, with the inlets distributed throughout the whole house. We will now describe the design of two very different houses, in which these principles are equally carried out.

CHAPTER II.

DESCRIPTION OF HOUSES.

§ 9. HOUSE No. 1.—This house is situated at the end of a row of marine villas near Liverpool, with the front towards the sea, and the entrance door at the side. The servants' department is at the back, with a separate passage to the vestibule, so that the door (self-closing) of the inner lobby remains closed when the front door is opened. The inner lobby is a mere passage leading to the library, and to a large inner hall or saloon, out of which the dining-room, drawing-room, and staircase open. The drawing-room communicates also with the library, and all these rooms are *en suite*, while each has a separate communication with the stairs without having to go through another room. For the sake of economy of space, the stairs are in the centre, and occupy no more room than is necessary. The fresh air is admitted into a chamber below the staircase, containing coils of hot-water pipes on the low-pressure principle, and a branch of this pipe passes round the skirting of the saloon, and through a conservatory opening out of it. There is also a small coil beneath the table in the passage. The fresh air, heated thus when required, passes partly into the staircase, and partly through shuttered openings into the saloon, which thus always contains a large supply of fresh warm air. Partly from this apartment, and partly from the staircase, the air is admitted to the other rooms through openings in the cornice near the ceiling, and "hit and miss" gratings forming the upper section of the architraves of the bedroom doors. The vitiated air is conveyed from a perforated ornament in the centre of the ceiling through a zinc tube into the foul-air chamber, which is an air-tight zinc drum about six feet diameter by five feet high, under the roof. Each room has its own tube to the zinc drum. The latter communicates partly by a zinc tube of proper dimensions, and partly by a shaft in the wall, with the bottom of the exhaust shaft in the kitchen chimney, and opens to the outer air by four apertures a little below the coping of the kitchen chimney. This exhaust shaft is formed by having the smoke flue constructed with fourteen-inch circular earthenware tubes built within a square brick shaft, the intervening space forming the air shaft, and deriving its heat from the smoke flue. The heating apparatus consists of a boiler heated by coke or gas in a cellar below the coil chamber, which, however, derives its supply directly from the open air, as indicated in the transverse section of accompanying plan. This house is in two stories, and the ground plan large in proportion to its size, so that there are few stairs to ascend. On the first floor there is a passage from the back stairs to the bedrooms, closed by a swing-door, so that no draughts or smells can penetrate. The dining-room and the front door can be reached without going through the house, and otherwise, the servants being always near their work, quiet and cleanliness are secured, and a smaller number of servants are required. The fireplaces, according to the recommendation of the *Blue Book*, are at the corners of the rooms, thus radiating the heat equally; and no chimneys are placed in the outer walls. The windows are of thick plate-glass with no shutters; the casements open outwards, and are made to shut tightly. The central hall or saloon is thirty feet long by eighteen broad and fifteen high. It forms a very pleasant apartment, and is an excellent music room, and as it contains a large volume of fresh warm air, the doors of the other rooms can be opened without causing cold draughts.

As the result of the above arrangements, for moderate rent, or the capital thereby represented, we have many of the comforts and even luxuries usually found only in the country houses of the most wealthy persons. The owner has not lived in it permanently, but only occasionally, and it has been occupied at different times by several tenants. The general result of ten years' experience is, that it has been found very pleasant to live in, as being warm, and, at the same time, airy and comfortable. The ventilating apparatus is so completely unobtrusive and self-acting, that several persons have lived in the house for a length of time without being aware of its existence. After a winter's residence in it, one gentleman had a house built for himself on a similar plan, which he now inhabits. He provided ample inlet of fresh warm air, but by some misunderstanding the ventilating flue in the kitchen chimney was not adopted, a circumstance we have lately been given to understand he now much regrets, after having tried the usual abortive expedients to supply its place. As a further testimony to the success of the plan of the house, we may quote the following remarks from Dr. INMAN's chapter, entitled "The House we live in," in his work *On the Preserva-*

tion of Health. The doctor thus describes his visit to the house:—"The day was bitterly cold, and the walk from the adjoining railway station was through snow up to our knees. As an habitual sufferer from cold feet, visions of misery haunted me, and I feared that physical suffering would prevent mental enjoyment. My fears were vain, exercise kept me warm until we reached the door, and when once inside I forgot all about the cold I had gone through." He then proceeds to describe the construction of the house, and of the ventilating and warming apparatus, and concludes: "I never once during my prolonged visit felt either too hot or too cold. Neither before nor since have I been in a residence which seemed to be so thoroughly comfortable, and the doctor and myself were soon at work over the plan of another." Circumstances, however, prevented him from carrying out his plan, and "he was obliged to put up with an ordinary brick and mortar tenement."—*Preservation of Health*, pp. 27, 28. See Plans.

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§ 9a. House No. 2.—This house is situated on the east side of Grove-street, Liverpool, and consists of basement, ground floor, and first, second, and third floor. The *basement* is devoted principally to the collection and warming of the fresh air. On the *ground floor* are the cellars, a ball-room, two professional rooms, a gentlemen's cloak-room and water-closet, and the main entrance, with vestibule and stairs lobby, and servants' entrance and lobby. The *first floor* is the living floor; on this is a drawing-room, with ladies' dressing-room and water-closet; a dining-room, with china closet; and a kitchen, with cook's pantry, larder, scullery, and butler's pantry. The *second floor* consists of the family bedrooms (four), with breakfast-room, housemaid's-closet, bath-room and water-closet; and the *third floor* of the servants' bedrooms (four), with children's play-room, store-room, and two water-cistern rooms. And above, beneath the ridge of the roof, is the *foul-air chamber*, into which the vitiated air of all the rooms of the house is collected, and from which it is drawn by the kitchen fire, by means of a shaft passing down to the ground floor, and then ascending behind the kitchen fire and up the kitchen chimney stack round the smoke flue.

The principal part of the house consists of a front and back block, each of about thirty-three feet by twenty feet, with a lobby nine feet wide between them, running north and south. This central lobby is the warmed air corridor or ventilating lobby; it is lighted by a window at its south end by day, and by RICKETS's globes at night; and it is shut off at its north end from the main staircase, vestibule and front entrance by vestibule doors. Out of it open all the principal rooms of the house.

The front entrance, with the vestibule and main staircase, twelve feet wide, are placed, not in the centre, but at the north end of the house.

The main staircase runs between the vestibule in front and the kitchen stairs behind, and is lighted by an ample skylight. The servants' entrance and lobby are from the south, behind the ventilating lobby, and the servants' stairs run up between the main staircase in front and the kitchen behind. By this arrangement there is an easy approach from the kitchen to the dining-room and drawing-room, and to both the front and the side door; and the lobby, into which opens the door that lets in the cold air by being frequently opened, is shut off from that out of which the living rooms open, and which could not be if the entrance were in the middle of the front.

The central corridor is an essential part of the house, and serves very important purposes; it serves, of course, as lobbies to the rooms on each floor, and a receptacle of furniture when cleaning the rooms; on the ground floor it serves also as a museum, and between the dining-room and drawing-room it serves also as a bagatelle-room and picture gallery; and by the introduction of gratings into ceiling and floor of each story, it also serves as an open corridor from basement to attics.

Along the centre of the ceiling of each story of the central corridor is an ornamental lattice work, two feet wide, and along each side of the floor above is an iron grating, one foot wide; these allow the warmed air to ascend from the lobby beneath to the lobby above, but the floors check it for the supply of each story, and prevent it from rising directly to the top one, as it would in a stairs lobby.

The incoming air is warmed by an apparatus on the high-pressure system. A PERKINS furnace, supplied by Mr. GIBBS, is fixed in the basement of the stairs lobby; the flow-pipe is carried up and run one length of the bedroom lobby; it is then brought down and run once along the picture gallery; and after that brought down to beneath the secondary inlet, or the opening in the ceiling of the basement of the central lobby, which it covers — running backwards and forwards the whole length ten times. Fresh air enters into the lower part of this basement, and, rising, is heated by the heated pipes, and then passes through into the lobby of the ground floor, and thence into the lobby of the first floor, and thence into that of the second floor, and thence into that of the third floor, so that the central corridor is filled from the ground floor to the attics with fresh warmed air; and may be kept permanently at 65 deg., or upwards, the winter through. Above the attic floor this corridor is continued to the slates and made into an air-tight chamber, under the ridge of the roof, to receive the outlets of vitiated air flues from the different rooms of the house. Out of this central corridor all the principal rooms of the house open; and out of it, and out of it only, they receive their supply of fresh air. The cornice round the ceiling of this corridor, and that of each of the rooms opening out of it, has a lattice central enrichment, seven inches deep, and the wall between these two cornices is perforated by as many seven inch by five inch openings as the joists will allow, so that the fresh air has a free passage from the corridor into the rooms, even when the doors are shut. The drawing-room has nineteen of these seven by five inch openings, making an inlet for fresh air of over *four and a half square feet*, distributed along the whole length of the wall of the opposite side of the room to the fireplace. The dining-room has fifteen of these openings, making an inlet of considerably over three and a half square feet. Over the gasalier in the centre of the ceiling of each room is a perforated ornament, covering a nine inch square opening into a zinc tube, nine inches by four and a half inches, making an outlet for the foul air of *forty and a half square inches*. This zinc tube goes along between the joists of the ceiling into a nine inch by four and a half inch flue in the brickwork of the wall, between the corridor and the room above, where it is regulated by a valve. This flue rises up inside the wall and opens into the foul-air chamber formed underneath the roof of the corridor. The flue from each room *opens separately* into this chamber; and there is a similar flue also from the cloak-room, the dressing-room, the breakfast-room, the bath-room, the kitchen, the hall lamp, and from all the water-closets. Out of the north end of this chamber goes a brick flue or shaft—the downcast—taken from the back staircase.

This outlet or downcast shaft goes straight down to below the first floor, and then crosses eastward and rises up behind the kitchen fireplace, where it is flat—six feet by one foot; it is then collected into a somewhat square shaft—32 in. × 26 in. Up the centre of this shaft runs a circular earthenware smoke flue from the kitchen fire, the outside diameter of which is eighteen and a half inches, leaving a foul-air shaft—the upcast—surrounding the smoke flue; and these, together, form a large chimney stack, which is carried up to a greater height than any other chimney of the house. See Plan.

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§ 10. Although the planning and erection of the houses just described involved many innovations, and much interference on the part of the proprietors, no difficulties or unpleasantness with the architects arose therefrom: on the contrary, they entered into the work willingly and intelligently, and did their best to carry out the proprietors' wishes. It is not, in fact, from architects of the higher ranks that objections to any intelligent endeavour to improve the construction of houses is to be anticipated; though we can scarcely expect that they will, of their own accord, introduce changes that involve extra trouble in the plans and drawings, and the superintendence of the erection; much less can we expect contractors and builders, voluntarily, to make changes that entail increased trouble and expense of building, and involve an increase of cost and rent. Architects would, indeed, have some difficulty in initiating any change involving extra expense, because the public naturally object to increase of cost, of the benefits of which they are not convinced; nor are architects specially likely of themselves to introduce changes that involve expense without display, as their sphere lies more with beauty and elegance of exterior than with the sanitary conveniences of the interior. Consequently we must not look for much improvement in house building until the public themselves are convinced of the advantage, to comfort as well as health, of having warmed and ventilated houses; it is therefore hoped that medical men especially, who are the best able to appreciate these benefits, will embrace every opportunity of pressing these matters on the attention of the public. The plan of ventilating and warming here advocated is not confined to any one kind of house, but can be applied to every kind: even the poorest class of houses might have the benefit of it if the principle of association were adopted; if, for instance, they were built in blocks, there would be no more difficulty in securing a share in the general plan of warming and ventilation than there is of sharing in the benefit of a common supply of water, gas, drainage, &c.: these remarks are also equally applicable to offices. When we look at the splendid blocks of offices of our merchants and manufacturers, with their grand and gorgeous exteriors, and reflect on the fact that in them our merchants, and manufacturers, and their clerks have to spend a great part of their lives either in a still, foul atmosphere, or with the windows open (subject to continual cold draughts, with the risk of disease), we grieve that it should be so, and hope that better offices may be erected at some future time. Nor is it only in houses and offices, and such like buildings, that the plan may be utilised; it is also applicable to hospitals, infirmaries, churches, lecture halls, libraries, museums, schools, and other public edifices, in fact, to every kind of building requiring warming and ventilation; although, of course, in public buildings, where there is not always a kitchen fire burning, the chimney of the heating apparatus will have to be utilised for the suction shaft, and in summer this cannot "cost nothing," because it will require a special fire, inasmuch as the heating apparatus will not then be in use; and in some instances it might require gas-burners in the upcast-shaft, or even a separate shaft. § 7, p. 34.

§ 10a. With respect to the cost in dwelling-houses being extra, there are some considerations to be made. It is true there are the flues in the walls and the zinc tubes in the ceilings, and the separate smoke flue and the increased size of the kitchen chimney, and perhaps some extra space to be allotted to the private or fresh warmed air corridor; but against these it may be noted that there may be a considerable saving by a general diminution of the brickwork and plastering of the whole house; for instance, the total height of the house may be much less, because instead of the living rooms requiring to be from 11 ft. to 13 ft. high, 10ft. to 12ft. will be ample; and instead of the bedrooms requiring to be 10 ft. to 11 ft., 9 ft. to 10 ft. will be ample; also the bedrooms may be considerably diminished in size, so that six may be gained where now only four can be had. "The continuous removal of the impure air, as it arises, is of very much greater importance than the cubical contents of air in a room . . . . the soldiers' rooms are about 12 ft. in height; with good ventilation, this might be reduced to 11 ft., or even 10 ft., without disadvantage." (*Blue Book*, p. 92.) The GOVERNMENT COMMISSIONERS recommend for each person in a sleeping apartment 800 cubic feet of air space (p. 99). Bedrooms in houses ordinarily accommodate not more than two persons; now a bedroom 9 ft. high and 15ft. by 15ft., without furniture, would contain 2025 cubic feet of air space, and would therefore allow each person at least

1000 cubic feet of air space; and, with good ventilation, this would be changed at least three times an hour, thus giving each person 50 cubic feet of fresh air per minute, instead of the standard quantity of 15 cubic feet. § 2a, p. 7, note.

§ 10b. The prejudice in favour of a "good, large, airy bedroom," is derived from the same source as the need of draughty windows, doors, and passages, viz., the alternative of want of air. A large bedroom unventilated is certainly less unwholesome than a small one; and, as we are in it only a part of the twenty-four hours, we can manage to exist on the large quantity of air and leakage. But a much smaller one than is usually desired is quite compatible with health and comfort, if properly ventilated: a prisoner in a cell 6 ft. × 10 ft., or even less, can, with proper ventilation, be kept in health. And not only in the saving of material but in the economy of space, and also in the saving of warming them, small bedrooms are desirable. And such saving in cost and space may enable the architect to study beauty in design and commodiousness for the rest of the house. As it is, what can architects do in changing the style of middle-class house building? They are constantly pressed to meet the requirements of the commercial value of a house as at present estimated, and forced to give as many and as large square boxes of rooms as will go under a roof and within four walls as can be got for the money. With such requirements, how can they study convenience, beauty, health or comfort? Whereas, if they could sacrifice something in the height of the living rooms and the size of the bedrooms, without injury to health, they would have scope for many and various improvements in the more important requirements of architecture.

§ 10c. An equivalent of the cost of the warming has already been noticed at §§ 6 and 7; so that, taking all things into consideration, we maintain that houses built in accordance with the principles herein advocated will, in the end, not be more costly than those built in the ordinary defective, unhealthy, and uncomfortable style. But even if there were some absolutely extra cost, there is ample return for it in comfort and health, and these are worth paying for. As before stated, "nothing for nothing" is a law of nature; and if comfort and health are to be procured, they must be paid for: and what, we would ask, can be said to be too high a price to pay for these blessings?

§ 10d. There is perhaps yet another circumstance that may be urged as an objection, viz., that it will be a continual trouble to regulate the quantity and temperature of the air admitted into the house. True, this point will require to be attended to. When there are but few persons in the house, the openings will require to be diminished; and when many, they will require to be enlarged. In cold weather, the warming apparatus will require to be in operation, and this in proportion to the coldness. It is also true that these conditions will necessitate a somewhat personal superintendence on the part of the tenant, and an intelligent care on the part of one of the servants. These are, however, but small costs for the comforts procured. Comfort and health cannot be obtained for nothing: if we would have them, we must pay for them in some way; "nothing for nothing," as before stated, is a law of nature. It cannot indeed be otherwise, if the same house must be accommodated, and made comfortable and healthy for a varying number of occupants, and in the varying seasons of the year. The same state of a house cannot possibly be comfortable and healthy to both many and few occupants, and in cold and hot weather. If all the arrangements of a house are fixed and permanent, discomfort and unhealthiness must inevitably result; for the number of occupants will vary, and the seasons will change, and we must either submit to the misery of these discomforts or to the trouble of obviating them. Practically, however, we soon arrive at an average size of inlets and outlets, which may be maintained most of the time; so very little trouble is experienced.

§ 10e. There may perhaps be a further objection, viz., that the benefits of such a house may be appreciated and understood by the original proprietor, and under his superintendence may work well; but though proprietors are transient, houses may be considered to be permanent, and after the original proprietor the house may fall into the hands of some one unacquainted with the objects and uses of the openings, flues, valves, and warming apparatus, which may then become sources of annoyance and discomfort. True, this would be very likely to happen, *unless provided against.* All risk, however, of any unpleasantness on this score may be prevented by fixing an indestructible tablet of explanations in some place where it must be seen by all tenants.

CHAPTER III.

PRACTICAL SUGGESTIONS.

§ 11. In the foregoing chapters we have entered somewhat in detail into the question of matters in which we wish to see some improvement in the ordinary system of house building, because they are not commonly thought of or adopted either by the public or architects. We shall now refer to a few points that come within the ordinary limits of the architect's duty. Upon these, therefore, it would be superfluous to go into any details; and the reason we mention them at all is that the public, wishing to build houses, should be reminded of the necessity of themselves observing them. Because if, from inadvertence on the part of either the official architect or the inferior workmen, they should be overlooked at an early stage, irreparable injury might result. In house building, as in many other things, it is not wise always to leave every step of a long and complicated process to mere workmen, or even their official superintendents; and the proprietor will lose nothing by himself taking an intelligent supervision. We therefore here notice a few of the principal points respecting which the proprietor should satisfy himself by examination that they have been attended to. With respect to the site, the principal points to which we would call attention are, that it and the immediate neighbourhood should be absolutely free from damp, should be well exposed to the sunlight, and should avoid the close proximity of overshadowing trees or close vegetation. The roof, gutters, drains, and water cisterns should be very carefully planned, and very closely looked after, and all the bends and traps of the soil, waste, and sink pipes should be ventilated, as described at p. 19, footnote. There should be a separate cistern for the supply of the water-closets; the cistern overflow-pipe should not be in any way connected with the drains, because if it is, the deleterious effluvia will pass up the overflow-pipe, and become absorbed by the water, especially if the cistern be covered; and all water cisterns should be carefully covered, in order to protect the water from the organic and inorganic particles that are always floating in the air.

The foundation should have very special attention; it should be so constructed as to be absolutely and permanently impermeable to wet, and should render impossible all ascending moisture, or damp or earthy exhalations. The means of so constructing a foundation are now abundant and cheap, and known to all architects and builders: still, this point is very frequently neglected; and we have seen many otherwise pretentious houses, in which the damp has risen many feet up the walls, and been a source of permanent discomfort and unhealthiness. Attention should also be given to the materials of the outer walls, as to their power to exclude damp, or their capacity for absorbing and transmitting water, and constituting damp walls. One common brick will absorb a pint of water: sandstone will absorb about half a gallon per cubic foot.

"When water presents itself," says Mr. CHADWICK, "in any part of such material, it readily diffuses itself by the power of capillary attraction, by which it is observed on some walls in Paris thirty-two feet from the foundation. Walls of such absorbent construction are subject to rising wet by capillary attraction, as well as to the driving wet of rain or storm. To guard against the driving wet on the coast expensive external coverings, 'weather slate,' are used. But these do not stay the rising wet. This wet having to be evaporated, lowers the temperature. Damp walls or houses cause rheumatism, lower strength, and expose the human system to other passing causes of disease."—*Sanitary Specifications*, p. 394; *Medical Mirror*, vol. 5. We suggest the desirability of using, at least for outer casings, some impermeable material, such as hard stone, granite, fire-bricks, or even glass itself; which, besides being impermeable to damp, are also bad conductors of heat, and therefore assist in the production of warm houses. We agree with Mr. CHADWICK, when he says: "I have stated that the best sanitary construction of a house, apart from any question of cost, would be on the principle of the Crystal Palace, only with thick slabs of opaque glass, and with double walls enclosing like double windows, a still air, which would be the best means of meeting external variations of heat and cold, and preventing the evils of the absorption of moisture or miasm," p. 395. And we also agree with the GOVERNMENT COMMISSIONERS in their strong recommendation of double panes of glass or double sashes to the windows (*Blue Book*, p. 64), and in their estimate that the extra cost in this provision for the preservation of heat would soon be returned in the saving in the cost of fuel, even in the poorest dwellings. In this country it is important, not only for cheerfulness and warmth, but also for healthiness, that the sun should shine into the living rooms: the aspect should therefore be south-east, and the windows should be so placed that the sun's rays may enter at the time when the rooms are most likely to be occupied. Though the window openings should admit much light they should be few, so as not to cut up the wall space, and the convenience of their position should be studied, and they should be well splayed both inside and out, so as to do with as little glass as possible, because the greater the surface of glass the colder the rooms in winter, and the hotter in summer. In ordinary houses a very large proportion of the heat of the fires is lost by radiation through the windows; in some cases as much as one-third of the total heat of the room is thus continually passing off. The cooling effect of each square foot of the glass of an ordinary window is equal to the cooling down of a cubic foot of the air of the room to the temperature of the external air. After many experiments on this point, the GOVERNMENT COMMISSIONERS say (pp. 64, 97): "From these experiments it is to be inferred that rooms where the cooling surface of glass is very large compared to their area can be scarcely habitable in cold weather, and that the only remedy would be the introduction of duplicate panes of glass. The experiments made for the determination of the effect of duplicate panes of glass will be found in Appendix F. From these we learn that with single panes of glass the thermometer in contact with the window inside read 2·1 deg. higher than the outside; and this result was obtained both from the experiments at the Board of Health and at Hartwell House. With double panes of glass separated five inches, the thermometer on the inside read 11·7 deg. in the drawing-room, and 12 deg. in the billiard-room at Hartwell House above those on the outside of the glass, the instruments being suspended in both cases from the window sash. With glass separated one foot at the Board of Health, the difference shown was $10\frac{1}{4}$ only in the four days, but the small amount was attributable to the sudden increase of external temperature from February 5 to February 6 of more than 10 deg. From the results above, we may fairly infer that the difference in cold weather would be much more than 12 deg. From these results we may readily see that great advantage would follow the use of double windows, and that it would effect a great saving of fuel and freedom from draughts, besides causing the wall and floor to be maintained at a warmer and more uniform temperature. Another advantage is the diminishing the effect of out-door sounds, particularly in towns, where the street noises are prevalent."

APPENDIX.

§ 12. For the assistance of those technically instructed, and as a contribution of practical results, we add here a few observations on the different methods that have been used for calculating the draught of hot-air flues, and an account of some of the experiments performed in House No. 2.

Different authors have used different modes of calculating the draught of hot-air flues, and these have given results which appear to differ remarkably from each other, as will be seen by the following instances, given by *Engineer** at page 172, in reference to the ventilation of the same room :—

Montgolfier	8·32 feet per second.
Davies Gilbert	7·88 ,,
Tredgold	4·8 ,,
Sylvester, in Annals of Philosophy .	1·61 ,,
Ditto, in Rees's Cyclopædia . .	0·78 ,,

And Mr. Hood† gives the following results obtained by the several modes of calculation in one and the same experiment (p. 296) :—

Quantity of air discharged.						Area of tube in sq. feet.	Pressure of blast in in. of mercury.	Place of experiment.
By calculation.					By experiment.			
Montgolfier.	Gregory.	Gilbert.	Sylvester.	Tredgold.				
16,159	15,152	14,855	5017	15,555	14,726	·5502	4·	Dowlais.

* *Theory and Practice of Warming and Ventilating*, by An Engineer.

† *Warming Buildings by Hot Water, and Ventilation, &c., &c.*, by Charles Hood, F.R.S., F.R.A.S., &c. Second Edition.

These authors do not explain these discrepancies, but merely state the plan they prefer and adopt. The result of this, with the still existing uncertainty belonging to the element of friction, is to engender a doubt of the value of any of the methods, and to induce architects and builders to look upon the whole system of suction ventilation as still not understood even by the most scientific men, and as too complicated and uncertain to be employed in practice.

This impression should, we think, be removed: and after considering the subject carefully, we have come to the conclusion that these discrepancies are indeed more apparent than real, and may be reduced to a very small compass, their cause explained, and the principles which run through them all be brought to that uniformity which is characteristic of all true science.

Gregory and Gilbert follow Dalton's law of the expansion of gases, which, as we shall show below, gives a smaller degree of expansion than does Gay Lussac's law, the one now usually followed; but the difference is only small. Again, these authors and Rankine also differ from Montgolfier, Tredgold, and Peclét in the mode of computing the "head" or force which causes the ascent of the column of air in the chimney. But the chief cause of the wide discrepancy shown in the above tables is an error in principle on the part of Sylvester, which is explained at p. 79. If, therefore, we eliminate Sylvester altogether from the question, we shall find that the several methods of calculating the velocity of ascent of air in hot flues differ comparatively little, and certainly not sufficiently to hinder the practical application of theory to ventilation. Nevertheless, as it is of consequence to remove all doubt, and to give the reasons for our recommendation of any particular formulæ, we think it well to give here two paragraphs, one devoted to the theory, and the other to practical directions, which may be of use to practical men who may not have at hand the sources from which these data are derived. In the preparation of these sections, we have to acknowledge the essential assistance kindly given by a friend, who is an expert in mathematics as well as a civil engineer in actual practice.

§ 12a. *Expansion of Air by Heat.*—Air, when not confined in a close vessel (or at constant pressure), expands when heated.

Its volume augments in proportion to the increase of temperature, and its weight is inversely proportional to its volume.

Before A.D. 1802, Dr. John Dalton investigated the ratio of expansion of gases, and according to him their expansion is a certain fraction of their volumes at any assigned temperature for one degree of increase on that temperature; and the increase of volume is obtained by raising that fraction to a power, the index of which is the number of degrees of difference between the two given temperatures; that is, if—

t° = the lower temperature,
T° = the higher temperature,

$\cdot 0020366$ or $\frac{1}{480}$th = the fraction or coefficient of expansion,*

and assuming the volume of air at t° to be 1, the volume at T will be

$$(1\cdot 0020366)^{T-t}$$

But the investigations of Gay Lussac, and afterwards of Dulong, Rudberg, and Regnault, have satisfactorily determined the increase in volume of a gas when the temperature is raised 1°, to be a certain fraction of its initial volume at the temperature of melting ice (32° Fahr.).

This fraction for constant pressures on the Fahrenheit scale is $\cdot 002039$ or $\frac{1}{490\cdot 4}$; 490·4 on the "Absolute" scale of temperatures being equal to 32° Fahr. ∴ 0° Fahr. on the same scale $= 490\cdot 4 - 32 = 458\cdot 4 = c$, a constant which we shall require in the following formulæ.

If V_1 be the volume of air at temperature t° the volume V_2 at any other temperature T° is

$$V_2 = V_1 \frac{458\cdot 4 + T}{458\cdot 4 + t}$$

* The ratio accepted at that date by scientific men.

or neglecting the decimal

$$V_2 = V_1 \frac{458+T}{458+t}$$

To compare the two methods we will take an example. Let

$$t^\circ = 32^\circ,$$
$$T^\circ = 132^\circ,$$

and the volume of air at $32^\circ = 1$.
Then the volume at 132°,
by Dalton's law $= (1{\cdot}002039)^{100} = 1{\cdot}1355$,
by Gay Lussac's law $= \frac{458+132}{458+32} = 1{\cdot}204$.

Weight of Air.—The density or weight of air, the pressure being the same, is inversely as the volume; so that if W_1 be the weight of a certain volume at the temperature t°, the weight W_2 of the same volume at any other temperature T° is

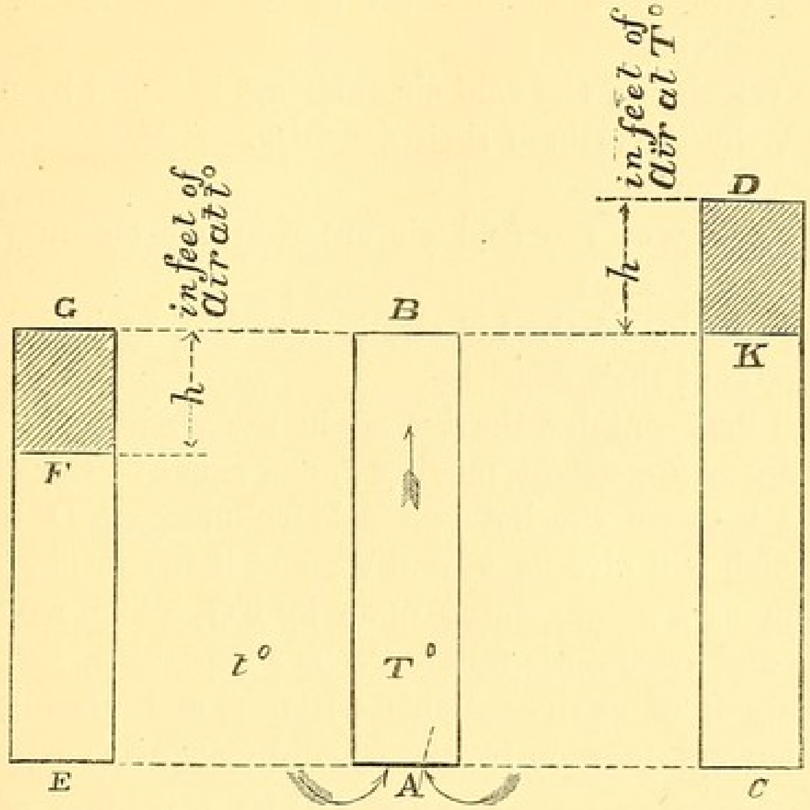
$$W_2 = W_1 \frac{458+t}{458+T}. \quad . \quad . \quad . \quad . \quad (2.)$$

Chimney Draught.—In estimating the rate of flow of heated air up a chimney, all writers base their formulæ on the well-established third law of motion as applied to the velocity of the fall of a heavy body in vacuo; but they vary in the mode of application, and obtain results which do not agree; but for practical purposes, the differences, except in one or two instances, cannot be considered large.

As, however, this want of agreement is calculated to throw a doubt upon the absolute truth of any method, it will be worth our while to inquire into the cause, at the point of divergence.

Let AB be a chimney containing heated air at the temperature T°, and let the external air be at the temperature t°.

Then, by reason of the difference of weight between the internal and external air, a certain upward motion will ensue in the hot air in the chimney, the cold air rushing in at A as the hot air leaves it at B.



Now, let a column of cold air (at $t°$) CK, equal to AB in height and sectional area, be raised to T°, and let CD represent its height when thus expanded; also, let a column of hot air (at T°) EG, equal to AB, be reduced to $t°$, and EF represent its height when so reduced; then FG and KD, the shaded portions of the diagram, represent the differences between AB at T° and when reduced to $t°$, and between AB at $t°$ and when raised to T°; but the former is measured by a column of cold air, and the latter by a column of hot air. This difference of "head" will, by many of our readers, be recognised at a glance as identical in principle with the difference between interest and discount on a sum of money.

Some writers, and amongst them we find Dr. Gregory, Davies Gilbert, Rankine,* and Peclét in the early editions of his *Traité de la Chaleur*, consider the moving force or "head" ($=h$) which produces the motion to be represented by KD; but Montgolfier, Tredgold, Peclét in the last edition of his *Traité de la Chaleur*, and others, rule that FG, or the difference in *cold air*, represents the true "head." If we calculate—

* On the Steam Engine and other Prime Movers.

V', the velocity of the hot air up the chimney, due to the "head" KD;

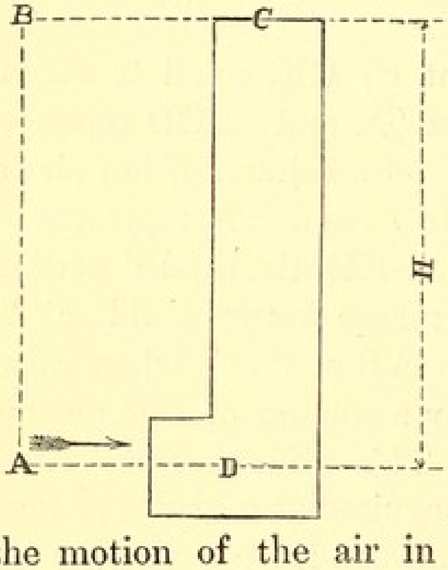
V, the velocity of the cold air entering, is found by multiplying V' by the ratio of their densities.

And if we calculate—

v, the velocity of the cold air entering the chimney, due to the "head" FG;

v', the velocity of the hot air, is found by multiplying V by the ratio of their densities.

We will first consider the *hot air* in the chimney as a weight acted upon by a constant moving force, equal to the difference in weight between the hot and cold columns = KD (diagram, p. 73), which will give us V' and V; and then consider the cold-air column as a weight acted upon by FG, which will give us v and v'; and afterwards follow Peclét's exposition, for to him is due the credit of analysing this question, and placing his deductions beyond question by careful and conclusive experiments.



Let CD be a column of air in a tube, and AB a column of air outside equal in height and volume.

Let AB be the colder, and therefore the heavier. Now, the weight of the atmosphere above CB, as it presses equally on every square foot of surface at that level, may be neglected in the following comparison of the weights of AB and CD, and in the calculations we make of the motion of the air in the tube which is caused by their inequality:

Let W' = the weight of AB,
W = the weight of CD,

Then $(W' - W)$ = a constant force or pressure acting at the mouth of the tube on W the weight of the air *in* the tube, and causing it to move upwards.

The velocity generated in the column of air CD by the force $(W' - W)$ will equal the velocity acquired by a heavy body falling freely from a height h under the force of gravity.

The value of h must first be ascertained and substituted in the equation $V' = \sqrt{2gh}$ in which $g = 32 \cdot 2$ feet the acceleration of gravity.

Let H = the heights of the columns of air, then h is found by the following proportion—

$$W : (W' - W) :: H : h \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (II.)$$

which is derived from the third law of motion. The enunciation of this law can only be satisfactory to one who has a clear conception of the term, "uniform acceleration." By "uniform acceleration" is meant the addition of equal increments of velocity in equal times; and if we say f is an acceleration due to a certain moving force acting on a certain body, we mean that in each successive unit of time the body acted upon moves over f more units of space than it did in the last unit of time. For example, if we take one foot and one second as the units of space and time, and a weight W is acted upon by a pressure causing an increase in the velocity of W's motion of two feet in each successive second: when W has moved over 10 feet in one second, it will pass over 12 feet in the next second, 14 feet in the next, and so on; f, the acceleration per second, being equal to 2, or f is said to be 2.

Now, the force (W'—W) that produces acceleration, being the resistance on the *driving* body due to the acceleration of the *driven* body (W), bears the same proportion to the driven body's weight which the actual rate of increase of velocity bears to the rate of the increase of velocity produced by gravity acting freely, that is—

$$(W' - W) : W :: f : g \quad . \quad . \quad . \quad . \quad . \quad . \quad (III.)$$

g being the acceleration of gravity $= 32 \cdot 2$; that is, according to our definition, the addition of 32·2 feet to the velocity of any falling body in each successive second.

But the spaces a body passes over in equal times are proportional to the accelerations; therefore, the space h that W will pass through with the accelerating force of (W'—W) acting on it, is to the space H it will pass through when falling freely by the force of gravity, as the acceleration f is to the acceleration g, that is—

$$f : g :: h : H,$$

but $(W'-W) : W :: f : g$ . . . . . by (III.)

therefore $(W'-W) : W :: h : H,$

and $W : (W'-W) :: H : h$ . . . . . (IV.)

As stated before, the velocity V′ which a heavy body will acquire in falling from a height h is the square root of twice g multiplied by h, that is—

$$V'=\sqrt{2gh} \quad \ldots\ldots \quad \text{(V.)}$$

and neglecting friction and other resistances, W will acquire in the tube CD a velocity V′ under the constant force (W′—W).

Example :

Let 80 feet = the height of the tube,
1 square foot = its sectional area,
Temperature of external air = 32° Fahr.
Temperature of air in the tube = 72° Fahr.

Then $80 \overset{\text{lbs.*}}{\times 0{\cdot}0807} = \overset{\text{lbs.}}{6{\cdot}456} = W'$,

and by (2) $6{\cdot}456 \frac{490}{530} = 5{\cdot}97 \text{ lbs.} = W.$

Then $(W'-W) = 6{\cdot}456 - 5{\cdot}97 = {\cdot}486$ lbs.

By (II.) $5{\cdot}97 : {\cdot}486 :: 80 : h$

```
         80
5·97)38·880(6·513 nearly
     3582
     ----
      3060
      2985
      ----
       0750
        597
       ----
       1530
```

By (V.) $V' = \sqrt{64{\cdot}4 \times 6{\cdot}513}$

$V' = 20{\cdot}48$ feet per second,

And $V = V' \times \frac{458+32}{458+72} = 18{\cdot}93$ feet per second.

Now, if we consider again the pressures at the mouth of the tube, we find the cold air seeking to enter with a force proportionate to the height of the chimney, and opposed by a constant force, the weight of the hot air within it; the difference between these pressures is FG in air at $t°$, and applying the first law in hydrodynamics, the velocity with which the air at $t°$ enters is $v=\sqrt{2gh}$, h being found by the following proportion :

* The weight in lbs. of one cubic foot of air at 32° Fahr.

$$W' : (W'-W) :: H : h.$$

Giving W, W', and H, the same values as in the last example we have—

$$6{\cdot}456 : {\cdot}486 :: 80 : h$$

```
     )38.880
      38736(6·0223
      14400
      12912
       14880
       12912
        19680
```

$$v=\sqrt{64{\cdot}4\times 6{\cdot}0223}$$

$$v=19{\cdot}69 \text{ feet per second.}$$

$$v'=v\times\frac{458+72}{458+32}=21{\cdot}29 \text{ feet per second,}$$

and collecting the results for comparison—

$$V=18{\cdot}93 \quad V'=20{\cdot}48,$$

$$v=19{\cdot}69 \quad v'=21{\cdot}29.$$

Extract from Peclét's "Traité de la Chaleur," Third Edition.

"To obtain the velocity of ingress of the exterior air at the point D, supposing the section of the pipe constant, we must recollect that the velocity of the flow of a liquid or a gas, setting aside the resistances depending on the form and size of the pipe, is given by the formula, $v=\sqrt{2gP}$, where P is the height of a column of fluid representing the pressure, and which would be in equilibrium with the pressure, however it might be produced.

"In the present case, P is evidently the height of a column of external air, and it is easy to find its value:

Denoting by H the height of the chimney from the centre of the section D,
by t° the external temperature,
by T the internal temperature,
M the pressure of the atmosphere at C in air at t°.

The pressure at the point D,* from outside inwards, measured by a column of air at t°, will be M+H, and the pressure in the contrary direction, measured in the same manner, will be—

$$M+H\frac{c+t^\circ}{c+T^\circ},$$

consequently, we shall have as the excess of the first pressure over the second—

* See Diagram, p. 74.

$$M+H-\left(M+H\,\frac{c+t^\circ}{c+T^\circ}\right)=H\,\frac{T-t}{c+T}=P,$$

and therefore—

$$v=\sqrt{2gH\,\frac{T-t}{c+T}} \quad . \quad . \quad . \quad . \quad (A),$$

which is the velocity of the *cold* air entering the pipe.

"For the velocity of v', or rate of flow of the *hot* air in the pipe, the velocities are in inverse proportion to the densities, and we shall have—

$$v'=v\frac{c+T}{c+t}\text{ whence } v'=\sqrt{2gH\,\frac{(T-t)\ (c+T)}{(c+t)^2}} \quad . \quad . \quad (B).$$

"Up to the present time, it has been admitted that the force in air at t°—

$$H\,\frac{T-t}{c+T}$$

was applied directly to the *hot* air, and the result was that the force in air at T being—

$$H\,\frac{T-t}{c+t}$$

the velocity of the heated air was—

$$V'=\sqrt{2gH\frac{T-t}{c+t}}$$

and we have for the velocity of ingress of the cold air—

$$V=\frac{V'(c+t)}{c+T}=\sqrt{2gH\frac{(T-t)\ (c+t)}{(c+T)^2}}$$

formulæ which are quite different from the formulæ (A) and (B), for we have evidently—

$$V'=v'\sqrt{\frac{c+t}{c+T}}\text{ and } V=v\sqrt{\frac{c+t}{c+T}}.$$

Therefore, the velocities V' and V are much less than the velocities v' and v; besides, the value of V presents a peculiarity which is not met with in the value v.

"If t° remain constant and the value of T° be progressively increased, the value of V increases at first and attains a maximum when

$$c+T=2\ (c+t)$$

that is, when

$$T = c + 2t,$$

and afterwards decreases indefinitely.

"Assuming $t^{\circ} = 32^{\circ}$, and calculating the values of

$$\frac{(T-t)\,(c+t)}{(c+T)^2}$$

with the following values of T—

100° 200° 300° 400° 500° 522° 544° 600° 700° 800° 900°,

we obtain

·10701 ·19013 ·22856 ·24505 ·24987 ·25 ·24988 ·24864 ·24409 ·23779 ·23063,

by which, we see at once, the value of V in the equation

$$V = \sqrt{2gH}\sqrt{\frac{(T-t)\,(c+t)}{(c+T)^2}}$$

becomes a maximum when

$$T = 522^{\circ} = c + 2t.$$

"The force of the air at t° acts directly on the *cold* air which enters the chimney, and not upon the *hot* air; and it is the velocity of the cold air that is afterwards transmitted to the hot air."

Sylvester finds an exposition in the movement of the air in the principle of Attwood's machine, as applied to the velocity of motion of two unequal weights, regarding the sum of the weights of equal volumes of the hot and cold air as a mass acted upon by a constant force equal to their difference of weight; that is, his proposition to find h will be—

$$(W' + W) : (W' - W) :: H : h,$$

but a little consideration is sufficient to show us that the mass of air in motion is the air in the tube only, for if we regard the air outside as divided into very thin horizontal laminæ which descend, but remain parallel during the flow of air into the tube, the area of the former being almost infinitely great in comparison with the latter, we may consider the velocity of its descent to be infinitely less, or that it is practically at rest.

Some writers first calculate the velocity of the flow of the atmosphere into a vacuum, and thence into a medium of less density than the atmosphere, but this involves the same principles as the foregoing, and gives the same results, according as the difference of density is given by feet of *hot* or *cold* air. It is only another way of stating the same case.

§ 12b. *Friction and other Resistances.*—The theory of the flow of gases and its application in detail to all the varied conditions met with in the construction of ventilating flues and passages in buildings, is much too wide a subject to handle within the limits of an Appendix, but if the remarks we make stimulate further inquiry on the part of those interested in the subject, and call the attention of builders to a few important points that must be observed in practice, the desired end will be obtained.

(1). In pipes or airways the resistance is directly as the length, that is, with double the length, all other conditions being the same, the resistance is doubled, and with three times the length it is trebled, and so on in any other proportion.

(2). The resistance is inversely as the diameter of a flue, so that a pipe five times as large as another, the velocity being the same in both cases, would present only one-fifth the resistance to the flow of air that the latter one would.

(3). The resistance increases as the square of the velocity of the air; if, therefore, in the same pipe we wish to pass during a certain period double the amount of air that has passed on another occasion, and calling the amount of air that passed on the former occasion unity, we shall have 2^2, or four times the amount of resistance to overcome in the latter case.

(4). The resistance varies with the nature of the internal surface of the pipes and flues. A glazed earthenware pipe offers less resistance than a rusty wrought-iron flue.

(5). A bend at right angles occasions a loss of force, which for practical purposes with the low velocities in ventilating flues we may take as equivalent to a complete stoppage of the current, or as a loss of head equal to that to which the actual velocity is due; a bend less than a right angle occasions a loss equal to the same force multiplied by the sine squared of the angle that the portion of the pipe on one side of the bend makes with the prolongation of the other side.

(6). A large and sudden change of section, as for instance when a pipe delivers fresh air into one end of a room which has to be drawn out by a pipe at the other end, may be taken practically as a loss of force equal to the "head" required to produce the velocity of flow in the pipe.

In applying to principles already enunciated to the ventilation of House No. 2, the theoretical quantity of fresh air that will pass through the flues with given temperatures must be found in the following manner.

1st. Ascertain the value of the "head,"

$$H\left(\frac{(T-t)}{c+T}\right)$$

in equation A, page 78, for the average temperatures of the rooms and lobbies. H being the difference of level between the fresh-air heating chamber, and the vitiated-air chamber, and T and t the temperatures inside and outside the house; 2ndly, find the value of the head,

$$\frac{l_1\,(T_1-t)}{c+T_1}$$

l_1 being the height of the downcast shaft, T, and t the temperatures inside the shaft and outside the house; 3rdly, find the value of

$$\frac{l_2\,(T_2-t)}{c+T_2}$$

l_2 being the height of the upcast shaft, T_2 and t the temperature inside the shaft and outside the house. As the outside air is assumed to be colder than the air within the building, we readily see the head or force in the rooms and in the upcast shaft is in the required direction, but the force in the downcast shaft is opposed to it, therefore it follows the available force for creating a current is the combined upward forces in the rooms and upcast, diminished by the upward force in the downcast, that is, the available "head" h in equation V, page 76, is,

$$\frac{H\,(T-t)}{c+F}-\frac{l_1\,(T_1-t)}{c+T_1}+\frac{l_2\,(T_2-t)}{c+T_2}$$

or the theoretical velocity v is—

$$v=\sqrt{2g\left(\frac{H(T-t)}{c+T}-\frac{l_1(T_1-t)}{c+T_1}+\frac{l_2(T_2-t)}{c+T_2}\right)}$$

The actual velocity will be obtained approximately by the following formula:

$$u=v\sqrt{\frac{1}{\frac{KH}{m_0}+\frac{Kl_1}{m_1}+\frac{Kl_2}{m_2}+N}}$$

in which

u=the actual velocity.
K=a coefficient of friction for dusty surfaces given by Peclét =·012.
m_0 m_1 m_2=the areas of the several shafts or pipes divided by their perimeters, circumferences, or rubbing surfaces.
N=the number of bends at right angles, and the number of enlargements of section as described in (5) and (6).

In houses ventilated in the same manner as House No. 2, the lengths of the flues and downcast shaft are determined by the height of the building.

The shape and area of the airways will probably be heavily taxed by the architect, in endeavouring to construct the largest and best proportioned rooms his roof will cover.

The height of the upcast will probably be limited by architectural considerations of appearance and expense; a shaft standing high above a roof requires special treatment, and cannot in all cases be made to harmonise with the rest of the design.

The temperature of the air in the rooms and downcast shaft will depend upon the seasons and the habits of the inmates of the house, and will not vary largely.

The temperature of the air in the upcast, if a powerful current through the house is desired, must be high; and when the other conditions are unfavourable, special means for heating the air can, and must be provided. This may be carried to any desired extent, and is simply a question of expense in proportion to the work done.

The following tables enable the builder to obtain without the use of algebraical formulæ, and accurately enough for practical purposes, the velocity of the air he may expect in the upcast shaft under almost any conditions of temperature, provided the upcast shaft be uniform in section and less in area than the downcast shaft, and less than the combined areas of the flues through which the air passes on its way through the house. *The cubic feet of air per second* is the product of the velocity given by the tables, multiplied by the area of the upcast shaft in square feet.

RULE.—Find in the left-hand column of Table No. I. the temperature of the outside air, and, following the row of numbers horizontally to the right, take that one which is immediately under the average temperature of the rooms, and multiply it by the height in feet of the vitiated air chamber above the fresh-air heating chamber, that is, by the difference of level, in feet, between the hot-water pipes in the fresh-air warming chamber in the basement, and the centres of the outlets of the flues from the rooms, discharging into the vitiated-air chamber at the top of the house. Secondly, find the number in Table I. at the intersection of the horizontal and vertical rows of numbers opposite the temperatures of the outside air and the upcast shaft, and multiply it by the height of the upcast shaft in feet, measuring from the centre of the cross shaft or passage connecting the downcast with the bottom of the upcast, to the centre of the outlet at the top of the upcast. Thirdly, find the number for the temperature of the outside air and the downcast shaft, and multiply it by the height of the latter in feet, that is, by the difference of level in feet between the centre of the cross shaft or passage connecting the bottom of the downcast shaft with the upcast, to the centre of the outlets of the flues from the rooms, discharging into the vitiated-air chamber in the roof. Add together the two former sums so obtained and subtract the latter, the result will be the available force for creating a draught. In Table II., find in one of the columns headed F the nearest number to this result, and in the adjoining column to the right (V) will be found the approximate velocity in feet per second in the upcast shaft.

Example:

Given, the temperature of the outside air		=40°
,, ,, ,, rooms		=60°
,, ,, ,, downcast		=64°
,, ,, ,, upcast		=75°
,, difference of level between the vitiated-air chamber and the fresh-air warming chamber		=45 ft.
,, difference of level between the vitiated-air chamber and the bottom of the downcast		=35 ft.
,, height of the upcast or difference of level between the centre of the cross shaft and the outlet		=60 ft.

In Table I. find 60° in the top row, and 40° in the left-hand column, and at the intersection of the numbers below, and to the right of these we find ·0386; multiply this number by 45—

$$\cdot 0386 \times 45 = 1\cdot 737 = \text{the upward force in the rooms.}$$

Similarly at the intersection for the temperature 75° and 40°, we find ·0657, which multiplied by 60—

$$\cdot 0657 \times 60 = 3\cdot 942 = \text{the upward force in the upcast.}$$

Again for temperatures 64° and 40° we find ·046, which multiplied by 35—

$$\cdot 046 \times 35 = 1\cdot 61 = \text{the upward force in the downcast.}$$

adding the first and second {1·737, 3·942}

5·679

and deducting the third . 1·61

we have . . . 4·069 = the theoretical "head."

In Table II. the nearest number in one of the columns F to 4·069 is 4·05, and in the next column to the right is 4·22, the velocity in feet per second which may be expected in the upcast shaft.

Owing to the relative positions of House No. 2, and some adjoining buildings, and to the form and position of the principal inlet and outlet, the velocity of the current of air in the upcast is either accelerated or retarded by winds from certain quarters.

TABLE I.

Values of t.	50	51	52	53	54	55	56	57	58	59	60	61	62	63
20	·0590	·0609	·0627	·0646	·0664	·0682	·0700	·0718	·0732	·0754	·0772	·0790	·0808	·0825
22	·0551	·0570	·0581	·0607	·0625	·0643	·0661	·0679	·0698	·0716	·0734	·0751	·0769	·0787
24	·0512	·0530	·0549	·0567	·0586	·0604	·0621	·0641	·0659	·0677	·0695	·0713	·0731	·0748
26	·0472	·0491	·0510	·0528	·0557	·0565	·0584	·0602	·0620	·0638	·0656	·0674	·0692	·0710
28	·0433	·0452	·0471	·0489	·0508	·0526	·0545	·0563	·0581	·0599	·0618	·0636	·0654	·0672
30	·0394	·0412	·0431	·0450	·0469	·0487	·0506	·0524	·0543	·0561	·0579	·0597	·0615	·0633
31	·0374	·0393	·0412	·0430	·0449	·0468	·0486	·0505	·0523	·0542	·0560	·0578	·0596	·0614
32	·0354	·0373	·0392	·0411	·0430	·0448	·0467	·0485	·0504	·0522	·0540	·0559	·0577	·0595
33	·0335	·0354	·0372	·0391	·0410	·0429	·0447	·0467	·0484	·0503	·0521	·0539	·0558	·0576
34	·0315	·0334	·0353	·0372	·0391	·0409	·0428	·0447	·0465	·0483	·0502	·0520	·0518	·0557
35	·0295	·0314	·0333	·0352	·0371	·0390	·0409	·0427	·0446	·0464	·0483	·0501	·0519	·0537
36	·0276	·0295	·0314	·0333	·0351	·0370	·0389	·0408	·0426	·0445	·0463	·0482	·0500	·0518
37	·0256	·0275	·0294	·0313	·0332	·0351	·0370	·0388	·0407	·0425	·0444	·0462	·0481	·0499
38	·0236	·0255	·0274	·0293	·0312	·0331	·0350	·0369	·0388	·0406	·0425	·0443	·0461	·0480
39	·0216	·0236	·0255	·0274	·0293	·0312	·0331	·0349	·0368	·0387	·0405	·0424	·0442	·0461
40	·0197	·0216	·0235	·0254	·0273	·0292	·0311	·0330	·0349	·0367	·0386	·0405	·0423	·0441
41	·0177	·0196	·0218	·0235	·0254	·0273	·0291	·0311	·0329	·0348	·0367	·0385	·0404	·0422
42	·0157	·0177	·0196	·0215	·0234	·0253	·0272	·0291	·0310	·0329	·0347	·0366	·0385	·0403
43	·0138	·0157	·0176	·0195	·0215	·0234	·0253	·0272	·0291	·0309	·0328	·0347	·0365	·0384
44	·0118	·0137	·0157	·0175	·0195	·0214	·0233	·0252	·0271	·0290	·0309	·0327	·0346	·0365
45	·0098	·0118	·0137	·0156	·0176	·0195	·0214	·0233	·0252	·0271	·0290	·0308	·0327	·0345
46	·0079	·0098	·0118	·0137	·0156	·0175	·0194	·0214	·0232	·0251	·0270	·0289	·0308	·0326
47	·0059	·0079	·0098	·0117	·0137	·0156	·0175	·0194	·0213	·0232	·0251	·0270	·0288	·0307
48	·0039	·0059	·0078	·0098	·0117	·0136	·0156	·0175	·0194	·0213	·0232	·0250	·0269	·0288
49	·0020	·0039	·0059	·0078	·0098	·0117	·0136	·0155	·0174	·0193	·0212	·0231	·0250	·0269
50		·0020	·0039	·0059	·0078	·0097	·0117	·0136	·0155	·0174	·0193	·0212	·0231	·0249
52				·0020	·0039	·0058	·0078	·0097	·0116	·0135	·0154	·0173	·0192	·0211
54						·0019	·0039	·0058	·0077	·0097	·0115	·0135	·0154	·0173
56								·0019	·0039	·0058	·0077	·0096	·0115	·0134
58										·0019	·0039	·0058	·0077	·0096
60												·0019	·0038	·0058
65														
70														
75														
80														

Values of t.	64	65	66	67	68	69	70	71	72	73	74	75	76	77
20	·0843	·0860	·0878	·0895	·0912	·0930	·0947	·0964	·0981	·0998	·1015	·1032	·1049	·1065
22	·0805	·0822	·0840	·0857	·0874	·0892	·0909	·0926	·0943	·0960	·0977	·0999	·1011	·1028
24	·0766	.0784	·0801	·0819	·0836	·0854	·0871	·0888	·0906	·0923	·0940	·0957	·0974	·0991
26	·0728	·0746	·0763	·0781	·0798	·0816	·0833	·0851	·0868	·0885	·0902	·0919	·0936	·0953
28	·0690	·0707	·0725	·0743	·0760	·0778	·0795	·0813	·0830	·0847	·0865	·0882	·0899	·0916
30	·0651	·0669	·0687	·0705	·0722	·0741	·0758	·0775	·0792	·0810	·0827	·0844	·0861	·0878
31	·0632	·0650	·0668	·0686	·0703	·0721	·0739	·0756	·0774	·0791	·0808	·0825	·0843	·0860
32	·0613	·0631	·0649	·0667	·0684	·0702	·0720	·0737	·0755	·0772	·0789	·0807	·0824	·0841
33	·0594	·0612	·0630	·0648	·0665	·0683	·0701	·0718	·0736	·0753	·0771	·0788	·0805	·0822
34	·0575	·0593	·0611	·0629	·0646	·0664	·0682	·0699	·0717	·0734	·0752	·0769	·0786	·0804
35	·0555	·0574	·0592	·0609	·0627	·0645	·0663	·0680	·0698	·0716	·0733	·0750	·0768	·0785
36	·0536	·0554	·0572	·0590	·0608	·0626	·0644	·0662	·0679	·0697	·0714	·0732	·0749	·0766
37	·0517	·0535	·0553	·0571	·0589	·0607	·0625	·0643	·0660	·0678	·0695	·0713	·0730	·0748
38	·0498	·0516	·0534	·0552	·0570	·0588	·0606	·0624	·0641	·0659	·0677	·0694	·0712	·0729
39	·0479	·0497	·0515	·0533	·0551	·0569	·0587	·0605	·0623	·0640	·0658	·0675	·0693	·0710
40	·0460	·0478	·0496	·0514	·0532	·0550	·0568	·0586	·0604	·0621	·0639	·0657	·0674	·0692
41	·0441	·0459	·0477	·0495	·0513	·0531	·0549	·0567	·0585	·0603	·0620	·0638	·0655	·0673
42	·0421	·0440	·0458	·0476	·0494	·0512	·0530	·0548	·0566	·0584	·0601	·0619	·0637	·0654
43	·0402	·0421	·0439	·0457	·0475	·0493	·0511	·0529	·0547	·0565	·0583	·0600	·0618	·0635
44	·0383	·0401	.0420	·0438	·0456	·0474	·0492	·0510	·0528	·0546	·0564	·0582	·0599	·0617
45	·0364	·0382	·0401	·0419	·0437	·0455	·0473	·0491	·0509	·0527	·0545	·0563	·0580	·0598
46	·0345	·0363	·0382	·0400	·0418	·0436	·0454	·0473	·0491	·0508	·0526	·0544	·0562	·0579
47	·0326	·0344	·0363	·0381	·0399	·0417	·0436	·0454	·0472	·0490	·0507	·0525	·0543	·0561
48	·0306	·0325	·0343	·0362	·0380	·0398	·0417	·0435	·0453	·0471	·0489	·0507	·0524	·0542
49	·0287	·0306	·0324	·0343	·0361	·0379	·0398	·0416	·0434	·0452	·0470	·0488	·0506	·0523
50	·0268	·0287	·0305	·0324	·0342	·0360	·0379	·0397	·0415	·0433	·0451	·0469	·0487	·0505
52	·0230	·0249	·0267	·0286	·0304	·0323	·0341	·0359	·0377	·0395	·0413	·0431	·0449	·0467
54	·0192	·0210	·0229	·0248	·0266	·0285	·0303	·0321	·0340	·0358	·0376	·0394	·0412	·0430
56	·0153	·0172	·0191	·0209	·0228	·0247	·0265	·0284	·0302	·0320	·0338	·0356	·0374	·0392
58	·0115	·0134	·0153	·0171	·0190	·0209	·0227	·0246	·0264	·0282	·0301	·0319	·0337	·0355
60	·0077	·0096	·0114	·0133	·0152	·0171	·0189	·0208	·0226	·0245	·0263	·0281	·0300	·0318
65			·0019	·0038	·0057	·0076	·0094	·0113	·0132	·0150	·0169	·0188	·0206	·0224
70								·0019	·0038	·0056	·0075	·0094	·0112	·0131
75													·0019	·0037
80														

Values of t.	78	79	80	82	84	86	88	90	95	100	105	110
20	·1082	·1099	·1115	·1148	·1181	·1213	·1245	·1277	·1356	·1434	·1510	·1584
22	·1045	·1061	·1078	·1111	·1144	·1176	·1209	·1241	·1320	·1398	·1474	·1549
24	·1007	·1024	·1041	·1074	·1107	·1140	·1172	·1204	·1284	·1362	·1439	·1514
26	·0970	·0987	·1004	·1037	·1070	·1103	·1135	·1168	·1248	·1326	·1403	·1479
28	·0933	·0950	·0966	·1000	·1033	·1066	·1099	·1131	·1211	·1290	·1368	·1444
30	·0895	·0912	·0929	·0963	·0996	·1029	·1062	·1095	·1175	·1254	·1332	·1408
31	·0877	·0894	·0911	·0944	·0978	·1011	·1044	·1077	·1157	·1236	·1314	·1391
32	·0858	·0875	·0892	·0926	·0959	·0993	·1026	·1058	·1139	·1219	·1297	·1373
33	·0839	·0857	·0874	·0907	·0941	·0974	·1007	·1040	·1121	·1201	·1279	·1356
34	·0821	·0838	·0855	·0889	·0922	·0956	·0989	·1022	·1103	·1183	·1261	·1338
35	·0802	·0819	·0836	·0870	·0904	·0937	·0971	·1004	·1085	·1165	·1243	·1320
36	·0784	·0801	·0818	·0852	·0886	·0919	·0952	·0985	·1067	·1147	·1226	·1303
37	·0765	·0782	·0799	·0833	·0867	·0901	·0934	·0967	·1049	·1130	·1208	·1285
38	·0746	·0763	·0781	·0815	·0849	·0882	·0916	·0949	·1031	·1111	·1190	·1268
39	·0728	·0745	·0762	·0796	·0830	·0864	·0897	·0931	·1013	·1093	·1172	·1250
40	·0709	·0726	·0743	·0778	·0812	·0846	·0879	·0912	·0994	·1075	·1154	·1232
41	·0690	·0708	·0725	·0759	·0793	·0827	·0861	·0894	·0976	·1057	·1137	·1215
42	·0672	·0689	·0706	·0741	·0775	·0809	·0842	·0876	·0958	·1039	·1119	·1197
43	·0653	·0670	·0688	·0722	·0756	·0790	·0824	·0858	·0940	·1021	·1101	·1180
44	·0634	·0652	·0669	·0704	·0738	·0772	·0806	·0839	·0922	·1004	·1083	·1162
45	·0616	·0633	·0651	·0685	·0720	·0754	·0787	·0821	·0904	·0986	·1066	·1144
46	·0597	·0614	·0632	·0667	·0701	·0735	·0769	·0803	·0886	·0968	·1048	·1127
47	·0578	·0596	·0613	·0648	·0683	·0717	·0751	·0785	·0868	·0950	·1030	·1109
48	·0560	·0577	·0595	·0630	·0664	·0698	·0733	·0766	·0850	·0932	·1012	·1091
49	·0541	·0559	·0576	·0611	·0646	·0680	·0714	·0748	·0832	·0914	·0995	·1074
50	·0522	·0540	·0558	·0593	·0627	·0662	·0696	·0730	·0814	·0896	·0977	·1056
52	·0485	·0503	·0520	·0555	·0590	·0625	·0659	·0693	·0778	·0860	·0941	·1026
54	·0448	·0465	·0483	0518	·0553	·0588	·0623	·0657	·0741	·0824	·0906	·0986
56	·0410	·0428	·0446	·0481	·0517	·0551	·0586	·0620	·0705	·0788	·0870	·0951
58	·0373	·0391	·0409	·0444	·0480	·0515	·0549	·0584	·0669	·0753	·0835	·0915
60	·0336	·0354	·0372	·0407	·0443	·0478	·0513	·0547	·0633	·0717	·0799	·0880
65	·0242	·0261	·0279	·0315	·0351	·0386	·0421	·0456	·0542	·0629	·0710	·0792
70	·0149	·0167	·0185	·0222	·0258	·0294	·0330	·0365	·0452	·0538	·0622	·0704
75	·0056	·0074	·0093	·01296	·0166	·0202	·0238	·0274	·0362	·0448	·0533	·0616
80				·0037	·0074	·0110	·0146	·01825	·0271	·0358	·0444	·0528

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TABLE II.

F	V	F	V	F	V	F	V	F	V
·01	·21	·34	1·23	·67	1·71	1·	2·1	2·65	3·42
·02	·28	·35	1·24	·68	1.72	1·05	2·15	2·7	3·45
·03	·36	·36	1·26	·69	1·74	1·1	2·2	2·75	3·48
·04	·42	·37	1·27	·7	1·75	1.15	2·25	2·8	3·51
·05	·45	·38	1·29	.71	1·77	1·2	2·3	2·85	3·54
·06	·51	·39	1·3	·72	1·78	1·25	2·35	2·9	3·57
·07	·55	·4	1·32	·73	1·8	1·3	2·4	2·95	3·61
·08	·58	·41	1·34	·74	1·81	1·35	2·43	3·	3·64
·09	·63	·42	1·36	·75	1.82	1·4	2·47	3·05	3·67
1	·66	·43	1·38	·76	1·83	1·45	2·52	3·1	3·69
·11	·69	·44	1·39	·77	1·84	1·5	2·56	3·15	3·72
·12	·72	·45	1·41	·78	1·86	1·55	2·6	3·2	3·75
·13	·75	·46	1·42	·79	1·87	1·6	2·64	3·25	3·78
·14	·78	·47	1·44	·8	1·88	1·65	2·68	3·3	3·82
·15	·81	·48	1·45	·81	1·89	1·7	2·73	3·35	3·84
·16	·84	·49	1·47	·82	1·9	1·75	2.77	3·4	3·87
·17	·87	·5	1·48	·83	1·91	1·8	2.81	3·45	3·9
·18	·88	·51	1·5	·84	1·92	1·85	2·85	3·5	3·93
·19	·91	·52	1·51	·85	1·93	1·9	2·89	3·55	3·96
·2	·94	·53	1·53	·86	1·94	1·95	2·93	3·6	3·99
·21	·96	·54	1·54	·87	1.95	2·	2·97	3·65	4·01
·22	·99	·55	1·55	·88	1·96	2·05	3·01	3·7	4·04
·23	1·	·56	1·56	·89	1·98	2·1	3·04	3.75	4·07
·24	1·03	·57	1·57	·9	1·99	2·15	3·07	3·8	4·09
·25	1·05	·58	1·59	·91	2·	2·2	3·1	3·85	4·11
·26	1·06	·59	1·6	·92	2·01	2·25	3·14	3·9	4·14
·27	1·09	·6	1·62	·93	2·02	2·3	3·18	3·95	4·18
·28	1·11	·61	1·63	·94	2·03	2·35	3·21	4·	4.2
·29	1·13	·62	1·65	·95	2·04	2·4	3·25	4·05	4·22
·3	1·15	·63	1·66	·96	2·05	2·45	3·28	4·1	4·25
·31	1·17	·64	1·68	·97	2·07	2·5	3·32	4·15	4·28
·32	·119	·65	1·69	·98	2·08	2.55	3·35	4·2	4·3
·33	1·21	·66	1·70	·99	2·09	2·6	3·38	4·25	4·32

NOTE.—For the purposes of this Table the actual velocity is taken to be 25 per cent. of the theoretical velocity.

TABLE II.—*continued.*

F	V	F	V	F	V	F	V	F	V
4·3	4.35	5·95	5·13	7·6	5·79	9.25	6·39	10·9	6·93
4·35	4·38	6·	5·15	7·65	5·81	9·3	6·4	10·95	6·94
4·4	4·4	6·05	5·17	7·7	5·83	9·35	6·42	11.	6·96
4.45	4·42	6·1	5·19	7·75	5·84	9·4	6·43		
4·5	4·45	6·15	5·21	7·8	5·86	9·45	6·45		
4·55	4·47	6·2	5·23	7·85	5·88	9·5	6·47		
4·6	4·5	6·25	5·25	7·9	5·9	9·55	6·49		
4·65	4·53	6·3	5·27	7·95	5·92	9·6	6·51		
4·7	4·56	6.35	5·29	8·	5·94	9·65	6·52		
4·75	4·58	6·4	5·31	8·05	5·96	9·7	6·54		
4·8	4·6	6·45	5·33	8·1	5·98	9·75	6·55		
4·85	4·62	6·5	5·35	8·15	6·	9·8	6·57		
4·9	4·64	6·55	5·37	8·2	6·01	9·85	6·58		
4·95	4·66	6·6	5·4	8·25	3·03	9·9	6·6		
5.	4·69	6·65	5·42	8·3	6·05	9·95	6·62		
5·05	4·72	6·7	5·44	8·35	6·07	10·	6·64		
5·1	4·74	6·75	5·16	8·4	6·09	10·05	6·66		
5·15	4·77	6·8	5·48	8·45	6·1	10·1	6·67		
5·2	4·79	6·85	5·5	8·5	6.12	10·15	6·69		
5·25	4·89	6·9	5·52	8·55	6·13	10·2	6·7		
5·3	4·83	6·95	5·54	8·6	6·15	10·25	6·72		
5·35	4·85	7.	5·56	8·65	6·17	10·3	6·73		
5·4	4·87	7·05	5·58	8·7	6·19	10.35	6·75		
5·45	4·89	7·1	5·59	8·75	6·21	10·4	6·76		
5·5	4·92	7·15	5·61	8·8	6·23	10·45	6·78		
5·55	4·95	7·2	5·63	8·85	6·25	10·5	6·8		
5·6	4·98	7·25	5·65	8·9	6·27	10·55	6·82		
5·65	5.	7·3	5·67	8·95	6·28	10·6	6·84		
5·7	5·02	7·35	5·69	9.	6·3	10·65	6·85		
5·75	5·04	7·4	5·71	9·05	6·31	10·7	6·87		
5·8	5·06	7·45	5·73	9·1	6·33	10·75	6·88		
5·85	5·08	7·5	5·75	9·15	6·35	10·8	6·9		
5·9	5·1	7·55	5·77	9·2	6·37	10·85	6·91		

Observations and Experiments

Carried on in House No. 2.

§ 14. This house was built in 1867, and it has been occupied by the proprietor since January, 1868. Observations of the temperatures and the circulation of the air have been made frequently during the whole time; and the general impression produced has been that in winter the central lobbies, even of the attic floor, could, with a proper distribution of the hot-water pipes, be prevented from falling lower than 65°, with the full current of air passing through them: and that in summer the whole house could, by a proper adjustment of the openings and flues, be prevented from rising above 75°, even on the hottest days. As stated at page 50, the strips of silk hung in the foul-air chamber have been observed frequently, and even in the still atmosphere of a summer evening, and when the kitchen fire was not burning, they have been found to be always moving in the right direction with sufficient force to indicate a good current out of the rooms. Since April 22nd, 1871, more definite observations have been made, and careful records kept of them. As stated in Chap. II., p. 54, this house consists of a central lobby 24 ft. × 9 ft., with rooms 19 ft. deep on each side, and having ground, house, bedroom and attic floors. The total cubic area of the house is about 38,000 cubic feet. The primary inlet is about $5\frac{1}{8}$th square feet, the secondary inlet about 16 square feet, the inlets into the rooms as large as they could be made, the total area of the outlets from the rooms of the house proper (and all others were closed during the experiments) into the foul-air chamber is about $3\frac{1}{3}$ square feet, the downcast shaft (or outlet from the foul-air chamber) is about $5\frac{1}{4}$ square feet, and the upcast (or ultimate vitiated-air outlet), at the place where the anemometer was, is $3\frac{3}{4}$ square feet,* height of vitiated-air chamber above heating chamber 47 ft., length of downcast shaft 35 ft., and length of upcast 54 ft., the canvas stretched across

* These areas do not bear a proper proportion to each other: in fact, a proper proportioning was not attempted: the architect made them all as large as he could; doubtless the flow of air through the house is, to some extent, interfered with by this want of proportion.

the primary inlet at I. (see Plan) is 171 square feet, the primary inlet is provided with valves, the secondary inlet is protected by hot-water pipes, which also extend into the central lobbies, giving a length of 285 ft., the chimney throats are provided with valves and register grates, and the outlets from the rooms are provided with valves between the room and the foul-air chamber, nearly all the windows in the house are fixed like church windows, there is a small window in each end of the foul-air chamber, and a small, well-made, tightly-fitting, thick plate-glass door into the downcast at C, and into the upcast at J. Thermometers have been placed outside (dry and wet bulb), in the ground floor central lobby, first floor, second floor, and third floor; the foul-air chamber, the downcast at C, the upcast (maximum and minimum registering) at J, and in the kitchen smoke flue 3 ft. up the flue and 11 ft. from the top of the chimney-pot. Anemometers (Casella's indicating accurately as low a velocity as 50 ft. per minute, and as high as 1200 ft.) have been placed in the primary inlet, in the termination of the vitiated-air flues from the rooms, in the foul-air chamber, in the downcast at C, and in the upcast at J. Observations and readings have been taken during the hot days of summer (see Experiments, August 15 to 31), the variable days of spring (see Experiment, April 22), of autumn (see Experiments, September 1, 25), and the cold days of winter (see Experiments, November 19, December 4), in the morning before the fires were lighted (August 16, 18), in the day at different times and in the varying states of the house (August 29, November 9, 19), and at night after the fires had gone out and the family gone to bed (August 21, September 15, October 11, 22, December 4); with many persons in the house (September 5, November 13), with few (October 24, and most of the other Obs.); with the fires lighted and with them out (November 19), with the gases lighted and with them out (September 5, December 4), with the doors of the rooms open and with them shut (November 3, December 4), with the warming apparatus in action and with it out (September 5, November 13, December 4), with the canvas stretched across the inlet and without it (October 8), with wind on the primary inlet (November 9), and with no wind (September 5), with an opposing wind on the ultimate outlets (September 10, November 5, 19), and with favouring wind on the ultimate outlets (November 9, August 18, 11 P.M., 19, 21, September 22, 23, 24); without the kitchen fire being lighted (August 17, 18), and with it in various degrees of heat; with the primary inlet fully opened (most of Obs.), and with it partially opened (December 7, 8).

§ 14a. The results arrived at are the following, viz., that in this house with an open kitchen fire (the opening 4 ft. from side to side and 2 ft. high above top bar), the fire grate 17 in. from side to side, 11 in. from front to back, and 14 in. from top bar to bottom of grate, the smoke flue beginning 4 ft. 6 in. above top bar, *i.e.*, 5 ft. above centre of fire, smoke flue 54 ft. long made of glazed earthenware pipes 1 in. thick, the internal diameter 15 in. and of chimney-pot 13 in.; with a good kitchen fire burning and the water in the boiler behind the fire boiling; with these conditions the smoke from the kitchen fire has a temperature of 230° as it enters the smoke flue and 195° as it escapes at the chimney-top;* and with the upcast surrounding the whole length of the smoke flue 46 ft., and flue pretty clear of soot, we thus therefore abstract only 35° of the waste heat of the smoke from the kitchen fire, and that though the upcast goes up close behind the boiler; and therefore we gain only an average increase of temperature in the winter of about 20° between the outside air and the air in the upcast for the production of draught or the suction of the vitiated air out of the house, and we thus produce a velocity of about 220 ft. per minute in the upcast. How much more of the waste heat of the smoke we could gain by having a cast-iron smoke flue, close kitchen range and contracted chimney-pot, we cannot at present say, but it is very likely we should gain at least 50° to 70°, which would possibly increase the velocity to about 300 or 350 ft. per minute in the upcast. It was also found that the velocity was interfered with in the summer by the heat of the foul-air chamber (see Experiments, August 29, September 1, 7), and still more so when the attic windows were open (August 29, 30).

§ 14b. The openings, flues, bends, &c., through which the

* See Observation, November 19.

air has to pass, will of course offer obstruction to its passage and retard its progress. There will, of course, be some difficulty to be overcome in its passage through the grating of the primary inlet in the outer wall (A). Again, at the canvas stretched across the passage of the primary inlet (I), again at the valve-openings of the primary inlet (Aa), again at the secondary inlet (B), again through the openings of the cornice of the rooms, also through the ceiling and floor grating in its passage from the ground to the first floor, and through the cornice there; also through the ceiling, floor and cornice of the second and third floors; and again through the central ornament in the ceiling of the rooms; by the bends in the zinc tubes; by the heat in summer and the cold in winter in the foul-air chamber; by the tendency to rise rather than fall in the downcast; by the increase of friction by the central smoke flue, with its inequalities and the cross-stays in the upcast; by the cooling effect of the part of the chimney outside the house, and by the bends outwards of the ultimate outlets. The sum total of these retarding influences we may somewhat compute by comparing the actual velocities as given at pages 93, *et seq.*, but the particular share contributed by each of these sources, it would require a long and careful series of observations to determine: some of these may perhaps be published on a future occasion. The retarding influence of the filtering canvas is referred to in Experiment, October 8; but repetitions of such experiments are necessary; observations, December 4, do not indicate any retarding influence by the room doors being shut, but more extended observations are necessary on this point, and they should be taken in the termination of the flue of each room in the foul-air chamber, as were the observations, April 22: the same remarks apply as to the influence of the fires; observations, December 19, however, appear to show that they do not interfere with the quantity of air passing up the vitiated outlets from the rooms, and this indicates that the inlets are ample for the supply of both. Observations, August 31, September 1, show that in the hot days of summer, when the outer air appears perfectly motionless, there is nevertheless considerable movement of the air through the house; and observations, August

17, 18, show that this is the case even when the kitchen fire is not lighted. Observations, September 10, indicate the necessity of the protection of the ultimate outlets from adverse winds.

§ 14c. The temperature of the different parts of the house, it will be observed, varied more with the state and uses of the house than with the season, or outside temperature. The interior of the house was cooler in summer than the outside temperature, 12° or 15° (July 24, 5 P.M., 1870; August 8, 3 P.M., 1871); and in winter it was warmer by 32° (December 4) when the inlets were open to their full extent, 34° when two-thirds open (December 7), and 36° when half open (December 8). The temperature varied with the open or closed state of the valves, *i.e.*, with the velocity of the passage of the air through the house (December 4, 7, 8); also, and especially in the central lobbies, with the temperature of the warming apparatus (November 13, 19, December 4, 7, 8). When the outside temperature was at 32°, and the primary inlet open to its greatest capacity, and the warming apparatus in operation to its full extent, the temperature of the central lobbies did not rise above 64°. This proves that 280 feet of piping are not quite enough for the greatest capacity of the inlets in the coldest weather; they are, however, enough for three-quarters of the opening, which is more than sufficient for ordinary purposes. Perhaps had the extra 36 feet of flow-pipe, which goes up the corner of the stairs lobby, also passed through the central lobby, it would have been sufficient for the full extent of the openings.

§ 15. The actual experiments were inaugurated by a general meeting of the gentlemen interested, on the 22nd April, 1871, in the early morning, in order to begin before the fires were lighted. At 6.30 A.M. there were present Dr. Hayward, Dr. Drysdale, Alfred Higginson, Esq., surgeon, Harry Footner, Esq., C.E., Alfred E. Fletcher, Esq., F.C.S., Henry Sumners, Esq., architect, and T. H. Harrison, Esq., architect. The weather was dull, heavy, warm, and wet—a heavy rain falling, with scarcely any wind, and what there was, was from south-east. The inlet openings are on the west side of the house. A minimum registering thermometer was hung outside, in the middle of one of the gratings of the primary inlet: this registered 48° at 6.30. The heating apparatus having been working through the night, a thermometer hung five feet from floor in central lobby on ground floor registered 65°. There are two rooms on this floor, both to the west, and they were at a temperature of 60°; the thermometer five feet from floor in central lobby on first floor registered 63°. There are two rooms on this—the house floor; one at the front or west, and the other at the back or east, occupying the whole length of the central lobby; the front or drawing-room registered 60°, the back or dining-room registered 62°; the central lobby on the second, the bedroom floor, 61°; and the central lobby on the third or attic floor, 59°.

§ 15a. Mr. Sumners entered the fresh-air chamber with a Casella's anemometer to register the velocity of the primary ingress of the air into the house, and commenced observations at 7.27 A.M. Dr. Drysdale and Mr. Footner entered the foul-air chamber—Dr. Drysdale, with a Biram's anemometer, to register the velocity of the air entering the foul-air chamber from the different rooms of the house, and commenced observations at 7.31; and Mr. Footner, with a Casella's anemometer, to register the velocity of the air passing out of the foul-air chamber through the downcast shaft, and he commenced observations at 7.45. Mr. Fletcher entered the breakfast room with a thermometer and his own anemometer, to register the temperature and velocity of the air passing up the upcast by means of a small hole through the brickwork at *Gb*, and commenced observations at 7.48. Mr. Harrison placed himself outside at the top of the kitchen chimney, with three thermometers, to register the temperature of the issuing smoke and foul air, and commenced observations at 7.45. Mr. Higginson placed himself by the Perkins's stove, to observe the temperatures of the warming apparatus. Dr. Hayward went about the house, to take the readings of the thermometers in the central lobbies and rooms, and to superintend the lighting of the fires and gases. At the commencement there were no fires lighted, and the register grates and the chimney throats were closed. See p. 92a.

THE conditions of the house were changed at 7·30 by having the kitchen fire lighted; at 8·10 by having chimney throats opened; at 8·30 by having fires in four rooms lighted; at 9·30 by having gases also lighted, room doors shut; and at 9·40 ditto, ditto, but doors open. Observations were taken and readings recorded every three minutes; but it will be unnecessary to give them all; the following will suffice, as they show the effect of each change in the condition of the house :—

Hour A.M.	CONDITION OF HOUSE.	TEMPERATURES. Outside.	Central lobby, ground floor.	Central lobby, first floor.	Central lobby, second floor.	Central lobby, third floor.	Foul-air chamber.	Upcast 10 ft. above centre of kitchen fire.	Upcast 14 ft. ditto, ditto.	Upcast 5 ft. below outlet.	VELOCITIES. Mr. Sumners in primary inlet.	Dr. Drysdale. Flue area.	Dr. Drysdale. Ft. per min.	Mr. Footner in downcast.	Mr. Fletcher in upcast, 14 ft. above centre of kitchen fire. Area 4½ sq. ft.
		deg.	deg.	deg.	deg.	deg.	deg.	deg.	deg.	deg.					
7·30	No fires lighted	50	65	64	60	59	61	...	64	...	206				
7·45	Kitchen fire burning	...	...	...	...	...	...	60	...	61	...	A.	97	87	
7·48	,, ,, . . .	...	...	...	...	...	...	...	...	...	277	...	...	87	54
8·0	Water in boiler boiling	...	66	65	63	59	59	63	64	61	352	...	...	72	
8·3	,, ,, . . .	...	...	...	...	...	...	...	64	...	242	...	...	72	93
8·9	,, ,, . . .	...	...	...	...	...	...	...	...	65	316	...	...	72	108
8·10	,, ,, . . .	...	...	...	...	...	58	...	...	...					
8·20	Chimney throats open	...	66	65	63	59	59	64	67	61	352	A.	135	79	
8·23	,, ,, . . .	...	...	...	...	...	...	...	...	...	352	D.	122	89	126
8·32	,, ,, . . .	...	...	...	...	...	...	...	...	...	316	D.	132	...	123½
8·36	,, ,, . . .	...	...	...	...	...	...	...	...	...	316	...	...	...	108
8·45	,, ,, . . .	...	...	...	...	...	...	65	...	62	388	D.	158	100	
8·55	,, ,, . . .	...	...	...	...	...	...	64	...	62	...	A.	186	103	
9·6	,, ,, . . .	...	...	...	...	...	...	...	...	...	352	I.	387	98	96
9·12	Room fires burning, doors shut .	...	67	66	64	61	60	66	68	61	320	I.	233	86	155
9·15	,, ,, ,, .	...	...	...	...	...	...	67	...	...	354	L.	276	95	
9·17	,, ,, ,, .	...	...	...	...	...	...	...	...	...	316	I.	233	...	140½
9·20	,, ,, ,, .	...	...	...	...	...	...	...	69	...	...	D.	351	102	
9·25	,, ,, ,, .	...	...	...	...	...	...	66	...	...	388	D.	351	111	
9·30	,, ,, ,, .	...	...	...	...	...	...	...	...	...	316	A.	206	92	122
9·33	Gases (23) burning, doors shut .	...	67	66	65	63	60	68	69	64	316	B.	251	95	
9·35	,, ,, ,, .	...	...	...	...	...	...	69							
6·37	,, ,, ,, .	...	...	...	...	...	...	...	69	...	316	L.	378	...	114
9·45	Gases burning, doors open . . .	...	67	67	65	63	59	69	69	63	388	D.	476	101	
9·50	,, ,, ,, .	...	...	...	...	...	...	70							
	Average velocity										325	...	245	90	112
	Number of observations										19	...	16	17	11

Flue A. North-west bedroom.
,, B. Waiting-room.
,, C. North-west attic.
,, D. Drawing-room.
,, E. South-west attic.
,, F. Study.
,, G. South-west bedroom.
,, I. Dining-room.
,, L. South-east bedroom.

The following observations were made in the foul-air chamber also about 6 P.M., May 13, 1871, by Dr. Drysdale and Dr. Hayward; there being no one in the rooms: a good kitchen fire and the water nearly boiling :—

Observations.	A. In front of opening.	A. Across top of up-flue.	B. In front.	C. In front.	D. In front.	E. In front.	F. In front.	G. In front.	
	101 123	182	144 167 154	210 144	173 144 154	125	135 135	159 148	
No. of observations	2	1	3	2	3	1	2	2	
Average in each .	112	...	155	177	157	...	85	103	
Average of total 16 observations									137

And the following were made August 27, about 7 P.M., under similar conditions; all across up-flue :—

123 | 159 | 113 | 167 | 113 | 167 | 177

Average of 7 observations 121

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§ 15b. At the beginning of August, 1871, an opening was made into the downcast shaft at C (*v* Plan), and on the 14th a Casella's anemometer (No. 173) was placed there so as to be in the centre, and about eight feet from entrance from foul-air chamber, and twenty-eight feet above transverse or entrance to upcast shaft; on and after the 15th, the following observations were made :—

Date. Day.	Date. Hour.	Temperatures. Outside. Dry.	Outside. Wet.	Inside Lobby. Ground Floor.	Inside Lobby. Attic Floor.	Foul-Air Chamber.	Shafts. Down. 7 ft. from Entrance.	Shafts.		Wind. Direction.	Wind. Force.	Barometer.		Velocity of Air. In Downcast.
Aug		deg.	deg.	deg.	deg.	deg.	deg.	deg.	(Not given until Aug. 20.)					Ft. per min.
15	10.30 A.M.	69	62	68	76					0	0	29·9	S.	96
,,	10.30 P.M.	64	61	68	75					N.W.	Gntle.	,,	,,	128
16	7.0 A.M.	66	63	67	75					,,	,,	,,	,,	125
,,	10.30 ,,	69	61	66	75					,,	,,	,,	,,	93
,,	1.30 P.M.	*72	66	67	75	76	74			0	0	,,	,,	134
,,	6.30 ,,	69	62	67	75	76	74			0	0		,,	122
,,	10.30 ,,	64	60	66	73		74			0	0	29·8½	F.	121

* Temperatures marked with an asterisk were taken when the sun's rays were more or less falling on the thermometer. August 16 was a very hot day, sun shining on foul-air chamber, raising its temperature to 76 deg. In the evening the thermometer fell a little, and a gentle rain commenced.

Aug		deg.	deg.	deg.	deg.	deg.	deg.	deg.	deg.					Ft. per min.
17	10.0 A.M.	62	60	65	72	73	71			S.E.	Gntle.	29·8	F.	102
,,	6.45 P.M.	67	65	68	72	74	72			,,	,,	29·6	,,	44
,,	11.45 P.M.	65	64	67	72		70			,,	,,	29·4	,,	62

At 10 A.M. there was a very slight movement of the air from S.E., and a drizzling rain falling, the kitchen fire had not been lighted, and the water in the boiler was nearly cold. The wind remaining the same all day, the evening was damp and cool with occasional rain; the water in the boiler was quite cold after 1 P.M.

Aug		deg.	deg.	deg.	deg.	deg.	deg.							Ft. per min.
18	6.45 A.M.	64	63	67	72	71	70			S.E.	Gentle.	29·3	S.	69, 66, 56
,,	10.30 ,,	67	64	67	72	74	70			,,	,,	29·4	R.	66, 91, 74
,,	11.15 P.M.	60	58	66	70	72	71			N.W.	Slight breeze.	29·5	,,	134, 144, 123

At 6.45 A.M. the wind, rain, fire, and water in boiler same

as 11.45 P.M.; on the 17th, at 8 A.M., the kitchen fire was lighted, and at 10.30 A.M., water in boiler nearly boiling. It was a fine warm morning, with the sun shining on foul-air chamber.

Date.		Temperatures.							Wind.		Baro-meter.		Velocity of Air.
		Outside.		Inside Lobby.			Shafts.						In Downcast.
Day.	Hour.	Dry.	Wet.	Ground Floor.	Attic Floor.	Foul-Air Chamber.	Down. 7 ft. from Entrance.	Up.	Direction.	Force.			
	A.M.	deg.	deg.	deg.	deg.	deg.	deg.						Feet per minute
19	8.0								NWN	Slight breeze increasing.	...	...	102, 122, 122
,,	10.0	60	55	63	70	72	69		,,	,,	29·7	R.	134, 134, 125 202, 123
,,	P.M. 2.30								,,	,,		,,	116
,,	10.50	62	59	65	70	74	70		,,	Decrease.	29·9	,,	118, 122, 111, 122

Wind continued strong all forenoon with a heavy rain falling. At 10.50 P.M. wind had much abated, and it had ceased to rain; the kitchen fire was out, and the water in boiler nearly cold.

On August 20th a thermometer was inserted into the upcast to the same place as on April 22nd, G*b*, and protected from the rays of heat from the smoke flue, after which the following observations were made:

Aug	A.M.	deg.	deg.	deg.	deg.	deg.	deg.	deg.					Feet per minute.
20	10.0	60	59	65	68	71	68	72	S.	Very gentle.	29·8	F.	134, 258, 241

Kitchen fire was low and water in boiler nearly cold. Rain had been falling for four hours.

Aug	P.M.	deg	deg.	deg	deg.	deg.	deg.	deg.					Feet per minute.
20	2.55	*67	64	65	68	71	68	74	S.	Very gentle.	29·7	F.	128, 116, 124

This observation was taken one and a half hour after cooking dinner; water in boiler boiling. The day was rather cold, and the inlet valves had been closed $\frac{3}{4}$; which will account for the diminished velocity.

Date.		Temperatures.							Wind.		Barometer.		Velocity of Air.
		Outside.		Inside Lobby.			Shafts.						In Downcast
Day.	Hour.	Dry.	Wet.	Ground Floor.	Attic Floor.	Foul-Air Chamber.	Down.	Up.	Direction.	Force.			
Aug	A.M.	deg.	deg.	deg.	deg.	deg.	deg.	deg.					Feet per minute
21	8.	61	58	65	68	69	68		N.W.	Slight breeze.	29·8	R.	178, 149, 136, 138
,,	11.0	61	56	64	70		69		,,	,,	29·9	,,	104
,,	P.M. 11.50	60	57	63	68		69	74	,,	,,	30·2	,,	136, 140, 151

A fine bright cool day with sun shining. At 8 A.M. good kitchen fire, water in boiler nearly boiling.

Day.	Hour.	Dry.	Wet.	Ground Floor.	Attic Floor.	Foul-Air Chamber.	Down.	Up.	Direction.	Force.	Barometer.		In Downcast
Aug 22	A.M. 7.55	deg. 55	deg. 52	deg. 61	deg. 67	deg. 68	deg. 67	deg. 72	0	0	30·0	F.	Feet per minute 125, 124, 122, 130
,,	10.30	60	55	62	68	69	68	73	S.W.	Very gentle	30·0 scarcely	,,	111
,,	P.M. 11.50	61	57	63	68		70		,,	,,	29·8	,,	118, 119, 119

At 7.55 A.M. small kitchen fire, but water in boiler nearly boiling. At 11.50 P.M. no kitchen fire, but water hot.

Day.	Hour.	Dry.	Wet.	Ground Floor.	Attic Floor.	Foul-Air Chamber.	Down.	Up.	Direction.	Force.	Barometer.		In Downcast
Aug	A.M.	deg.	deg.	deg.	deg	deg.	deg.	deg.					Feet per minute.
23	10.15	63	57	63	70	70	69	74	S.W.	Gentle breeze	29·7	F.	125, 136, 140

At 9.0 A.M. one half of the canvas screen was fixed at I. At 10.15 A.M. moderate kitchen fire, water nearly boiling: sun shining on attic. Tried upcast thermometer turned towards smoke flue, *i.e.*, unprotected from rays of heat: did not perceive any difference.

Day.	Hour.	Dry.	Wet.	Ground Floor.	Attic Floor.	Foul-Air Chamber.	Down.	Up.	Direction.	Force.	Barometer.		In Downcast
Aug 23	P.M. 1.20					deg. 72	deg 70						Feet per minute 140

Good kitchen fire, water boiling, no sunshine, nobody in house.

Day.	Hour.	Dry.	Wet.	Ground Floor.	Attic Floor.	Foul-Air Chamber.	Down.	Up.	Direction.	Force.	Barometer.		In Downcast
Aug	P.M.	deg.	deg.	deg.	deg.		deg.						Feet per minute
23	11.50	61	59	64	68		70		S.W.	Gentle breeze.	29·7	S.	111, 114, 118, 119

No kitchen fire, water below boiling, dry, cool night.

Date.		Temperatures.							Wind.		Barometer.		Velocity of Air.
		Outside.		Inside Lobby.			Shafts.						In Downcast.
Day.	Hour.	Dry.	Wet.	Ground Floor.	Attic Floor.	Foul-Air Chamber.	Down.	Up.	Direction.	Force.			
Aug	A.M.	deg.	deg.	deg.	deg.	deg.	deg.	deg.					Feet per minute.
24	10.0	60	58	63	67	69	68	74	S.S.E.	Very gentle breeze.	29·5	F.	122, 125, 114

Poor kitchen fire, water not quite boiling, general clouds, raining heavily.

Aug	P.M.	deg.	deg.	deg.	deg.	deg.	deg.						Feet per minute.
24	1.15	*67	64	65	67	68	67		S.W.	Rather strong breeze.	29·3	F.	128, 160, 160, 157

Good fire, water boiling.

Aug	P.M.	deg.	deg.	deg.	deg.		deg.						Feet per minute.
24	11.55	60	54	64	66		67		S.E.	Strong breeze.	29.5	R.	140, 142, 122

Ceased raining during the afternoon, warming apparatus not in operation, inlet valves $\frac{4}{5}$ closed.

Aug	A.M.	deg.	deg.	deg.	deg.		deg.						Feet per minute.
25	10.10	61	55	63	66		66		S.E.	Strong breeze.	29·7	R.	119

Other half of canvas screen fixed; so that during the following observations, all the incoming air had to pass through canvas. Inlet valves open.

Day.	Hour.	Dry.	Wet.	Ground Floor.	First Floor.	Second Floor.	Attic Floor.	Foul-Air Chamber.	Down.	Up.	Direction.	Force.	Barometer		Velocity of Air.
Aug	A.M.	deg.	deg.	deg.	deg.	deg.	deg.	deg.	deg.	deg.					Feet per minute.
27	10.20	61	57	63	66	68	67	67	67		0	0	33·0	R	102, 107, 109
,,	11.55	62	60	63	66	69	68		72		0	0	30·3	R.	
28	8.48	59	57	63	66	68	68	68		72	S.S.E.	Very gentle movement.	30·4	R.	
,,	8.15	70	64	65	69	70	70		73	77	S.E.	,,	30·2	F.	

At 8.48 A.M. small fire, water only warm, morning bright, sun shining. At 8.15 P.M. very small fire, water nearly boiling.

Date.		Temperatures.									Wind.		Baro-meter.		Velocity of Air.
		Outside.		Inside Lobby.					Shafts.						
Day.	Hour.	Dry.	Wet.	Ground Floor.	First Floor.	Second Floor.	Attic Floor.	Foul-Air Chamber.	Down.	Up.	Direction.	Force.			In Downcast.
Aug	A.M.	deg.	deg.	deg.	deg.	deg.	deg.	deg.	deg.	deg.					Feet per minute.
29	8.40	61	58	64	67	70	69	70	70	74	S.E.	Very gentle movement.	30·1	F.	118, 116, 122
,,	2.20	*74	65	66	69	72	72	75	74	80	0	0	30·0	S.	

Outer air quite still, hot sunshine on foul-air chamber, fire nearly out, water below boiling. Current in downcast very irregular, sometimes very rapid for a few seconds, then very slow, then absolutely stopping a second or two, then starting off rapidly again; never really reversed. (See Aug. 30, 8.38 A.M.)

Aug	P.M.	deg.	deg.	deg.	deg.	deg.	deg.	deg.	deg.	deg.					Feet per minute.
29	4.50	76	66	67	70	70	72	76	74	80	0	0	30·0	S.	56, 78, 58

Same remarks apply to this as previous observation.

Aug	P.M.	deg.	deg.	deg.	deg.	deg.	deg.		deg.	deg.					Feet per minute.
29	11.45	64	56	66	69	72	70		72	76	W.	Very gentle movement.	30·0	S.	95, 109, 99

No kitchen fire for the last two hours, water nearly cold.

Aug	A.M.	deg.	deg.	deg.	deg.	deg.	deg.	deg.	deg.	deg.					Feet per minute.
30	8.38	63	60	65	68	70	70	71	71	75			29·9	F.	84, 102

I now found two attic windows were open, and had been during the previous day, and the current reversed, as shown by the silks hanging in foul-air chamber being occasionally driven back into the flues of said attics.

Aug	P.M.	deg.	deg.	deg.	deg.	deg.	deg.		deg.	deg.					Feet per minute.
31	11.50	64	61	66	69	72	72		73	76	S.	Very gentle movement.	29·8	F.	116, 114, 110, 114

The day had been very close and sultry, fire out for two hours, water nearly cold.

Date.		Temperatures.									Wind.		Barometer.		Velocity of Air.
		Outside.		Inside Lobby.					Shafts.						
Day.	Hour.	Dry.	Wet.	Ground Floor.	First Floor.	Second Floor.	Attic Floor.	Foul-air Chamber.	Down.	Up.					In Downcast.
Sep. 1	A.M. 8.50	deg. 63	deg. 60	deg. 65	deg. 69	deg. 72	deg. 72	deg. 72	deg. 72	deg. 76	0	0	29·9	R.	Ft. per min. 93, 105, 104

A very sunny hot morning, outer air quite still, fire just lighted, water lukewarm.

Sep. 2	A.M. 11.50	deg. 62	deg. 57	deg. 64	deg. 67	deg. 70	deg. 77		deg. 71	deg. 77	0	0	29·8	F.	Ft. per min. 121, 125, 125

No fire, water nearly cold.

Sep. 3	A.M. 8.10	deg. 60	deg. 56	deg. 63	deg. 67	deg. 69	deg. 69	deg. 70	deg. 70	deg. 72	S.W.	Very gentle movement.	29·7	F.	Ft. per min. 111, 114, 119, 109

Fire only just lighted, water cold.

Sep. 3	P.M. 11.20	deg. 62	deg. 61	deg. 64	deg. 66	deg. 69	deg. 68			deg. 75	S.	do.	29·6	do.	Ft. per min. 105, 102 105

A damp cloudy night, no fire, but water nearly boiling.

Sep. 4	A.M. 10.30	deg. 59	deg. 58	deg. 64	deg. 67	deg. 68	deg. 68	deg. 68	deg. 68	deg. 72	S.	do.	29·6	S.	Ft. per min. 107, 115

Small fire, water hot, heavy rain all morning.

Sep. 4	P.M. 11.15	deg. 59	deg. 56	deg. 63	deg. 65	deg. 67	deg. 67		deg. 68	deg. 73	S.W.	do.	29·8	R.	Ft. per min. 125, 134, 138, 124

Fire very low, water below boiling, fine afternoon and evening; now just beginning to rain, very little wind, slight increase to-night.

DATE.		TEMPERATURES.									WIND.		BAROMETER.		VELOCITY OF AIR.
		Outside.		Inside Lobby.					Shafts.						
Day.	Hour.	Dry.	Wet.	Ground Floor.	First Floor.	Second Floor.	Attic Floor.	Foul-air Chamber.	Down.	Up.					In Down-cast.
Sep.	A.M.	deg.	deg.	deg.	deg.	deg.	deg.	deg.	deg.	deg.					Ft. per min.
5	10.0	60	56	62	63	66	67	67	68	70	N.W.	Very gentle breeze.	29·9	R.	105, 114, 108

Very low fire, water below boiling, fine morning.

Sep.	P.M.	deg.	deg.	deg.	deg.	deg.	deg.		deg.	deg.					Ft. per min.
5	10.40	60	56	63	65	66	67		68	72	0	0	30·0	R.	115, 119, 119, 116

A fine cool night, fire very low, water below boiling, twenty-one persons in house.

Sep.	A.M.	deg.	deg.	deg.	deg.	deg.	deg.	deg.	deg.	deg.					Ft. per. min.
6	10.45	61	56	62	64	68	68	68	67	73	S.W.	Very gentle movement.	29·9	F.	115, 115, 111

Fire low, water below boiling.

Sep.	P.M	deg.	deg.	deg.	deg.	deg.	deg.	deg.	deg.	deg.					Ft. per min.
7	3.20	*63	60	62	65	69	69	72	70	74	S.W.	Very gentle movement.	29·8	F.	106, 108

Been a wet night, now alternate cloud and sunshine.

Sep.	P.M.	deg.	deg.	deg.											Ft. per min.
9	1.40	*62	59	64							S.E.	Gentle breeze.	29·5	R.	105, 101

Rather good fire, water boiling.

Date.		Temperatures.									Wind.		Barometer.		Velocity of Air.
		Outside.		Inside Lobby.					Shafts.						
Day.	Hour.	Dry.	Wet.	Ground Floor.	First Floor.	Second Floor.	Attic Floor.	Foul-air Chamber.	Down.	Up.					In Down-cast.
Sep.	P.M.	deg.	deg.	deg.	deg.	deg.	deg.	deg.	deg.	deg.					Ft. per min.
10	1.40	*70	61	64	66	68	68	...	...	80	S.E.	Very slight breeze in gusts.	29·7	S.	

Tolerably good fire, and water boiling. Sometimes anemometer moved rapidly, then slackened, and actually stopped for a few seconds, and occasionally indicated a return current for a few seconds; then rapidly revolved again, and so on, as though the strong south-east wind, in gusts, did sometimes really overcome the suction power.

Sep.	P.M.	deg.	deg.	deg.	deg.	deg.	deg.		deg.	deg.					
10	11.30	62	60	64	67	68	66		67	74	S.E.	Ditto.	29·8	R.	

Same remarks apply to this as previous observation, except that there was no reverse current, though fire was out and water below boiling.

Sep.	P.M.	deg.	deg.	deg.	deg.	deg.	deg.	deg.	deg	deg					Ft. per min.
11	5.30	*70	65	67	68	71	72	74	72	78	0	0	30·0	R.	79, 90, 70

During the day, workmen had been at the warming apparatus. At 6 P.M. the house was warm throughout; ground-floor lobby being 69°, first floor 69°, second floor 71°, and stove flow-pipe 235°, and return 168°.

Sep.	A.M.	deg.	deg.	deg.	deg.	deg.	deg.	deg.	deg.	deg.					Ft. per min.
13	8.40	58	56	63	66	68	68	68	67	73	N.E.	very gentle breeze.	30·2	R.	128, 126, 136. 130

A cool bracing morning, fire just lighted, water below boiling.

Date.		Temperatures.									Wind.		Barometer.		Velocity of Air.
		Outside.		Inside Lobby.					Shafts.						
Day.	Hour.	Dry.	Wet.	Ground Floor.	First Floor.	Second Floor.	Attic Floor.	Foul-air Chamber.	Down.	Up.					In Down-cast.
Sep.	P.M.	deg.	deg.	deg.	deg.	deg.	deg.	deg.	deg.	deg.					Ft. per min.
13	1.25	*64	58	68	69	71	74	70	69	75	N.E.	...	...	...	102
15	11.40	60	57	63	66	67	66	...	66	70	E.S.E.	Gentle breeze.	30·2	S.	119, 119, 118, 118, 113

No fire, water below boiling.

Sep.	P.M.	deg.	deg.	deg.	deg.	deg.	deg.		deg.	deg.					Ft. per min.
16	11.50	60	57	63	66	68	66		67	72	do.	do.	30·2½	R.	113, 115, 118, 118

No fire, water nearly cold.

Sep.	P.M.	deg.	deg.	deg.	deg.	deg.	deg.		deg.	deg.					Ft. per min.
17	11.50	54	51	60	63	66	64		64	70	E.N.E.	Gentle movement.	30·1¾	F.	130, 125, 132, 126

No fire, water below boiling.

Sep.	A.M.	deg.	deg.	deg.	deg.	deg.	deg.	deg.	deg.	deg.					Ft. per min.
18	8.0	52	49	58	62	64	64	63	63	68	do.	do.	30·1	F.	301, 214, 193, 208

Tolerably good red fire, water nearly boiling.

Sep.	P.M.	deg.	deg.	deg.	deg.	deg.	deg.	deg.	deg.	deg.					Ft. per min.
19	3.40	*56	53	58	...	...	...	...	63	70	...	...	...	...	109
,,	11.50	51	49	64	63	64	65	...	62	68	E.S.E.	Gentle movement.	29·9	F.	140, 144, 146, 149

Being a very cold day (wind being E.N.E.), and one of the children having bronchitis, inlet valves were nearly closed at 9 A.M., ground-floor lobby being 58°. At 8 P.M. stove was lighted and valves opened ¼. At 11.40 P.M., valves were opened to the full. At 11.50 flow-pipe 210°, return 130°. At this time no kitchen fire, water below boiling.

Date.		Temperatures.									Wind.		Barometer.		Stove.		Velocity of Air.
		Outside.		Inside Lobby.					Shafts.								
Day.	Hour.	Dry.	Wet.	Ground Floor.	First Floor.	Second Floor.	Attic Floor.	Foul-air Chamber.	Down.	Up.							In Down-cast.
Sep.	A.M.	deg.	deg.	deg.	deg.	deg.	deg.	deg.	deg.	deg.							Ft. per min.
21	10.5	54	50	61	64	65	65	64	63	68	S.W.	Gentle movement.	29·5	F.	...	...	132, 138, 138.
„	P.M. 1.15	*55	51	60	63	64	64	64	64	68	W.N.W.	Gentle breeze.	29·5	S. but inclined to F.	...	...	136, 128, 125

Moderately good red fire; water boiling; no fire in house proper; stove not lighted.

Sep.	P.M.	deg.	deg.	deg.	deg.	deg.	deg.		deg.	deg.							Ft. per min.
21	11.50	52	49	63	64	65	66		63	68	do.	Gentle movement.	29·4½	F.	...	...	134, 134, 140

Stove lighted at 11 P.M. At 11.50 flow-pipe 190°, return 90°. A little red fire at bottom of grate; water nearly boiling; been raining since 7 P.M.

Sep.	A.M.	deg.	deg.	deg.	deg	.deg.	deg.	deg.	deg.	deg.							Ft. per min.
22	7.55	53	48	60	62	64	65	60	61	67	N.W.	Sharp breeze in gusts.	29·5	R.	...	...	138, 154, 180, 144

Kitchen fire just lighted (chimney having been swept at 6.30 A.M.); dull coal fire, water below boiling; stove flow-pipe 160°, return 80°. It was noticed that the stronger the gust of wind, the slower the revolution of the anemometer.

Date. Day.	Date. Hour.	Temperatures. Outside. Dry.	Outside. Wet.	Inside Lobby. Ground Floor.	Inside Lobby. First Floor.	Inside Lobby. Second Floor.	Inside Lobby. Attic Floor.	Inside Lobby. Foul-air Chamber.	Shafts. Down.	Shafts. Up.	Wind.		Barometer.		Stove.		Velocity of Air. In Down-cast.
Sep.	A.M.	deg.	deg.	deg.	deg.	deg.	deg.	deg.	deg.	deg.							Ft. per min.
22	1.30	*57	50	63	65	68	69	64	64	72	N.W.	Sharp breeze in gusts.	29·6	R.	...	...	198, 163, 169, 142

Small red fire, water boiling. Stove flow-pipe 170°, return 80°.

Day.	Hour.	Dry.	Wet.	Ground Floor.	First Floor.	Second Floor.	Attic Floor.	Foul-air Chamber.	Down.	Up.	Wind.		Barometer.		Stove.		In Down-cast.
Sep.	A.M.						deg.		deg.	deg.							Ft. per min.
23	8.0									69	N.W.	Gentle movement.	29·6	S.			
,,	P.M.																
,,	1.30						72	...	66	76	do.	do.	29·5	F.	...	...	140

Good red fire; water boiling.

Day.	Hour.	Dry.	Wet.	Ground Floor.	First Floor.	Second Floor.	Attic Floor.	Foul-air Chamber.	Down.	Up.	Wind.		Barometer.		Stove.		In Down-cast.
Sep. 24	P.M. 1.15	deg.	deg.	deg.	deg.	deg.	deg.	deg.	deg.	deg. 72			29·4	F.			Ft. per min.
,,	1.25	*51	48	65	66	66	70	63	63	72	W.	Gentle breeze.	29·4	S.	...	...	178, 180, 277, 315, 163, 169
,,	11.35	50	49	68	63	68	68	...	64	70	W.	Gentle breeze.	29·6 nearly	F.	...	...	125, 130, 126, 136, 134, 134, 138

At 1.15 P.M. good red kitchen fire for cooking, and water boiling. At 11.35 no fire, water below boiling. At 1.15 P.M., on examination of maximum registering thermometer, which had been hanging down the upcast shaft, seven feet above kitchen fire, for the last two months, it was found to register 87°. Heavy rain all day up to 4 P.M. At 1 P.M. stove flow-pipe 228°, return 112°. Drawing-room, waiting-room, and study outlet-valves closed all day. At 2.30 P.M. Casella's anemometer indicated 540 feet per minute velocity in primary inlet.

Date.		Temperatures.										Wind.		Barometer.		Stove.		Velocity of Air.
		Outside.		Inside Lobby.					Shafts.									
Day.	Hour.	Dry.	Wet.	Ground Floor.	First Floor.	Second Floor.	Attic Floor.	Foul-air Chamber.	Down.	Up.								In Down-cast.
Sep.	A.M.	deg.	deg.	deg.	deg.	deg.	deg.	deg.	deg.	deg.								Ft. per min.
25	8.30	47	45	60	63	64	67	62	61	70	S.S.E.	Very gentle movement.	29·6	R.	...	...	140, 140, 138, 140

Small, bright, red fire; water boiling; stove flow-pipe 216°, return 80°; fine dry morning, cool, but sun shining.

Day.	Hour.	Dry.	Wet.	Ground Floor.	First Floor.	Second Floor.	Attic Floor.	Foul-air Chamber.	Down.	Up.	Wind.		Barometer.		Stove.		Velocity of Air.
Oct.	P.M.	deg.	deg.	deg.	deg.	deg.	deg.	deg.	deg.	deg.							Ft. per min.
8	4.30	*54	49	60	61	65	67	...	64	72	N.W.	Gentle breeze.	29·8	R.	...	...	134, 132, 122, 122, 128, 122 with canvas.
,,	4.50	,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	126, 128, 149, 140, 151, 130 without canvas.

Good fire, water nearly boiling; stove flow-pipe 200°, return 110°. It would thus appear that the presence of the canvas causes a slight diminution in the velocity.

Day.	Hour.	Dry.	Wet.	Ground Floor.	First Floor.	Second Floor.	Attic Floor.	Foul-air Chamber.	Down.	Up.	Wind.		Barometer.		Stove.		Velocity of Air.
Oct.	A.M.	deg.	deg.	deg.	deg.	deg.	deg.	deg.	deg.	deg.					flow	return	Ft. per min.
10	9.35	46	44	60	61	63	65	59	59	65	S.E.	Gentle breeze.	30·3	,,	190	78	347, 347, 301, 347, 331, 331, 315

Good dull fire, water boiling.

An opening was now made into upcast shaft at G*b*, and the anemometer and thermometer (maximum and minimum) fixed in narrowest part, about twenty-seven feet above kitchen fire, in locality of average temperature and current, after which the ollo wing observations were made:—

Date.		Temperatures.								Wind.		Barometer.		Stove.		Velocity of Air	
		Outside.		Inside Lobby.				Shafts.									
Day.	Hour.	Dry.	Wet.	Ground Floor.	First Floor.	Second Floor.	Attic Floor.	Down.	Up.					Flow.	Return.	In Downcast.	In Upcast.
Oct.	P.M.	deg.	deg.	deg.	deg.	deg.	deg.	deg.	deg.							Feet per minute.	Feet per minute.
20	11.35	49	45	58	62	63	62	62	69 {had been up to 72.	N.W.	...	29·8	R.	...	... {	132, 132, 138, 151	347, 241, 234, 287, 202
21	A.M. 7.40	...	...	...	...	...	...	...		...	...	...	...	...	...	124	214

Up to this time, the outside thermometer had been so placed that the sun shone a little on it from about noon to about 4.30 P.M. (See Remark, August 16.) It was now (October 22) placed quite in shade, and the following observations made :—

Oct.	P.M.	deg.	deg.	deg.	deg.	deg.	deg.	deg.	deg.			inches				Feet per minute.	Feet per minute.
22	11.30	49	48	56	62	63	61	61	66 {had been up to 71.	S.W.	{Gentle movement.}	30·1½	R.	0	0 {	130, 126, 128, 122	220, 289, 208, 220, 214

No fire, water below boiling. About 3.10 P.M. upcast anemometer tried in different positions, to make certain mean current. Fifteen observations were taken consecutively in ten minutes; total register, 1500 feet. The same anemometer was then taken to primary inlet, and fixed for six minutes at a time in several of the openings, registering 175, 175, 176, 174 feet per minute.

Oct.	A.M.	deg.	deg.	deg.	deg.	deg.	deg.	deg.	deg.							Feet per minute.	Feet per minute.
23	8.40	46	46	56	62	61	60	60	64	S.W.	{Gentle movement.}	30·1	F.	0	0 {	125, 126, 122	241, 220, 226

Good fire, water boiling.

Date. Day.	Date. Hour.	Temperatures. Outside. Dry.	Temperatures. Outside. Wet.	Temperatures. Inside Lobby. Ground Floor.	Temperatures. Inside Lobby. First Floor.	Temperatures. Inside Lobby. Second Floor.	Temperatures. Inside Lobby. Attic Floor.	Temperatures. Shafts. Down.	Temperatures. Shafts. Up.	Wind.		Barometer.		Stove. Flow.	Stove. Return.	Velocity of Air. In Downcast.	Velocity of Air. In Upcast.
Oct.	A.M.	deg.	deg.	deg.	deg.	deg.	deg.	deg.	deg.							Feet per minute.	Feet per minute.
24	9.40	52	51	59	62	63	64	61	68	S.	Gentle movement.	30·0	F.	134	65	106, 108, 115	214, 193, 169

Good smoking fire, water boiling.

Day.	Hour.	Dry.	Wet.	Ground Floor.	First Floor.	Second Floor.	Attic Floor.	Down.	Up.	Wind.		Barometer.		Flow.	Return.	In Downcast.	In Upcast.
Nov	A.M.	deg.	deg.	deg.	deg.	deg.	deg.	deg.	deg.							Feet per minute.	Feet per minute.
4	9.45	45	44	50	60	59	56	54	65	N.	Gentle movement.	30·1	R.	0	0	111, 106, 111	188, 160, 173, 198

Good red fire, water boiling; fine, dry, cool morning; study, waiting-room, and dining-room each having a small fire.

Day.	Hour.	Dry.	Wet.	Ground Floor.	First Floor.	Second Floor.	Attic Floor.	Down.	Up.	Wind.		Barometer.		Flow.	Return.	In Downcast.	In Upcast.
Nov	A.M.	deg.	deg.	deg.	deg.	deg.	deg.	deg.	deg.							Feet per minute.	Feet per minute.
5	11.30	46	42	57	61	61	58	55	67	E.	Gentle breeze in gusts.	30·1	S.	170	90	114, 96 96	140, 202, 146, 142

Good blazing kitchen fire, water boiling; no fire in house proper; bright clear morning, sun shining into bedroom and attic lobbies.

Day.	Hour.	Dry.	Wet.	Ground Floor.	First Floor.	Second Floor.	Attic Floor.	Down.	Up.	Wind.		Barometer.		Flow.	Return.	In Downcast.	In Upcast.
Nov	A.M.	deg.	deg.	deg.	deg.	deg.	deg.	deg.	deg.							Feet per minute	Feet per minute.
9	9.45	44	41	50	60	57	54	55	65	NNW.	Gentle movement.	29·5	R.	0	0	121, 115, 128	193, 220 301, 258

Good smoking kitchen fire; water not quite boiling; small fire in breakfast-room; three small fires in house proper; sharp hail showers.

Date.		Temperatures.								Wind.		Barometer.		Stove.		Velocity of Air.	
		Outside.		Inside Lobby.				Shafts.									
Day.	Hour.	Dry.	Wet.	Ground Floor.	First Floor.	Second Floor.	Attic Floor.	Down.	Up.					Flow.	Return.	In Downcast.	In Upcast.
Nov	P.M.	deg.	deg.	deg.	deg.	deg.	deg.	deg.	deg.							Feet per minute.	Feet per minute.
9	1.0	44	42	58	61	59	...	55	66	N.W.	Sharp breeze in gusts.	29·6	R.	204	130	144, 154, 144, 151	315, 258, 315, 315, 289

Good kitchen fire for cooking, small fire in dining-room and breakfast-room; stove fire had been lighted about an hour; all the room doors open.

Nov	P.M.	deg.	deg.	deg.	deg.	deg.	deg.	deg.	deg.							Feet per minute.	Feet per minute.
9	1.24	...	...	...	...	...	...	...	...	...	...	...	...	...	...	125, 125, 144, 134	258, 249, 315, 289, 268

Same remarks apply to this observation as above, except that the room doors were shut. It will thus appear that the room doors being open gives a slight increase in the velocity.

Nov	P.M.	deg.	deg.	deg.	deg.	deg.	deg.									Feet per minute.	Feet per minute.
13	2.0	40	38	54	61	59	57										
,,	4.30	43	42	64	64	61	56	55	66	S.E.	Gentle movement.	30·1	S.	316	224	134, 125, 122, 124	241, 241, 268, 258

Stove was not lighted until 2 P.M., and its door only half open up to 4.30 P.M.; inlet valves open to full; no fire on ground floor; one room door open; one small fire on first floor, and one room door open; no fire on second floor; three doors open; two doors open on attic floor; good kitchen fire, water nearly boiling; twenty persons in house.

Date.		Temperatures.								Wind.		Barometer.		Stove.		Velocity of Air	
		Outside.		Inside Lobby.				Shafts.									
Day.	Hour.	Dry.	Wet.	Ground Floor.	First Floor.	Second Floor.	Attic Floor.	Down.	Up.					Flow.	Return.	In Downcast.	In Upcast.
Nov	NOON.	deg.	deg.	deg.	deg.	deg.	deg.	deg.	deg.							Feet per minute.	Feet per minute.
19	12.0	39	37	52	60	57	53	50	62	S.E.E.	Gentle breeze.	30·2	R.	180	80	125, 132, 125, 125, 122, 118	220, 208, 234, 234, 220, 208, with all room doors open.
"	"	...	...	...	...	...	...	...	...	...	...	...	...	...	...	132, 140 130, 125, 125, 126	277, 249, 249, 234, 258, 234, with all room doors shut.

At 12 noon, there being a good, large, blazing kitchen fire, made up for cooking, and the water boiling. A thermometer was suspended in the beginning of kitchen smoke flue, five feet above fire: it showed a temperature of 230°. It was then taken outside, and hung down into smoke flue eleven feet from outlet, where it showed a temperature of 195°, the flue being pretty clear of soot. At same time, thermometer in upcast, seven feet above fireplace, showed 55°; at seven feet below, anemometer 63°; on a level with anemometer, 64° (downcast having got up to 51°); and at four feet below ultimate outlet (opposite that in smoke flue at 195°), it showed 55°. At this time, no fire was burning in the house proper, except very small and low in dining-room; no fire in breakfast-room. At 2 P.M., six fires were lighted in house proper, two requiring 800 cubic feet of air each per minute (dining-room and drawing-room), and four, each requiring 600 cubic feet air per minute (waiting-room, study, and two bedrooms). At 3 P.M., the following observations were taken:—

Date.		Temperatures.								Wind.		Barometer.		Stove.		Velocity of Air.	
		Outside.		Inside Lobby.				Shafts.									
Day.	Hour.	Dry.	Wet.	Ground Floor.	First Floor.	Second Floor.	Attic Floor.	Down.	Up.					Flow.	Return.	In Downcast.	In Upcast.
Nov	P.M.	deg.	deg.	deg.	deg.	deg.	deg.	deg.	deg.							Feet per minute.	Feet per minute.
19	3.0	40	39	58	61	58	54	51	63	S.E.E.	Gentle breeze.	30·2	S.	228	170	132, 140, 130, 125, 125, 126	277, 249, 249, 234, 258, 234, all room doors shut, & six fires burning
Dec. 4	8.15	32	30	64	64	...	...	...	...	N.NE.	Gentle movemnt.	30·2	R.	250	170		
,,	8.30	...	...	61	...	...	...	...	...	...	...	...	...	230	160		
,,	8.45	...	...	61	...	...	...	...	...	...	...	...	...	240	158		
,,	9.0	...	...	60	64	59	54	50	60	...	...	...	...	...	...	122, 134, 125, 125	226, 226, 220, 234.
,,	9.15	...	...	...	...	...	...	...	...	...	...	...	...	260	170		
,,	10.0	...	...	60	...	...	...	...	...	...	...	...	...	288	188		
,,	10.3	...	...	62	...	...	...	...	...	...	...	...	...	296	196		

December 3 and 4 were cold, frosty days. There were very few persons in the house. Inlet valves one-third open, stove door one-eighth open; small bright stove fire. At 8.20 P.M., stove fire was raked out, and re-lighted with 26 lbs. of coke; stove door and inlet valves fully opened. By 8.30 stove flow-pipe was 230°, return 160°; ground-floor lobby 61° (dining-room, on first floor, and study, on ground floor, each a very small fire); dining-room 64°. At 9 P.M., ground-floor lobby 60°, first floor 63½°, second floor 59°, attic floor 54°, downcast 50°, upcast 60; moderate kitchen fire, with water boiling. At 9.15 P.M., stove 260° and 170°, 14 lbs. more coke added. At 10 P.M., stove 288°, 188°; ground-floor lobby, 60°. At 10.3 P.M., another 14 lbs. coke added; stove 296°, 196°; ground-floor lobby, 62°.

Date.		Temperatures.								Wind.		Barometer.		Stove.		Velocity of Air.	
		Outside.		Inside Lobby.				Shafts.									
Day.	Hour.	Dry.	Wet.	Ground Floor.	First Floor.	Second Floor.	Attic Floor.	Down.	Up					Flow.	Return.	In Downcast.	In Upcast.
Dec	P.M.															Feet per minute.	Feet per minute.
4	11.0	32	30	62	64	61	55	50	60	...	...	...	...	298	198	116, 118, 113	234, 258, 234, 241, all room doors *open*, 16 gases lighted, kitchen fire nearly out, water below boiling.
"	"	...	...	...	...	...	...	...	...	...	...	...	...	..	...	122, 121, 124, 128	249, 258, 249, 249, all doors *shut*; same gases, &c

Dining-room, 64°; door open, fire nearly out, six gases; drawing-room 52°, no fire, door open, eight gases lighted five minutes; large windows, blinds up.

Day.	Hour.	Dry.	Wet.	Ground Floor.	First Floor.	Second Floor.	Attic Floor.	Down.	Up	Wind.		Barometer.		Flow.	Return.	In Downcast.	In Upcast.
Dec	P.M.			deg.	deg.	deg.	deg.	deg.	deg.							Feet per minute.	Feet per minute.
4	11.45	...	...	62	64	62	55	...	...	...	...	...	...	288	194	125, 122, 122,	258, 249, 268, 241, all room doors *open*, & gases out 15 minutes
"	"	...	...	"	"	"	"	...	...	...	...	...	...	"	"	124, 124, 124, 122, 124	188, 234, 258, 249, 258, 249, all doors *shut*; gases out.
7	10.30	32	30	66	66	65	64	52	61	N.NE.	Gentle breeze.	30·3	S.	294	196		

Inlet valves only two-thirds open; freezing; skating going on.

Date.		Temperatures.								Wind.		Barometer.		Stove.		Velocity of Air.	
		Outside.		Inside Lobby.				Shafts.									
Day.	Hour.	Dry.	Wet.	Ground Floor.	First Floor.	Second Floor.	Attic Floor.	Down.	Up.					Flow.	Return.	In Downcast.	In Upcast.
Dec	A.M.	deg.	deg.	deg.	deg.	deg.	deg.	deg.	deg.								
8	10.45	32	30	68	68	66	62	53	62	NN.E	Gentle breeze.	30.2	F.	294	198		

Inlet valves only half-open; freezing; skating going on.

Day.	Hour.	Dry.	Wet.	Ground Floor.	First Floor.	Second Floor.	Attic Floor.	Down.	Up.	Wind.		Barometer.		Flow.	Return.	In Downcast.	In Upcast.
Dec	P.M.	deg.	deg.	deg.	deg.	deg.	deg.	deg.	deg.								
13	3.0	47	46	54	59	57	54	...	54	W.	Gentle movemnt.	30·2	S.				
,,	5.0	...	...	52	58	57	54										
,,	10.0	...	...	68	68	65	63	63	...	...	...	...	...	300	196		
,,	11.0	...	...	70	70	66	64	...	...	...	...	...	..	310	200		

The day not being cold, stove fire was not lighted after going out the previous evening; few persons in the house; drizzling rain all day, with fog; inlet valves one-fourth open. At 3 P.M. opened valves to full; at 5 P.M. ground-floor lobby 2°, and first floor 1° cooler. Stove lighted at 7.40 P.M.: at 8.0 flow-pipe 208, return 100; inlet valves opened one-half. At 10.0 temperature increased as indicated; valves closed to one-fourth; at 11.0 house very hot, but not close.

Warming Apparatus.

§ 16. There are two kinds of warming apparatus—the low and the high pressure systems.

The *low-pressure* system consists of a boiler with pipes, from one to four inches diameter, and a supplying cistern. In the best arrangements, coils of pipe, about two inches diameter, are placed where the warmth is required; and smaller pipes are used to carry the water from the boiler to the coils. A large size and great length of pipe are rendered necessary by the fact that the water cannot be raised much above 200°, and indeed very seldom up to that. From the size and length of the pipe the apparatus is bulky and unsightly, and the heat cannot be well distributed along different lobbies. In consequence of the large mass of water and slow circulation, it is a long time in getting up the heat, but the heat once up it is maintained for a long time after the stove fire goes out, which indeed it is very apt to do in the night. The fire may be fed with either coal, slack, or coke, and requires attendance about three or four times in twenty-four hours. The total primary cost for such a house as we have supposed would be about 60*l.*, and the permanent expense about 6d. for every twenty-four hours the apparatus is kept at *full* work ; of course, for smaller houses, the cost and expense would be less.

The *high-pressure* system consists of a continuous circle of pipe, one inch in diameter; one part of the circle is formed into a small coil and placed within a stove, the other part is distributed throughout the house or lobbies: the top pipe of the small coil is continued up to the highest part where the heat is required, and then brought down to the stove again, making on its way any number of bends, twists, or coils, in any place where warming is required. There is no supply cistern, but the pipes are filled full of cold water and then screwed up, and they thus form a continuous circle of pipe filled with water, one part of the circle being within the stove, and the other within the house or lobbies. The fire is lighted within the small coil in the stove; this heats the water in the small coil and causes it to rise, which it does up to the highest part of the circle, and being pushed on returns to the stove, thus forming a circulation of hot water through the whole of the pipes—through the stove and through the house. Of course, the water becomes expanded by the heat: this is provided for by placing in connexion with the highest part of the circle what is called an expansion tube; *i.e.*, a tube into which the water may expand as it becomes heated : this expansion tube is so proportioned as to prevent any undue pressure on the pipes, and so prevent any risk of bursting. A further provision is made against undue pressure, and all possibility of explosion prevented by so proportioning the coil within the stove to the coil radiating the heat (*i.e.*, 10 feet to

100 feet), as to prevent all possibility of raising the temperature above 400°, which is equal to a pressure of 212 lbs. on the square inch, whilst the pipes are made to bear, and are tested with, a pressure of 5600 lbs. on the square inch. The pipes are small and neat, and may be distributed throughout the house anywhere, and even placed altogether out of sight; and as they can be raised to a very high temperature—300° to 400°—they radiate an immense amount of heat. This apparatus gets up the heat very quickly, but it also cools rapidly after the stove fire goes out, which, however, it very seldom does if properly attended to; and thus the heat can be maintained constantly. It does, however, happen sometimes, even in cold weather, that the pipes require the addition of a little water, and then the stove must be let out, and the pipes allowed to become cold. Coke only is used for the fire, which requires attendance only two, three, or at most four times in twenty-four hours. The total primary cost for such a house as we have supposed would be about 40*l.*, and the permanent expense about 4¾d. for every twenty-four hours the apparatus is kept at *full* work—110 lbs. of coke, the average price of which is 8s. per ton. (See Observation, December 4). Of course, for smaller houses, the cost and expense would be less.

Both apparatus are perfectly safe; as safe at least as an ordinary kitchen boiler. The only risk connected with either is, that if the fire be allowed to go out in frosty weather, the water in the pipes may freeze, and if the fire be then lighted steam will form, and, in the high-pressure system, may burst the coil within the stove and put the fire out. This is, however, the only danger connected with this apparatus.

Perhaps the low-pressure system is preferable in places at a distance from large towns; because an ordinary ironmonger can attend to any accident or necessary repairs; also in small houses, or where the warming is required only in one lobby or hall. The high-pressure system is perhaps to be preferred in large establishments, or where there are several lobbies to be warmed. Only properly experienced workmen can attend to any repairs required.

Cast-iron Smoke Flues.

§ 17. Cast-iron smoke flues of fifteen inches diameter are made by iron-founders in nine feet lengths, about four or five-eighths of an inch thick, and are charged from 42s. to 50s. per length. The ordinary fifteen inch diameter gas mains have perhaps better fitting joints, and are about the same thickness, length, and price.

THE END

LONDON
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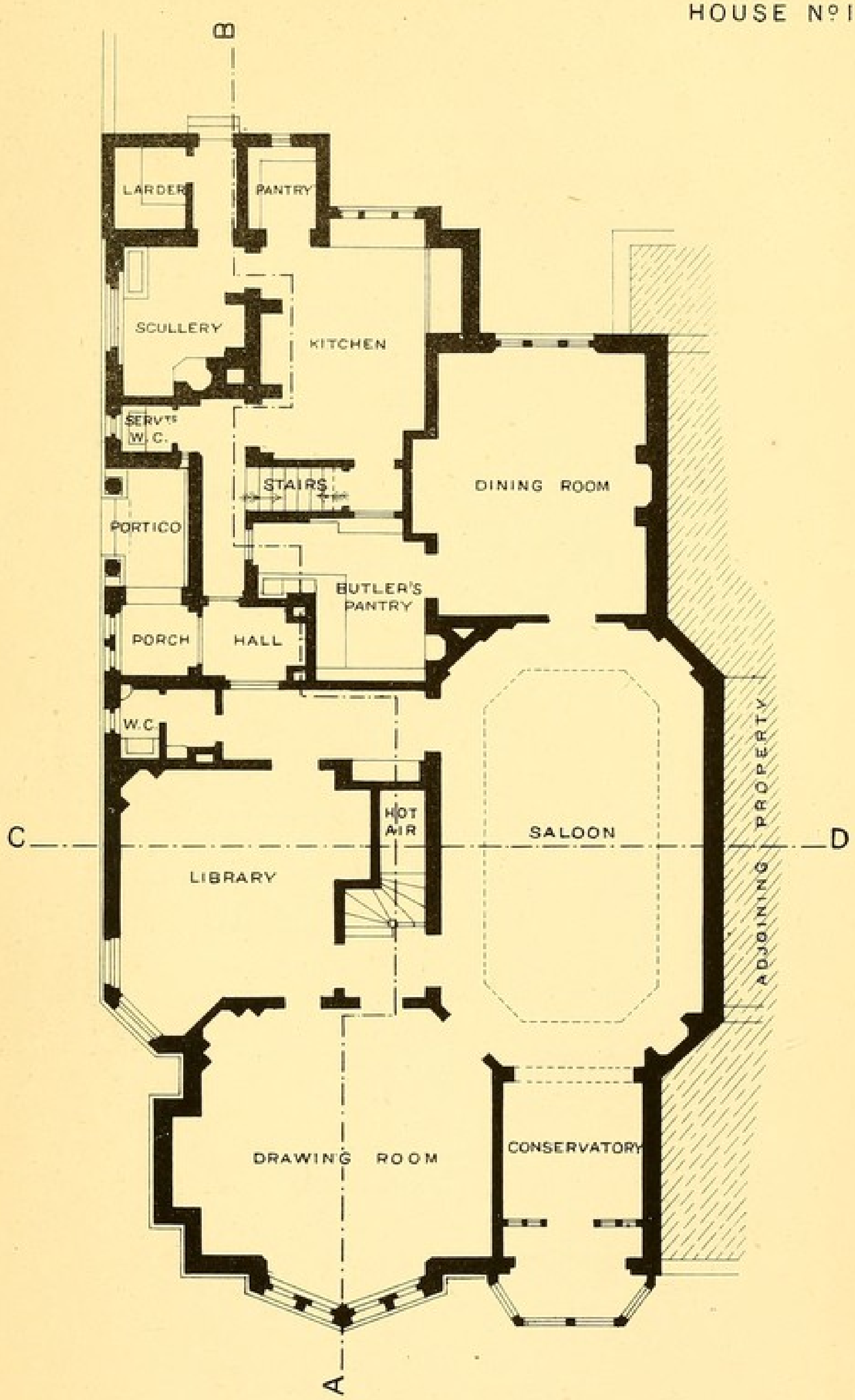
HOUSE No. I.



GROUND PLAN

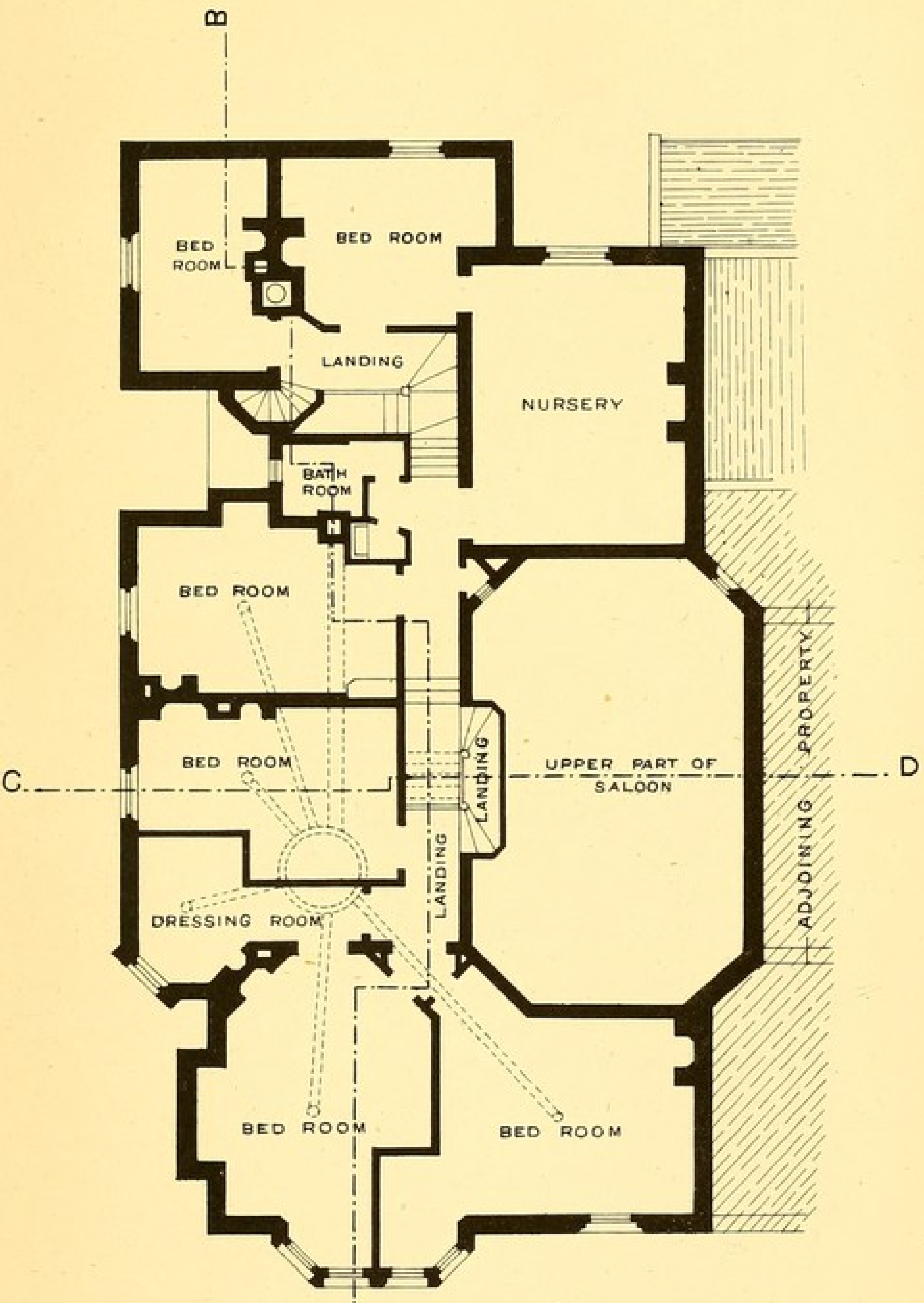
10 5 0 10 20 30 Feet

HENRY SUMNERS, ARCHT

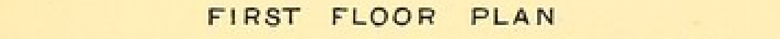
KELL BROS. LITH.

London - E & F. N. Spon, 48, Charing Cross

HOUSE No. 1.



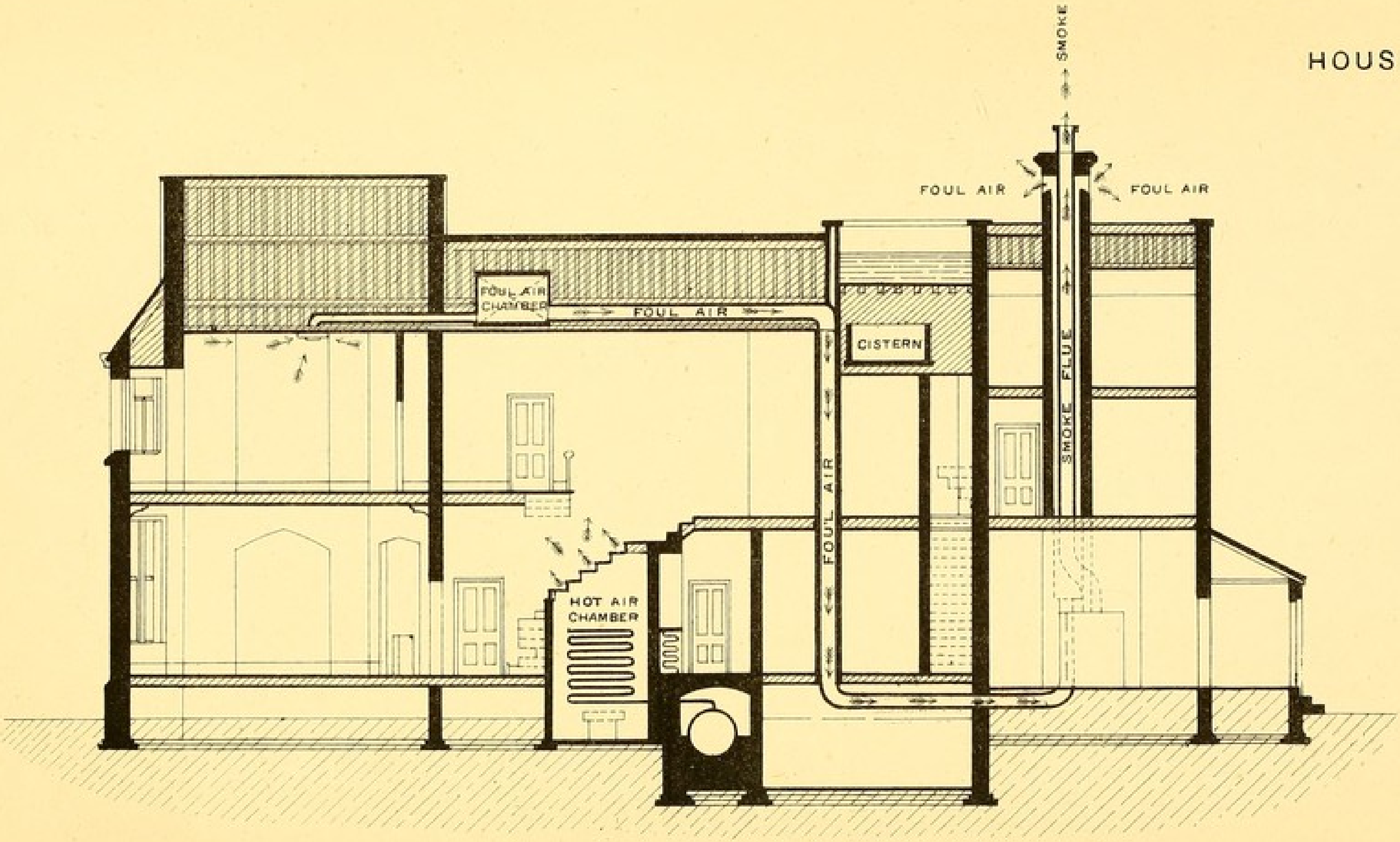
FIRST FLOOR PLAN



KELL BROS. LITH.

London - E & F. N. Spon, 48, Charing Cross.

HOUSE No. 1



SECTION ON THE LINE A. B.

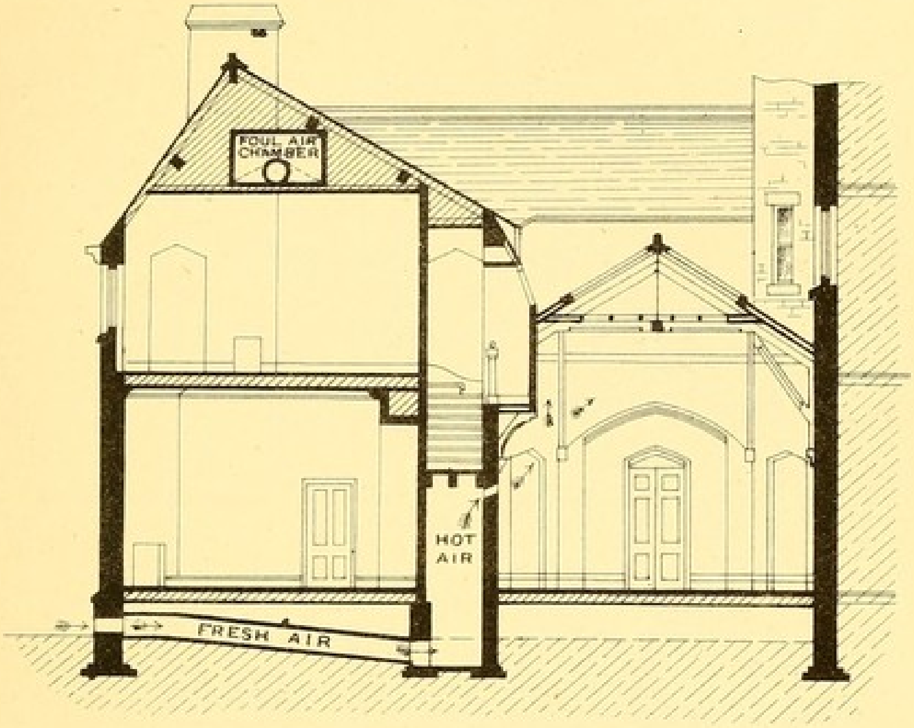
10 5 0 10 20 30 Feet

HENRY SUMNERS, ARCHT

KELL BROS. LITH.

London: E. & F. N. Spon, 48, Charing Cross

HOUSE No. 1.



SECTION ON THE LINE C.D.

10 5 0 10 20 30 Feet

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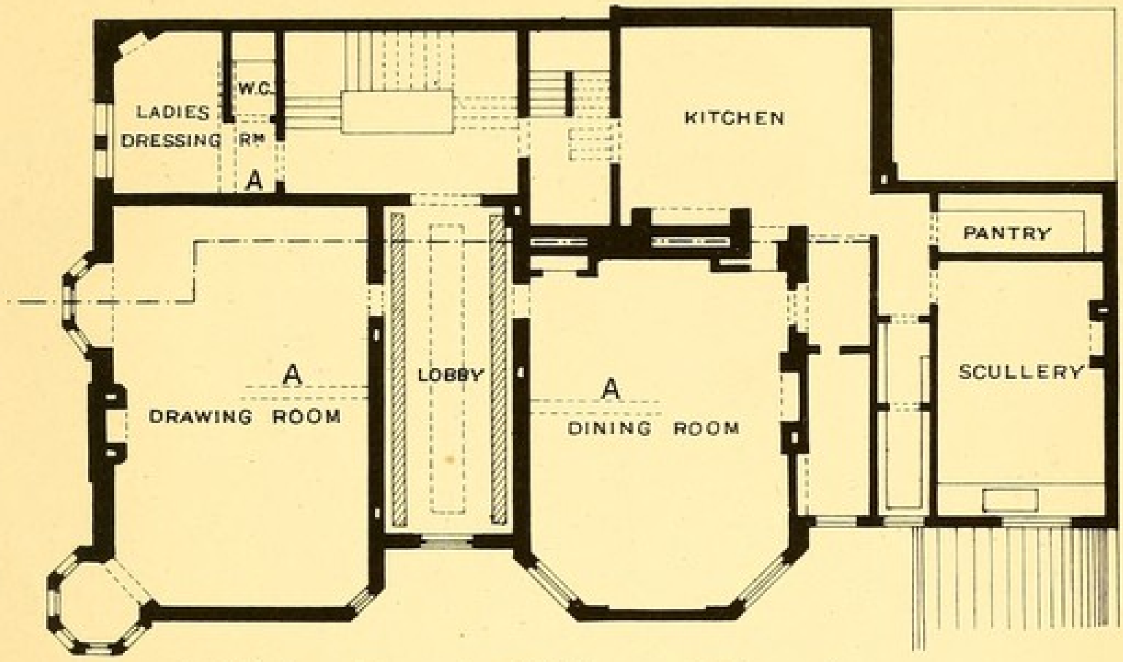
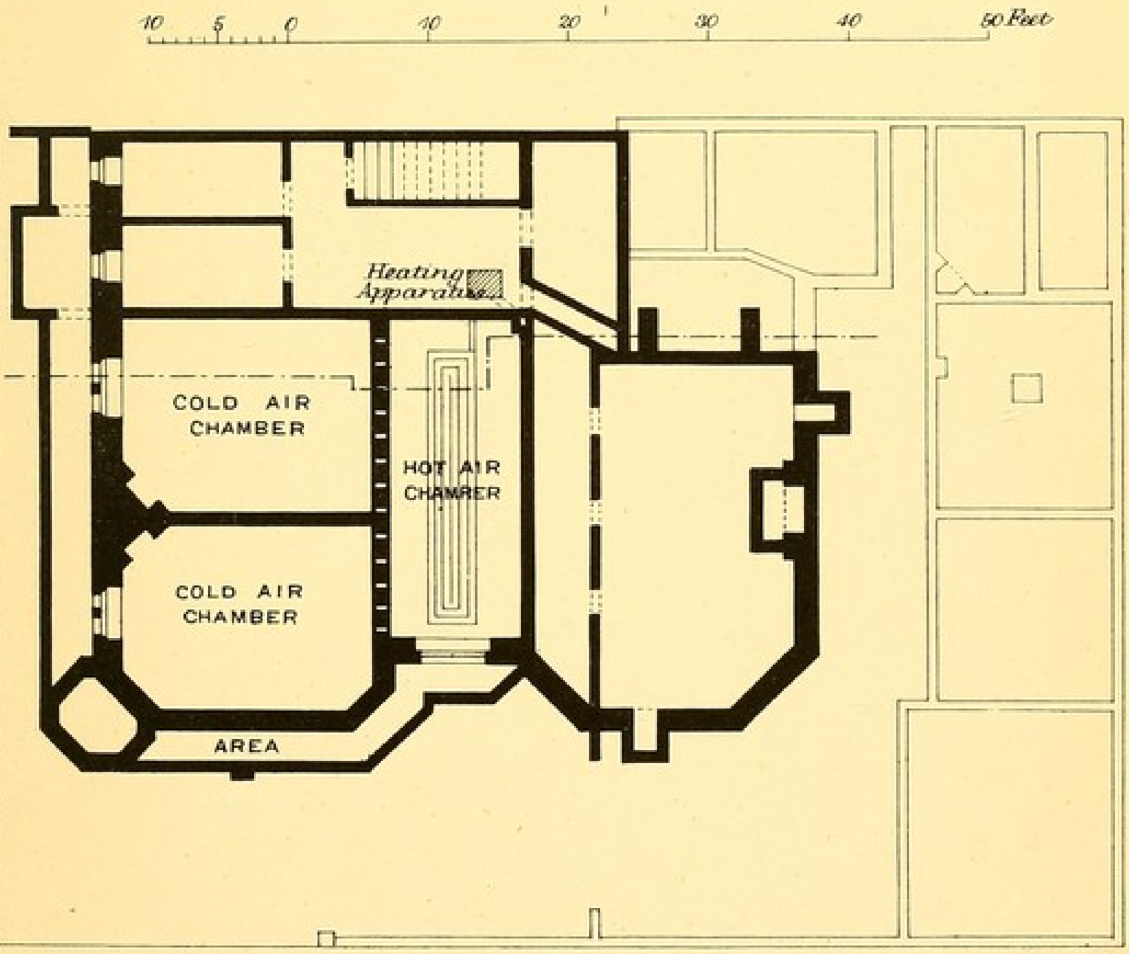
KELL BROS. LITH.

HOUSE No 2



A.A.A. Zinc Flues in Thickness of Floor above.

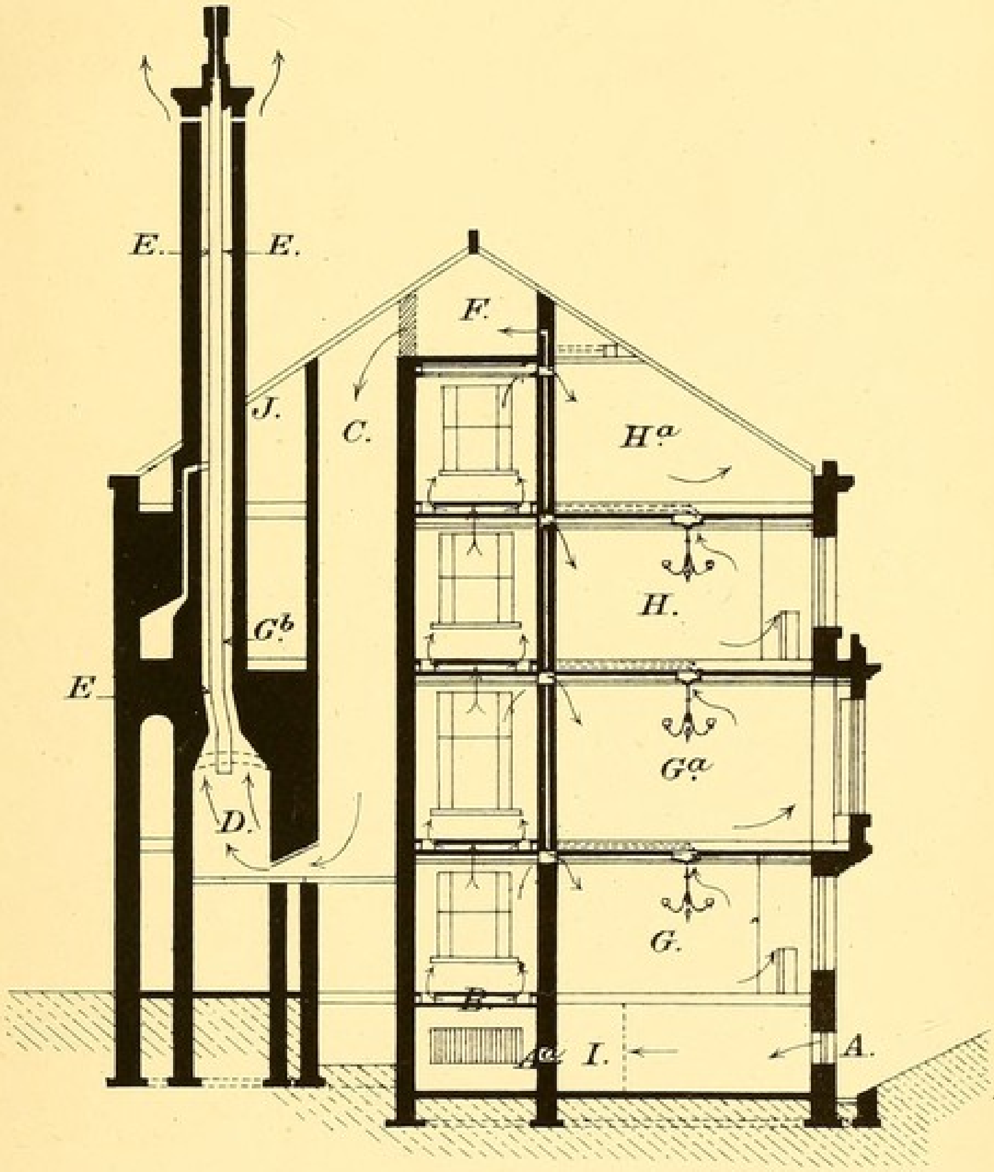
FIRST FLOOR PLAN.



BASEMENT PLAN.

HELL BROS. LITH.
London - E & F. N. Spon, 48, Charing Cross.

HOUSE No 2



SECTION.

A. A^a Primary Inlet.
B. Secondary d°.
C. Downcast Shaft.
D. Kitchen Fire.
E. Upcast Shaft.
F. Foul Air Chamber.
G. Study.
G^a Drawing Room.
G^b Breakfast Room.
H. Bedroom.
H^a Attic.
I. Canvas across Inlet.
J. Opening into Shaft.

10 5 0 10 20 30 40 50 Feet

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