ON THE VENTILATION OF PUBLIC BUILDINGS.

By GENERAL MORIN.

The renewal of air in buildings is only rendered necessary by the vitiation resulting from the respiration and exhalations of the occupants, and by the accumulation of the products of combustion from artificial lighting; and the writer has been led by his own observations and the consideration of the results obtained by others to the following conclusions as to the principles on which the ventilation of buildings should be based :—

First—Ventilation consists in getting rid of all vitiated air and replacing it by fresh air.

Secondly—The principal object of ventilation is to get rid at once of all vitiated air. It ought to be removed in general from the point nearest to the place where the vitiation takes place, in order to prevent any further diffusion into the room; and on the contrary fresh air ought to be introduced at the point furthest removed from the occupants of the room.

Thirdly—The different arrangements that proceed by *Suction*, when well proportioned and well carried out, are more effectual than those which depend exclusively on blowing in the fresh air, as the latter do not in every instance and at all times ensure the vitiated air being uniformly and continuously expelled.

Fourthly—The quantity of fresh air required, whatever may be the height from which it has to be drawn, and whatever the quantity, can be obtained by suction alone, and without the aid of any blowing apparatus, by giving to the inlet openings for the fresh air sufficiently large dimensions, and by suitable arrangement.

Fifthly—Suction can easily be obtained either by means of the ordinary open fireplaces with chimneys or similar heating apparatus, or by means of special fireplaces placed at the bottom of the

exhausting flues and acting as auxiliaries when the rooms are large. The air to be removed ought to flow towards the bottom of these fireplaces, and wherever possible by means of special air flues leading from openings close to the sources of vitiation.

Sixthly—Ventilation by suction by means of fireplaces and chimneys can be adapted to the proportions and arrangements of every kind of room, as it resembles the ordinary and natural ventilation of rooms, and the volume and temperature of the fresh air supplied can be varied as required. It only requires the construction at a small expense of fireplaces with their chimneys, and of air flues, which when once constructed cost but little to keep up; and also the regular feeding of the fireplaces, which any common attendant is competent to do. On the contrary, ventilation by means of blowing or other mechanical apparatus necessitates, besides the flues and chimneys common to both systems, the addition of blowing machines and engines with special air passages, special artisans, engineers, and firemen, and involves an extra cost for keeping up.

Seventhly—In hospitals with several stories, the blowing-in system does not afford the same guarantee as that of suction against the diffusion of the vitiated air from one room to another through the openings of the discharging flues, when it happens that the pressure and movement of the air of the room are disturbed by the opening of doors and windows.

Suction produced by simple fireplaces and chimneys, with sufficient area of opening for allowing the fresh air to replace the vitiated air, and without any mechanical apparatus, is consequently the most desirable means in the writer's opinion for effecting the ventilation of buildings, except in rare cases; and where special circumstances may necessitate the forcing in of fresh air by mechanical means, the action of a strong suction should also be added. This necessity never occurs in buildings where a continuous supply and removal of a nearly uniform quantity of air is required, but only when on the contrary this service has to be varied frequently between different portions of the same building, and when the quantities of air to be removed differ greatly from one day or from one hour to another; as in the case of the St. George's Hall,

Liverpool, where mechanical ventilation exclusively is adopted, and the quantity of air required varies in the extreme proportion of 1 to 50. In such cases it may become necessary, or at least useful, to employ mechanical apparatus in addition to the action of suction, in order to ensure a sufficient supply of fresh air.

The following proportions for the quantity of air required to be supplied per hour for each person are based upon the results of a large number of experiments by different observers, and though higher than the rates formerly adopted are not in the writer's opinion at all exaggerated :—

Hospitals for ordinary patients	2000 to 2400 Cubic Feet.
Ditto, in cases of epidemic	5000 „
Workshops, ordinary trades	2000 „
Ditto, unhealthy trades	3500 „
Prisons	1700 „
Theatres	1400 „, 1700 „
Meeting Halls	1000 „, 2000 „
Schools for Children	400 „, 500 „
Ditto, Adults	800 „, 1000 „

The temperature of the air in places abundantly ventilated, and having a continuous renewal of the air, can be allowed to be maintained at a higher point than in rooms not well ventilated ; but as a general rule the temperature should not exceed, in

Hospitals	61° to 64° Fahr.
Workshops, Barracks, and Prisons	59° „
Schools	66° „, 68° „
Meeting Rooms	66° „, 72° „
Theatres	68° „, 72° „

The fresh air supplied should be at nearly the same temperature as the one to be maintained in the room ; but this has to be increased to as high as 85° or 95° Fahr., if there is a large cooling surface of glass ; or to be diminished where the room is heated by a large number of lights or a large concourse of persons. For the purpose of regulating the temperature, the supplied air, warmed by some heating apparatus, has to be received first into a chamber into which cold air can be introduced for mixing with it.

The following relations between the volume and temperature of the air and the areas of the air flues have been obtained from theory and practice combined :—

$$V = C \sqrt{(T - T')} H$$

$$Q = CA \sqrt{(T - T')} H$$

In which A = sectional area of the exhausting flue.

H = height of exhausting flue.

T = average temperature of air in flue.

T' = temperature of external air.

C = coefficient, constant for each air flue as regards
its proportions and arrangement.

V = average velocity of air in the flue.

Q = volume of air passed per second.

The results derived from these relations are that the velocity of the escaping current is proportional to the square root of the excess of the temperature of the heated air in the flue over the external air, and also to the square root of the height of the flue or chimney; and the volume of air extracted is consequently proportional in addition to the sectional area of the flue.

The position of the openings for the admission and removal of the air is a point of great importance; and none of these should be made at the level of the floor, as is too often the case, because they are then exposed to obstruction by sweepings and rubbish from the floor. The openings for the admission of fresh air, whether warm or cold, should be placed near the ceiling, or at such a height that no person may receive the impression of a draught. The openings for the abstraction of the air should on the contrary be placed generally in the lower part of the room.

The velocity of the air should continually increase through the several passages of the building, from its entrance to its final discharge, which is best effected by the use of a single shaft for taking off the air from the whole building; and the velocities should be about—

2.3 to 2.9	feet per second	at the entrance
3.3	3.9	„ „ in the first passage
4.3	4.6	„ „ in the second passage
5.9	6.6	„ „ in the discharging shaft.

These speeds can be easily obtained in most cases by an excess of 70° to 80° in the temperature of the discharging shaft over the external air, except in the case of theatres, where a difference of 95° to 105° is required, on account of the complication of the passages. When the supply openings are in the ceiling, so that the air descends vertically, the velocity of the current entering through them should not exceed 1.6 feet per second; but when the air enters at the sides of the room at a considerable height the velocity may be as high as 3.3 feet per second without causing inconvenience. The plan of ventilation by suction has been objected to as causing objectionable draughts of air when doors are opened communicating with the exterior; but this sensation of draughts is got rid of when suitable proportions are adopted, and when care is taken that the passages communicating with the exterior are suitably warmed. The ordinary chimneys of houses produce in many cases a sufficient abstraction of air even without a fire, from the ordinary difference of temperature between the internal and external air; and this ventilating power can easily be increased by introducing into the chimney a vertical pipe containing a few gas burners.

An example of the application to a large building of the principles of ventilation described in the present paper is shown in Figs. 1 to 3, Plate 11, which represent the Public School in the Rue des Petits Hôtels in Paris. This building contains an elementary school A A for 400 children, and a drawing school B for 270 pupils. The ventilation is at the rate of 350 cubic feet per hour per person, and the warming is effected by two heating stoves C C with vertical tubes. The warmed air is supplied to each story by three vertical channels D, which discharge into a long wide passage E extending the whole length of the rooms, and into this passage external cold air can be admitted to regulate the temperature. The supply of air flows into the rooms horizontally near the ceilings, as shown by the arrows.

The rooms of the drawing school B are open at night, and offer special difficulties in ventilation, from the large number of gas burners in use. The plan of abstracting the vitiated air close to the

floor cannot be exclusively applied in this case, as it would cause the discomfort of pouring down air of 85° to 95° temperature upon the heads of the occupants. It is necessary therefore to allow the heated gases from the combustion of the lights to escape through the openings F in the ceiling, but at the same time fresh air is made to enter at the sides near the ceiling. In such cases, when the room has not attics above it through which the outlet openings in the ceilings can discharge, special flues are required to be made for this purpose, and these should be situated as far as possible from the points where the admission of fresh air takes place. By means of this plan of ventilation the temperature of the above rooms has been maintained until 10 o'clock at night at 71° at a height of 5 feet above the floor, and at an average of 75° near the ceiling; but before this plan was adopted these temperatures were 80° and 91° respectively.

The discharge openings should be made along both of the longer sides of the room, as shown at G G in Fig. 1, and should be as numerous as possible; and their total effective area should be such as to limit the velocity of the air passing through them to 2.3 feet per second. They communicate with descending passages H, converging below into a main discharge passage K leading to the bottom of the discharging shaft J. The chimney pipes I from the hot-air stoves C are made to pass up this shaft for assisting the draught, but a small fire L at the bottom of the shaft is also requisite.

An example of the ventilation of a large meeting room is shown in Figs. 4 to 7, Plates 12 and 13, representing the Lecture Theatre of the Conservatoire des Arts et Métiers (in which the present meeting is held) and in which the ventilation arrangements have been carried out by the writer, and have been satisfactorily working for the last four years.

The vitiated air is taken off through a large number of orifices made in the risers of the steps A A, Fig. 4, opening into the space B below the seats, which communicates by an outlet passage C, Fig. 5, with the discharging shaft D; the requisite draught is maintained in the shaft D by means of a fire at the bottom, dampers being placed

in the passage C to moderate the current of the air. The supply of fresh air is introduced from a mixing chamber E in the roof, and enters the lecture theatre through openings F F distributed over the surface of the ceiling.

In such buildings the ventilation should provide an amount of 1000 cubic feet of air per hour for each person, and the area of openings for the abstraction of the vitiated air should be sufficient to prevent its velocity through the openings exceeding 2.3 to 2.6 feet per second, the openings being distributed as uniformly as possible over the whole of the steps A A. The velocity of the air in the outlet passage C should not exceed 3.9 feet per second; and the velocity in the discharging shaft D should amount to 6.6 feet per second, in order to ensure the stability of the current.

The inlet openings F F for supply of fresh air, when situated in the ceiling, should have such an area as to allow the velocity not to exceed 1.6 feet per second; in this lecture theatre, where the total quantity of air admitted reaches 170 cubic feet per second, the area of openings slightly exceeds the above proportion. When it is requisite in such places for the inlet openings to be at the sides, they should be situated on two opposite sides, and as high from the floor as practicable.

As the ventilation of buildings like this lecture theatre is required to be in action only when they are occupied, whilst the warming is needed to be in operation previously to their occupation, it is necessary to have the means of warming them by special orifices, in addition to those which supply the ventilation. For the purpose of warming, the large hot-air stove G is employed, Fig. 4, situated under the lower end of the room; and the air necessary for combustion is supplied to it from the basement through the passage H. The fresh air to be heated is admitted through a separate passage I from the open courtyard adjoining, and after being heated by the stove is delivered into the room through the four openings J J in the floor; these are only opened during the preparatory warming of the lecture theatre while it is empty, and as soon as it is occupied they are closed. A constant supply of hot air is maintained to the two lobbies K K by the openings L L, and also by

N

the openings MM to the laboratory N at the back of the lecture theatre; this prevents any objectionable draughts of cold air occurring whenever the intervening doors are opened during the occupation of the theatre; and the doors being all made to open outwards, the tendency of the entering air is to close them. At the upper end of the lecture theatre a similar heating stove is provided, but of smaller size, for warming the main entrance staircase and vestibule at that end of the room.

A portion of the hot air from the stove G is conveyed by the ascending pipe P to the mixing air chamber E in the roof; and in order to ensure its equal diffusion over all parts of the lecture theatre, the mouth of the hot-air passage Q is widened out to the full width of the air chamber E, as shown in the plan, Fig. 6; while a hood R is placed over the central inlet opening F, and screens SS are interposed at the two side openings, in order to prevent an undue proportion of the fresh warm air from entering the lecture theatre through these three nearest openings. A branch from the hot-air passage Q to the two side openings TT, Fig. 7, ensures a proper supply of hot air to each of these openings. A similar supply of hot air is introduced at the other end of the roof by the passage V from the smaller heating stove at that end of the lecture theatre. The fresh cold air is admitted into the roof chamber E through the entrances UU, Figs. 4 and 7; and by the arrangement shown in the drawings of the hoods R and screens S at the ceiling apertures, the thorough mixing is ensured of the cold and the heated air previous to entering the lecture theatre, the orifices of the hot-air passages Q and V being situated in all cases close underneath those admitting the cold air. By means of the valves UU the entrance of the cold air to the mixing chamber E is regulated according to the temperature desired in the mixed air introduced for ventilation; in winter this temperature should be about $3\frac{1}{2}^{\circ}$ below that maintained in the lecture theatre, which should be about 68° .

The ventilation of a large theatre is illustrated by Figs. 8 and 9, Plates 13 and 14, representing the Théâtre Lyrique in Paris, in which the principle of the writer's plan of ventilation was adopted;

but this was unfortunately only partially carried out in the details, so that the full advantage is not realised in the results.

The number of seats in this theatre is 1470. For the ventilation of the stage and its dependencies, special means have to be applied by an auxiliary discharge flue above the stage, intended for use when required to remove any large quantities of smoke from extensive illuminations. In the body of the house, where the maintenance of a constant ample ventilation is required, there should be a supply of fresh air of 1400 cubic feet per hour for each person, with the means of increasing this in summer to 2000 cubic feet per hour. It is important for the supply of fresh air to be obtained from open spaces or gardens, if possible, or else by special shafts bringing the air from a point above the buildings, and far removed from the outlets of vitiated air. In the case of the theatre shown in the drawings, the inlet for fresh air is made in the square of the Tour St. Jacques, by means of a well $11\frac{1}{2}$ feet diameter, communicating by a tunnel A of the same area with the space underneath the theatre, Fig. 9, where the warming apparatus and the mixing air chambers are situated. The velocity of the current in the inlet passage A was ascertained to be 3.08 feet per second in a special examination that was made some years since, and the sectional area of the passage being 97 square feet, the volume of fresh air admitted amounted to 300 cubic feet per second, which was somewhat in excess of the quantity that the apparatus was designed to supply. This area of inlet however has subsequently been allowed to be contracted considerably by the growth of ivy at the entrance.

The admission of the fresh air to the body of the house from the main supply shafts P P, Fig. 8, takes place between the floor joists or through the false bottoms made under the floors of each of the rows of boxes and gallery, as shown by the arrows at B B, Fig. 9, the air entering horizontally all round the theatre through these spaces, which should not be less than 5 to 6 inches clear height. The fresh air is also admitted by openings from about 10 feet height in the vertical walls on each side of the stage, and also by auxiliary channels under the flooring of the passages, intended specially

for extra summer ventilation, and controlled by valves. For preventing the occurrence of unpleasant draughts upon the opening of doors into the exterior passages, these passages have to be warmed to a temperature of about 68° , and inlets of warm air are provided opposite the different doors in the passages.

A portion of the air, on entering by the main inlet passage A, Fig. 9, is warmed by traversing two sets of heating apparatus C C placed in the basement; and the remainder is delivered into mixing chambers for regulating the temperature of the air supplied in the building. The area of passage through the heating apparatus is 97 square feet, and the volume of warm air supplied is 245 cubic feet per second, giving a velocity of current of 2.5 feet per second.

The vitiated air is taken off through numerous openings in the lower part of the sides of the boxes and passages, and in the risers of the steps in the gallery, each box or pair of boxes having a separate discharging flue; and the total area of these openings has to be such as to allow the velocity of the air not to exceed 2.3 to 2.6 feet per second. The exhausting flues E E from the several tiers of boxes are made to rise towards the dome F above the chandelier, while those from the pit, orchestra, and boxes on the ground tier are carried below the floor into main flues leading to the vertical shafts G G; and the area of these exhausting passages should be such as to give a velocity of current of 3.3 to 3.9 feet per second. In the pit and orchestra, outlet gratings should be placed all round the sides, and in the sides of the air passages underneath the seats; these outlets open into the space left under the floor, which leads to the main exhausting shaft G on each side, this space being divided accordingly into two portions by the central partition J. The outlet gratings should not be placed in any case in the floor, as was done in this theatre, contrary to the writer's intention.

The cast-iron chimney pipes I I from the heating apparatus are carried up the exhausting shafts G to aid the draught, the pipes being kept isolated throughout; and a small firegrate H is placed at the bottom of each shaft, for use when extra ventilation is required in summer. The area of the exhausting shafts G G is required to be such as to give a velocity of current of 5.6 to 5.9 feet per second;

and they should lead, when possible, to the dome F over the centre of the theatre, into which all the outlet flues from the upper tiers of boxes also discharge. The general outlet shaft K above this dome should be built of brick, not metal, and should be carried at least 20 or 25 feet above the top, its area being such as to give a velocity of current of about 6·6 feet per second.

A series of experiments on the ventilation were made on five successive nights in May, 1863, with the external temperature ranging between 56° and 74° ; and the result obtained was that with an average consumption of 4 cwts. of coal per night, costing 7s. to 8s., the removal of 166 cubic feet of air per second was effected, amounting to 1400 cubic feet per hour per seat of the pit and orchestra. With this ventilation the temperature of the house can be maintained within comfortable limits; but this extent of ventilation is not actually employed, as the intended use of the two large exhausting shafts G G is not carried out. The experiments made at the same time on the ventilation of the boxes showed that an abstraction of 377 cubic feet of air per second was effected by the centre shaft over the dome, amounting to 1800 cubic feet per hour per seat. The actual average ventilation for the whole house during the five evenings was found to be 1330 cubic feet per hour per seat. By this uniform ventilation the temperature in the different rows of seats was maintained most remarkably constant, the average temperatures in the first and fourth tiers being 68° and 70° respectively, when the external temperature was 52° ; and when the latter was 70° , their temperatures were 78° and 80° respectively: in other large theatres however, which are not so ventilated, these temperatures are not unfrequently as high as 95° to 105° .

At another trial in November 1863, when the external temperature was as low as 39° , the temperatures within the house were found to be maintained at

66° on the Stage.

71° in the Orchestra Stalls.

73° „ „ Boxes.

74° „ „ Gallery.

The above results show the satisfactory manner in which the mode of ventilation that has been described effects the objects intended; but the full benefit of these results is unfortunately not received in the present case, from the arrangements being only partially carried into regular use; and it has to be remarked that however perfect the ventilating arrangements may be in the construction of a building, it is indispensable that the working of them should be under the constant charge of properly qualified and responsible management, in order to ensure the desired object being systematically attained.

The PRESIDENT said they were greatly indebted to General Morin for his kindness in granting the use of the Lecture Theatre in which they were now assembled, and for the valuable facilities afforded by him for the present Meeting in Paris, as the Director of the Conservatoire Impérial des Arts et Métiers. The efficiency of the system of ventilation carried out upon the principles advanced in the paper, with which General Morin had favoured them, was practically illustrated by the agreeable condition and temperature of the air at the present moment in the Lecture Theatre, notwithstanding the number of persons now assembled in it on a summer day.

GENERAL MORIN expressed his pleasure in welcoming the Members of the Institution on the occasion of their Meeting in Paris, and his gratification in receiving them at the Conservatoire.

Mr. EDWIN CHADWICK remarked that the two opposite systems of ventilation—the one by propulsion or driving in the air by mechanical means, and the other by suction or creating a draught by heating the air in the discharge flues—might both be seen in operation in Paris, in different wards of the Lariboisière Hospital near the Northern Railway Station; there had been considerable controversy respecting the relative advantages of the two plans as carried out in that building, and he did not know of any better practical example of the two methods. The fresh air supplied by propulsion

was warmed, and driven in by engine power by means of a fan; and in abstracting the vitiated air by suction, it was taken off close to the points of greatest vitiation, namely between each of the beds in the ward. From a careful examination made of the subject by physicians he had been led to conclude that the system of suction, as described and advocated in General Morin's paper, was not only the most economical, but also the best in regard to the degree of purity maintained in the air of the building, as the system of propulsion was found to be attended with the disadvantage that the current of fresh air driven into a room would sometimes pass through direct to the outlet, without thoroughly expelling the vitiated air, and thus allowed an objectionable accumulation of vitiated air to take place in particular portions of the room. The arrangements for ventilation by suction at the above hospital had been developed and carried out with very decided success by the late M. Léon Duvoy, who had undertaken to give a supply of 2000 cubic feet of air per hour for each bed in the wards, heated to a uniform temperature of 60° Fahr., at a charge of 1*l.* per bed per day; and the actual cost he understood had been found to be only about half that amount, the price of the coals used being about 40*s.* per ton in Paris at the time. The rarefaction necessary for effecting the ventilation was obtained by means of a hot-water tank at the top of the building, and the ends of the air flues being carried up through this tank by means of thin iron pipes, an upward current of air was established by the heating of the air within the flues, whereby the vitiated air was abstracted from the building with a uniform draught, as tested by holding a lighted candle at the bottom of any of the air flues. In some cases the vitiated air was taken off upwards, and in others downwards, and the ventilation was effected with complete success in each way. For the purpose of saving heat, a coil of water pipes or a water jacket was placed round the chimney of the furnace employed for heating the water in the hot-water tank, and by this means nearly two-thirds of the heat escaping into the chimney was found to be saved. The fresh air admitted to the building was warmed by being made to pass between a number of thin iron pipes containing the heated water supplied to the hot-water tank. The warming of the Madeleine Church,

containing 2,000,000 cubic feet of space, had also been undertaken by M. Duvoir at a cost of 11s. 2d. per day; and also the ventilation and warming of the Palais de Justice, a prison, and several other public buildings, as well as a number of private houses: the warming of eight-story houses had been undertaken by him at from 3s. to 4s. per day, and the very small quantity of coal consumed for the purpose was remarkable. On a small scale the same principle of ventilation by suction might also be carried out by simply placing a lighted lamp or candle in the bottom of a properly constructed air flue; or by building air flues parallel and contiguous to the chimney flues, so as to be heated by the latter. The simple manner in which the ventilation by suction had been carried out in the Lecture Theatre of the Conservatoire under General Morin's directions, the ventilation being completely maintained without requiring special attendance, appeared to him to be much in advance of any attempts that he had met with previously; and he thought it would be a great benefit if the same plan could be introduced in England for the ventilation of public buildings.

In conjunction with the ventilation of buildings, the warming of the air supplied had hitherto been the chief subject of attention in France and England and other northern countries; but for hot weather even in this climate it was desirable that attention should be given to the corresponding question of cooling the air, and in the tropics this was an absolute necessity. In an experiment made by M. Duvoir at the Palais de l'Institut on cooling the supply of fresh air by passing it between a series of pipes through which a stream of cold water flowed, the meeting hall had been cooled down to a considerable extent on a hot summer day, while occupied; and this result deserved the particular attention of any one entrusted with the ventilation of buildings in India or other tropical countries, where the effectual cooling of the air was of such great importance.

Mr. J. WHITLEY concurred in the importance of having a system of ventilation not requiring constant attention, particularly for private houses, where such attention was out of the question. Having himself carried out for house ventilation in a large number of cases the principle of suction advocated in the paper, he had found that, by

simply taking advantage of the rarefaction produced by the ordinary chimneys, sufficient exhausting power was available for ensuring a constant supply of fresh air in all the rooms and passages of a house ; and by this means a room closed and fully occupied for a length of time, such as a sleeping apartment, was made to retain as pure an atmosphere as if unoccupied. In the plan that he had used, a suitable outlet from the room into the chimney was made at the level of the ceiling for the escape of the vitiated air, and a corresponding inlet for the fresh air was made in a distant part of the room ; and whenever the chimney was not heated by a fire in the room, a jet of gas lighted at the bottom of the inlet to the chimney was found sufficient to produce the necessary amount of rarefaction, as named in the paper.

MR. BRAMWELL enquired whether it had been found necessary, in the system of ventilation described in the paper, to introduce any moisture along with the supply of air artificially heated.

GENERAL MORIN replied that he had not found any necessity for introducing moisture with the air supplied, because he had adopted the plan of heating only a small portion of the air, and mixing this with a quantity of fresh cold air, so that the mixture contained a sufficient supply of moisture to prevent any sensation of dryness, without requiring any addition of moisture by artificial means. When the whole of the air supplied was heated, as in the case of the British Museum, and St. George's Hall, Liverpool, it was generally found necessary to provide special arrangements for restoring to the air the degree of sensible moisture which it had previous to the heating process. But in most cases only a moderate amount of heating was required even in winter, as it was found that the air supplied should be introduced at a temperature of $3\frac{1}{2}^{\circ}$ to $5\frac{1}{2}^{\circ}$ Fahr. below that to be maintained in the building. In the case of the Lecture Theatre in which they were now assembled the extent of accommodation was limited to about 700 persons, but the ventilating arrangements had been carried out upon a scale which would be amply sufficient for an assemblage of 1200 persons.

MR. C. W. SIEMENS thought there must be more need of moistening the air in winter than in summer, because at a lower temperature the point of saturation of the atmosphere was lower, and when below the

freezing point it was devoid of moisture altogether; while at the same time there would then be the greatest proportion of heated and dry air to be mixed with it. He enquired whether in winter there was ever found to be any necessity for adding moisture to the air.

GENERAL MORIN replied that in a room containing only two or three persons it might under such circumstances be desirable to moisten the supply of air, because the quantity of moisture exhaled in respiration was not then enough to saturate the air. But in an assembly of a great number of persons there was an objectionable excess of moisture in the atmosphere from exhalation; and therefore in most cases, instead of adding moisture to the air, the object to be aimed at he thought was rather to introduce dry air, with a view to get rid as far as possible of the excess of moisture already existing in the atmosphere of the room.

Mr. C. W. SIEMENS enquired in reference to the plan that had been mentioned, of cooling the supply of air for ventilation in hot countries, whether General Morin had made any experiments on that subject, and whether the mode of carrying out the system of suction would be the same in that case, by introducing the cold fresh air at the ceiling and drawing off the vitiated air below, or whether the arrangement would have then to be reversed. It would be very advantageous he considered if the plan of introducing the fresh air at the ceiling could still be adhered to.

GENERAL MORIN replied that an illustration of the supply of air for cooling purposes was afforded by the Lecture Theatre in which they were now assembled, where the internal temperature was at all times of the year above the required degree when the room was fully occupied, and needed always to be kept down by a liberal supply of fresh cool air, which was introduced at the ceiling, the ventilating arrangements in this case having been completely carried out according to the system described in the paper. At the Corps Législatif on the contrary the cold air was introduced at the floor of the assembly hall, through very narrow openings of only about 1 inch height, situated in the risers of the steps; and the result had been the presence of very disagreeable draughts about the legs of people, showing the mistake of letting the fresh air enter at the floor. At the

present moment the supply of fresh air in the Lecture Theatre was at the rate of as much as 13,000 cubic feet per hour per person; but as it was introduced at the ceiling of the room and through a number of large openings, there was not the slightest sensation of draught, while the atmosphere in the room was maintained fresh and cool. Even had the day been considerably hotter, the extent of ventilation provided for would have been sufficient to keep down the interior temperature below that outside. In special experiments he had employed the pipes of the heating apparatus for the converse purpose of cooling the air, by circulating a stream of cold water through them, and making the supply of air pass between them on its way to the entrances of the room. By this additional means, when the temperature in the room had been 68° Fahr. and the external temperature 66° Fahr., he had succeeded in reducing the internal temperature by 4° or 5° Fahr. In the case of intense summer heat or in tropical countries the requisite cooling effect might no doubt be readily obtained by having recourse to a fine spray of water in the main air passages in the basement of the building, just sufficient to moisten the whole of the surfaces over which the fresh air had to pass in entering, so as to bring into play the cooling effect of rapid evaporation. He had originally contemplated applying this mode of cooling in the ventilation of the Conservatoire, but he had found in practice that an ample cooling effect was obtained by the abundant ventilation, without the necessity of this additional provision for the purpose.

Mr. W. FAIRBAIRN considered the subject of ventilating large public buildings was one of the greatest importance at the present day, and required serious consideration. In the paper just read he had been much struck with the large allowance of air stated to be required for the efficient ventilation of buildings where a number of people were congregated together, amounting to as much as 1500 to 2000 cubic feet per hour for each person. In the case however of a barracks in London, it had been found that the quantity of fresh air supplied was less than 500 cubic feet per hour per individual; and the result had been that men who came strong and healthy from the country became consumptive in a few months and a great number

died, the rate of mortality being even greater in the barracks than on a campaign. He enquired whether the principles of ventilation enunciated in the paper had been applied to any of the barracks in Paris.

With regard to the mode of effecting the ventilation by introducing the fresh air at the ceiling and taking off the vitiated air at the bottom, this was a direct reversal of the plan generally adopted in England, of supplying the fresh air at the bottom and discharging the vitiated air at the top of the room, which he himself had hitherto been accustomed to consider the most natural way of ventilating a building. There was no doubt however that the system described in the paper possessed an important advantage in the very slow velocity at which the fresh air was brought in, amounting to only 2 or 3 feet per second; and it was evident that with such a velocity there was not much danger of any person catching cold in the room, as the speed was not sufficient to produce any sensation of draught. Moreover by removing the vitiated air at the bottom, the carbonic acid gas, which constituted the principal element of vitiation and naturally tended to the bottom by its greater specific gravity, was taken off at once, without contaminating the fresh air in the rest of the room; and this he thought was a very important feature in the system. A somewhat greater force of draught would of course be required to take off the vitiated air at the bottom instead of the top; but it was no doubt worth while to have rather more heating power for this purpose in the upcast shafts, on account of the advantage attending the immediate removal of the vitiated air at the bottom of the room. He hoped there might be opportunities of seeing the same mode of ventilation tried for public buildings in England, where there was at present so much room for improvement in that respect.

GENERAL MORIN said he had seen the report of the English commission upon the ventilation and warming of barracks, and had been much interested in the excellent plan of ventilating chimney proposed for the purpose by Capt. Douglas Galton. Experiments had also been tried upon the subject in the Paris barracks near the Hôtel de Ville (Caserne Napoléon); but owing to some defect in the arrangements the direction of the current was found sometimes to

reverse itself, bringing back the vitiated air into the building instead of carrying it off; and the men had suffered from ophthalmia in consequence. He had not yet had any opportunity of applying to barracks the system of ventilation described in the paper. The importance of taking off the vitiated air at the bottom of the room, whereby alone it could be removed at once without polluting the atmosphere within the building, was sufficiently demonstrated by a visit to the basement of the Lecture Theatre in which they were now assembled; and in simply passing along quickly under the seats of the theatre when occupied by a number of persons, he had felt completely stifled by the poisonous atmosphere drawn off from the room. It was not surprising therefore that in large assemblies persons were frequently made ill by mere defect of ventilation; and in the case of hospitals it appeared not unreasonable to suppose that the very walls of the building must become impregnated with infection. These difficulties he considered could only be effectually obviated by the system described in the paper, ensuring the immediate removal of all the vitiated air by taking it off at the bottom of the room.

The PRESIDENT moved a vote of thanks to General Morin, which was passed, for his kindness in contributing the valuable paper that had been read, and so actively promoting the interest of the Meeting of the Institution in Paris.

The following paper was then read :—

VENTILATION OF PUBLIC BUILDINGS.

Plate II.

Fig. 1. Transverse Section.

Public School, Rue des Petits Hôtels, Paris.

Fig. 2. Plan of First Floor.

Fig. 3. Plan of Basement.

VENTILATION OF PUBLIC BUILDINGS. *Plate 12.*

Conservatoire Impérial des Arts et Métiers, Paris.

Fig. 4. *Longitudinal Section of Lecture Theatre.*

Fig. 5. *Plan of Basement.*

(*Proceedings Inst. M. E. 1867. Page 62.*)

Scale $\frac{1}{300}^{th}$

Conservatoire Impérial des Arts et Métiers, Paris.

Fig. 6. *Plan of Roof of Lecture Theatre.*

Fig. 7. *Transverse Section at XX.*

Théâtre Lyrique, Paris.

Fig. 8. *Plan.*

(Proceedings Inst. M.E. 1867. Page 61.)

Scale $\frac{1}{300}^{th}$

10 5 0 10 20 30 40 50 60 70 80 Feet.

Théâtre Lyrique, Paris.

Fig. 9. *Vertical Section.*

(Proceedings Inst. M. E. 1867. Page 61.)

Scale $\frac{1}{300}^{th}$

10 5 0 10 20 30 40 50 60 70 80 Feet.