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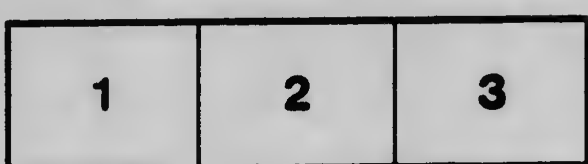
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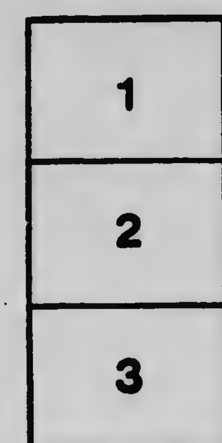
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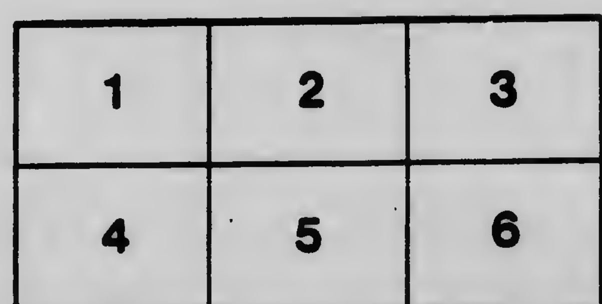
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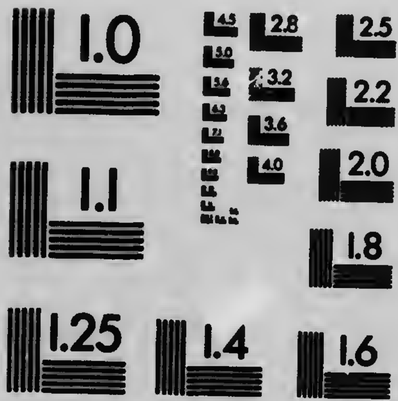

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BULLETIN 119. **APRIL, 1902.**

Ontario Agricultural College and Experimental Farm.

VENTILATION OF FARM STABLES AND DWELLINGS.

By Prof. J. B. Reynolds.

For people who live in house, ventilation is one of the many problems that have to be solved. Abundance of sunlight and of fresh pure air is the basis of cure that has been adopted at modern consumptive sanitariums. The prevalence of tuberculosis among both cattle and men is to a considerable extent due to close confinement, for longer or shorter periods, in ill-ventilated and badly lighted rooms. Dark, close basement stables for cattle, and tightly-bottled-up dwellings for men, women, and children, are too often found in this and other countries.

Ventilation is a matter more of accident than of plan in most of our houses and stables. As a consequence, the inmates are breathing the same air over and over again. This would be bad enough if every inmate of the house were perfectly heathy, for the products of respiration, even of a healthy animal, are a mild poison, which are, however, prevented from doing much harm by being more or less diluted. But when we remember not only that the expired breath of an unhealthy animal contains the usual constituent of carbonic acid, but that its presence is very likely to infect the air with the germs of disease as well, the necessity for frequently changing the air of occupied rooms is quite apparent.

In warm seasons, and in warm climates, the problem of ventilation is a comparatively easy one. We have only to throw open our dwellings to the action of the breeze, and the air is continuously changed. But in the wintry season, and in rigorous climates, the question is one of considerable complexity ; for along with the demand for fresh air comes another more immediately urgent—the demand for warmth. In cold weather, these two requirements must necessarily conflict, and the one need is satisfied at the expense of the other. That being the case, we manage to have the more urgent need satisfied, and neglect the remoter necessity. We are more sensitive to cold than to impure air ; and in order to secure a proper degree of warmth without too great cost, we are content to ignore the fact that we are breathing impurities.

During the greater part of the year in this country, the question of ventilation involves the question of temperature. We have not only to make provision for bringing fresh air into our dwellings, but we must warm it artificially after it is introduced. Therefore, ventilation, particularly for dwellings, is doubly expensive. We have to provide contrivances for renewing the air in houses and stables. That is one item of expense. In stables we have to guard against too great a reduction of temperature, and hence a system of ventilation in stables requires either careful watching or special appliances for warming the air. In houses, we generally expect to warm the incoming air by the consumption of a little more fuel.

That is the second item of expense. It remains for us, therefore, to sit down and count the cost, whether we will put up with the dangers and inconveniences and discomforts of bad ventilation, or pay the charges for introducing and keeping up a system of changing and purifying the air that we breathe in our dwellings, or that the animals under our charge breathe in their stables.

WHAT IS VENTILATION? Theoretically, perfect ventilation consists in removing the unwholesome products that are diffused through the air of occupied rooms, as rapidly as these products are formed. But perfect ventilation exists only in theory. Practically, we are satisfied if we can remove a certain portion of these products,—carbonic acid gas and moisture from the lungs,—and dilute the remainder to a definite standard, by mixing with pure fresh air. An ordinary test of a system of ventilation, is to determine the percentage of carbonic acid gas present in the

"Light and Airy."

air of the room, and compare this with the amount of the same constituent that is found in pure air. In any case, ventilation consists in removing certain portions of the air, and continually introducing fresh air. The rate at which this is done will fix the degree of completeness of the ventilating arrangements. For this constant removal and introduction of fresh air, certain forces operate, which forces depend upon certain physical principles. It is important that every man who is thinking of ventilating his house or stables, should understand these principles, in order that he may adapt the suggestions that are made in this pamphlet to suit his own circumstances.

THE PROBLEMS IN VENTILATION. The object to be gained in ventilation is the maximum quantity of fresh air. But with the introduction into a room of large quantities of fresh and generally cold air, we must guard against the possible consequences, viz., *drafts*, *cold*, and *dripping* or condensation of moisture within the room. The problem[illegible]en are:

(1) To find a force that will keep the air in motion: removing foul air and bringing in fresh;
(2) To introduce and distribute the air so as to avoid drafts;
(3) To prevent the ventilated room from becoming too cold;
(4) To prevent condensation of moisture in the room.

NATURAL AIDS TO VENTILATION. Under the first of the above mentioned heads, there are certain natural forces or tendencies in the gases of which air is composed, that aid in ventilating a room or stable. The first of these we shall consider under the head of "Gravity."

Built in the day[illegible]tion was, not how to let fresh air in, but how to keep it out.

When the ai[illegible]ed, it has a tendency to expand, and will do so if allowed. The re[illegible] of the expansion is that it becomes lighter, bulk for bulk, than the cooler air. The warm air, as a consequence of its lighter weight, is displaced by the cooler air, and driven upward, on the principle that heavy bodies sink when immersed in fluids that are lighter than themselves. A stone when thrown on the top of water sinks to the bottom on exactly the same principle that cold air flows in underneath or falls down through warm air and forces the latter upward. This sinking of cold air and rising of warm air is called *convection*, and this convectional movement of air is one of the forces, if we may so speak, that operate in ventilating buildings. In an occupied room or stable, the heat from the bodies of the occupants warms the air and produces the upward tendency. If this tendency is encouraged so far as to allow the rising air to escape altogether, and if at the same time provision is made for the cooler fresh air to find its way into the room or stable, we have ventilation. Whether or not this convectional movement is a sufficient force to give satisfactory ventilation, is a question to be considered later.

The second of these natural aids to ventilation is "Diffusion."

The air that we take into the lungs may contain but little water-vapor; and, if pure, it contains a very small percentage of carbonic acid gas. The latter is a chemical compound of carbon and oxygen. It exists in the free atmosphere in very small quantities,—the average amount of which has been estimated at 3½ volumes of carbonic acid gas in 10,000 volumes of air. On the other hand, the breath expired from the lungs is saturated with moisture, and contains between 4 per cent and 5 per cent. of carbonic acid gas; or, to state it in the same form as above, in 10,000 volumes of expired air there are about 430 volumes of carbonic acid gas. The problem of ventilation is to prevent these two products—moisture and carbonic acid gas—from accumulating in excess within the occupied spaces. Aqueous vapor, at the same temperature and pressure, is lighter than air; carbonic acid gas is considerably heavier. It might be supposed, therefore, that when these products are emitted from the lungs, the aqueous vapor would raise to the ceiling, and the carbonic acid gas settle to the floor. There is a tendency to this movement; but, at the same time, a process goes on which is equally as effective as the force of gravity. This process is known as *diffusion*. A simple illustration of diffusion may be seen by putting a few drops of milk into a glass of clear water. Soon the milk is seen to diffuse through the water, giving a uniform whitish shade to the whole. The same thing goes on with the aqueous vapor and carbonic acid gas. Instead of separating completely according to density, from the air of the room, these products diffuse throughout the whole room; so that wherever the foul air opening is placed, it will find almost uniform proportions of the products that ventilation is required to remove. If any difference, however, exists in the distribution of these gases, the excess of carbonic acid will be found at the floor; while that of water-vapor will be found at the ceiling.

Another aspect of diffusion is the movement of gases through porous walls. Suppose that the air of a room becomes overcharged with carbonic acid gas, and at the same time robbed of its oxygen; then the carbonic acid will diffuse outward through the plaster of the walls, and through the brick or between the clapboards; and the oxygen from the outside will in the same manner diffuse into the room. So that a natural ventilation proceeds at all times, even if the room appears perfectly air-tight. This natural ventilation is, of course, most rapid in rooms that have the greatest amount of wall-space exposed to the free outside atmosphere.

A third natural aid to ventilation is the *wind*. When the fresh air inlets are on the windward side of the building, there will be no question about plenty of ventilation. But when the wind blows from the side opposite the inlets, there is little or no ventilation. To make free use of the wind, therefore, it is necessary, either to have *inlets* at *all sides* of the buildings, or to have inlets that *always face* the *wind*. These two methods will be illustrated in detail in discussing particular systems of ventilation.

Under the second head, namely, distribution of fresh air in the stable, it is necessary to admit the air directly into the stable through a *number of small openings* rather than one large opening. How this may be done is shown in the plans of ventilation given below.

The third point, namely, temperature, constitutes a great difficulty in the ventilation of stables in winter. To introduce fresh cold air into a stable at any considerable rate and to draw off warmer air, necessarily cools the stable, and may cool it below the point of comfort and safety. Without artificial heating, the only safeguards against a temperature too low are: (1) A crowded stable, in which the animal heat given off is sufficient to warm large quantities of incoming air; hence the amount of ventilation may be, as it should be, in proportion to the number of animals in the stable. (2) A naturally warm, tight stable, which allows but little cold or drafts to enter the stable, other than by ventilating arrangements. (3) Shut-offs in the inlet and outlet pipes, so that the amount of ventilation can be controlled according to the temperature of the incoming air, the principle being to get as much fresh air as is consistent with a proper stable temperature,—between 35° and 45°. (4) A sub-earth duct, by means of which the fresh air, before being admitted to the stable, is carried for some distance through an underground pipe, 6 feet deep or more. The earth-temperature at that depth being much higher than that of the outside air, the air is warmed in passing through the duct, and enters the stable at a much higher temperature than it would if admitted directly. (5) Provision for drawing off the foul air at the floor, as an alternative to ceiling outlets. With floor outlets, the air drawn off is colder than that drawn off at the ceiling, and hence the stable is not chilled so much. Ceiling outlets, however, encourage a more rapid ventilation, and it is therefore advisable to provide both,—by extending the foul air box to the floor, leaving the lower end open, and providing a flap in the box near the ceiling, to open or shut as is required.

The fourth problem in ventilation is to prevent dripping, or condensation of moisture in the stable. In an ill-ventilated stable, the moisture from the breath and from other sources often condenses on the cold ceiling or walls. In a well-ventilated stable, the moisture is carried off with the impure air before condensation can occur. There are two cases, however, in which ventilation is sometimes the cause of dripping. First, the moisture may condense on the pipes or boxes carrying the cold fresh air. This is more likely to occur if these pipes are at the ceiling of the stable, and especially if the cold air is admitted at the ceiling—the condensation occurring where the cold air comes in contact with the warm moist air at the ceiling. Secondly, dripping may occur from the outlet boxes, especially if these are long. The preventives of dripping are generally, a brisk movement of air, forcing the moist air out before condensation can occur; fresh air inlets at the floor; and outlet pipes as short and direct as possible.

Plans of Ventilation in Detail.

Following are various plans of ventilation that are actually in use in this country. There are advantages and disadvantages in all.

Some are comparatively cheap, some more costly. Some require more or less constant attention to prevent too great cooling; some are almost automatic. The distinctive features of each will be discussed in connection with the descriptions.

That most of the stables in this country stand in need of some form of ventilation more than is provided at present is evident from the

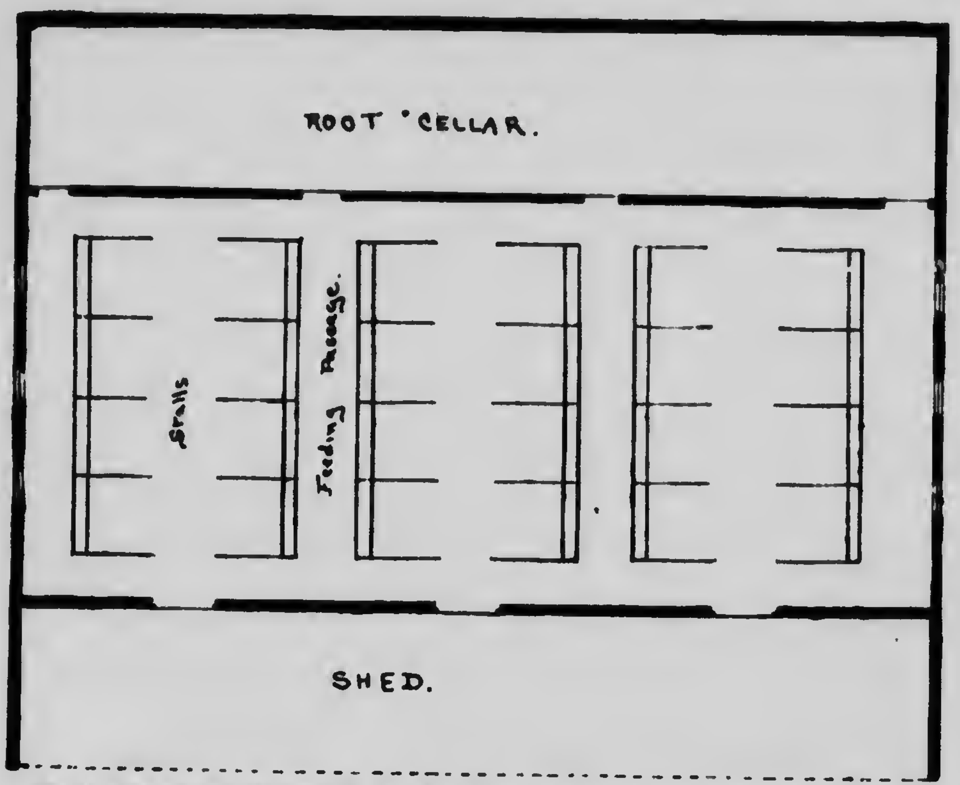

Fig. 2. Showing the great defect in many fine stables,—a limited amount of light and an equally limited amount of ventilation.

following instances, the first of which is furnished by a quotation from the "Nor' West Farmer" of April 20th, 1900: "I have built a stable with grout and roofed it with ship-lap. I find it too warm and close. My windows are made to open, but they let in so much cold air that the walls and roof are continually wet. I leave feed shoot open to let out the warmth, but still the walls keep wet, and the drip from the roof falls on the stock. How can I best ventilate it so as to keep the wet off the walls?"

The second instance of an ill-ventilated stable is represented in Fig. 2, showing the plan of a stable. This building is known locally as the Model Barn, on account of its up-to-date arrangements and fixtures. From the illustration, it can be readily seen that in the construction of the building, two most important items were almost entirely ignored,—

light and fresh air. The stable, as the plan shows, is about 36 x 80, with a root cellar at one side along its whole length. Only the faintest of borrowed light and still less air can penetrate to the stable from this side. Along the other side is an open shed, with which the stable communicates by means of doors. When these doors are open, the stable gains a certain amount of borrowed light and air; when they are shut, the only media for conveying light and air are small fan-lights above the doors, covered of course with dirt and cobwebs, and apparently not intended to be opened. At each end of this long stable are three small windows, which struggle bravely to light the interior. How they succeed in the attempt in the gloomy days of midwinter may be conjectured, when it is stated that on a bright afternoon in May, the writer could not see to read or take measurements at the middle of the stable, and was compelled to move to the end near the windows in order to record observations. So much for light, and ventilation was no better. Not the smallest contrivance for taking away foul-air, moisture, and other harmful products so abundant in a crowded stable.

These instances illustrate the prevailing indifference to these matters that exists among builders. It is not a sufficient answer to say that the cattle in such a stable seem to get along well enough without fresh air and light, and that there is no need for going to trouble and expense to secure these conditions. It is true that impure air is very slow and insidious in its effects, and generally leaves no specific mark as a sign of its harmfulness. But it is none the less harmful to health and vitality.

DIMENSIONS OF PIPES, SHAFTS, ETC. It is very difficult to give any sort of rule that will suit even the majority of cases as regards the dimensions of ventilating arrangments. If we assume that an opening 6 inches in diameter will deliver, under ordinary pressure, enough air for one animal, then an inlet pipe 20 inches in diameter will furnish enough air for 12 animals. It would be proper to allow 25 to 30 square inches of inlet space for each animal. So that a box 3 feet wide and 1 foot deep, having a cross-area of 432 square inches, would provide air for about 16 animals.

As to outlet pipes, the more of them the more perfect is the ventilation. Practically however, it would scarcely ever be necessary to provide more than two or three of these outlets in the ceiling or at the floor. The total area of the foul-air shafts should be from one-fifth to one-tenth greater than the area of inlet pipes, since the warm air leaving the stable occupies greater space than the cool air entering. For instance if a box 3 ft. by 1 ft. is used to bring in the fresh air, then two ventilators 2 ft. by 10 in. would be sufficient to draw off the foul air. And it would be inadvisable to make the outlet much larger comparatively than this. When the ceiling ventilators are too large, there is often a down draft which interferes with the working of the system.

The first plan of ventilation to be described is that in use in the stable of Mr. W. D. Cargill, of Cargill, Ont. The description of the plan has been kindly furnished by the proprietor, and is here given: "Our barns all have a stone foundation 11 feet high, and around this, as close to the top as possible, we built in 5 or 6 inch tile about 6 feet apart, run-

Fig. 3. Ventilation of barn, by means of tile built in the wall.

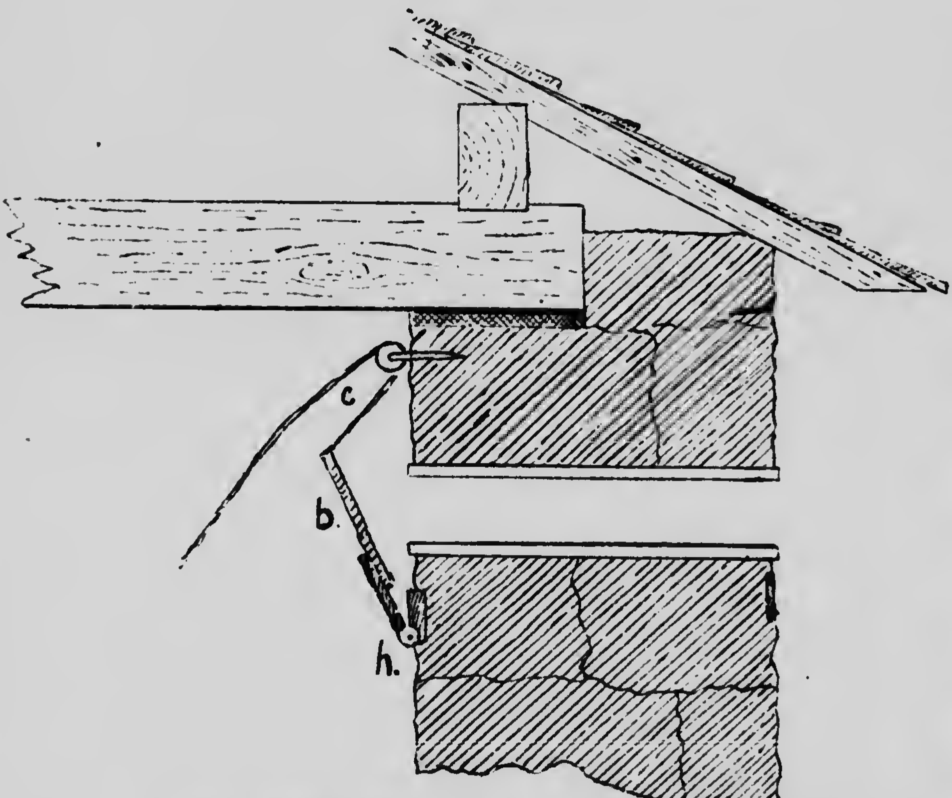

Fig. 4. System of ventilation by means of tile built in the wall.

ning through the wall. These are put in all around the building, and we find the plan gives all the ventilation necessary. If weather is extremely cold, some of the tile may be stopped up with a wisp of hay.

" We also have windows in foundation stand up as in a house, (most barns have them opposite) and top half of the window lowers if extra ventilation is required."

Fig. 3 is a horizontal section of the above plan of ventilation, showing a section through the wall at the level of the tiles. Attention is called to the statement of Mr. Cargill as to the occasional necessity of stopping up the tile with a wisp of hay. The writer suggests another plan for this, the same contrivance serving another useful purpose. Fig. 4 is a vertical section of the wall through one of the tile. The suggestion is that a 12 inch board, marked *b* in the plan, be hinged at *h*, and raised or lowered by a cord *c* passing over a pulley. By drawing the board close to the wall and holding with a hook or button, the pipes are practically closed. By tipping the board more or less on a slant, as in the figure, the incoming air is deflected upward and the danger of drafts may be avoided.

Fig. 5. Plan devised by Prof. King, of Wisconsin. Horizontal projection showing fresh air inlets.

Fig. 6 shows the system of ventilation originated by Prof. King for use in stables, and with his kind permission, the plan and his description of it, are inserted here.

A single ventilating flue D E rises above the roof of the main barn, and is divided below the roof into two arms A B D, one at each side, which terminate near the level of the floor at A. These openings are provided with ordinary registers, with valves to be opened and closed when desired. Two other ventilators, one at each side, are placed at B, to be used when the stable is too warm, but are provided with valves to

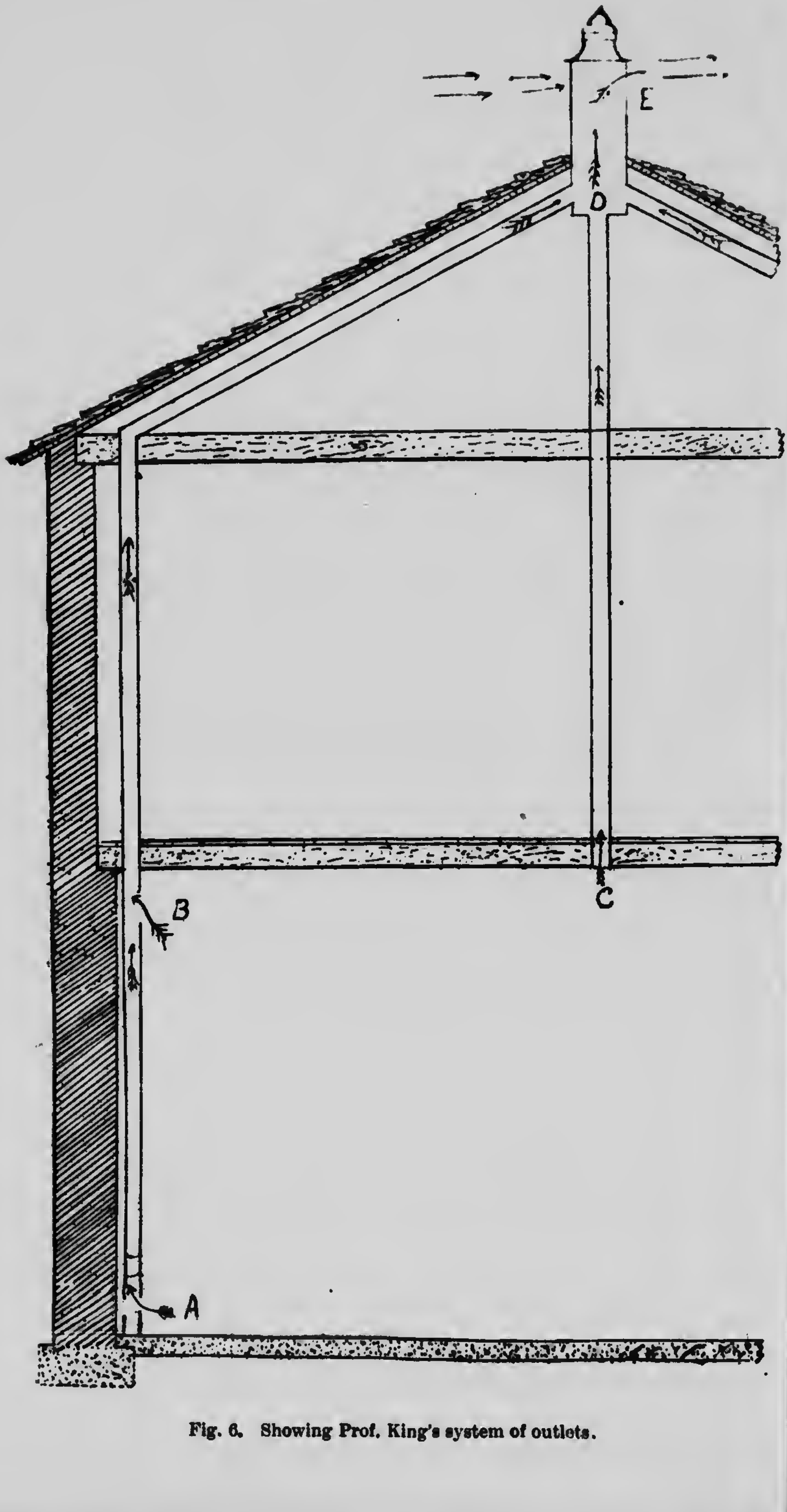

Fig. 6. Showing Prof. King's system of outlets.

be closed at other times. C is a direct 12 inch ventilator leading into the main shaft, and opening from the ceiling, so as to admit a current of warm air at all times to the main shaft to help force the draft. This ventilating shaft is made of galvanized iron, the upper portion being 3 feet in diameter. The a r enters the stables at various points as shown in the plans 5 and 7 at F G.

Next is, represented in Fig. 8, the plan of ventilation in use at the stables of Dr J. G. Rutherford, Dominion Veterinarian, Portage la Prairie. With his kind permission, the description given by himself in his paper on Stable Hygiene is subjoined :

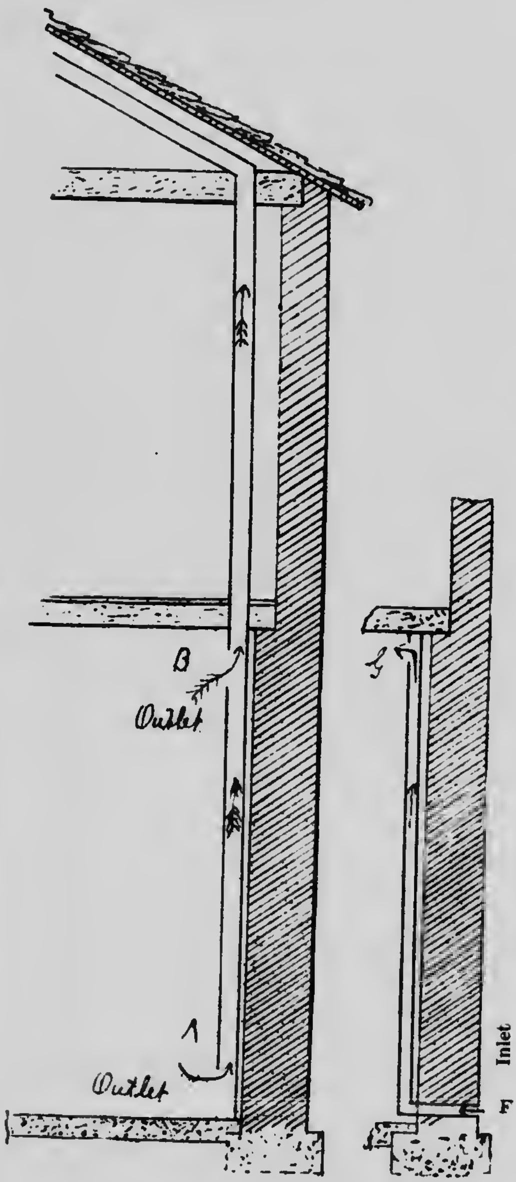

Fig. 7. King.

"I got my first start from a very intelligent English farmer who was on a visit to this Province some eight or nine years ago. He recommended placing U pipes under the wall behind the horses, and drain tile through the wall over their heads, but was forced to admit on cross-examination that when the wind blew in through the latter his ventilation went on strike until the wind changed. I adopted the U pipe part of the plan, using, however, wooden boxes, but substituted for the drain tiles adjustable side louvres at the top of a large shaft running to the roof. These, however, were not a success, for the wind was sometimes in the opposite direction in the morning from that in which it had been at night, and on such occasions the stable smelt to heaven.

"I finally closed up the louvres altogether, putting in, instead, a galvanized iron pipe or chimney of considerable dimensions, furnished with an ordinary rain cap, and a large damper manipulated with cords from the stable floor. When the damper is open, the foul air, being warm, rapidly rises, passes out through the chimney and is steadily replaced by

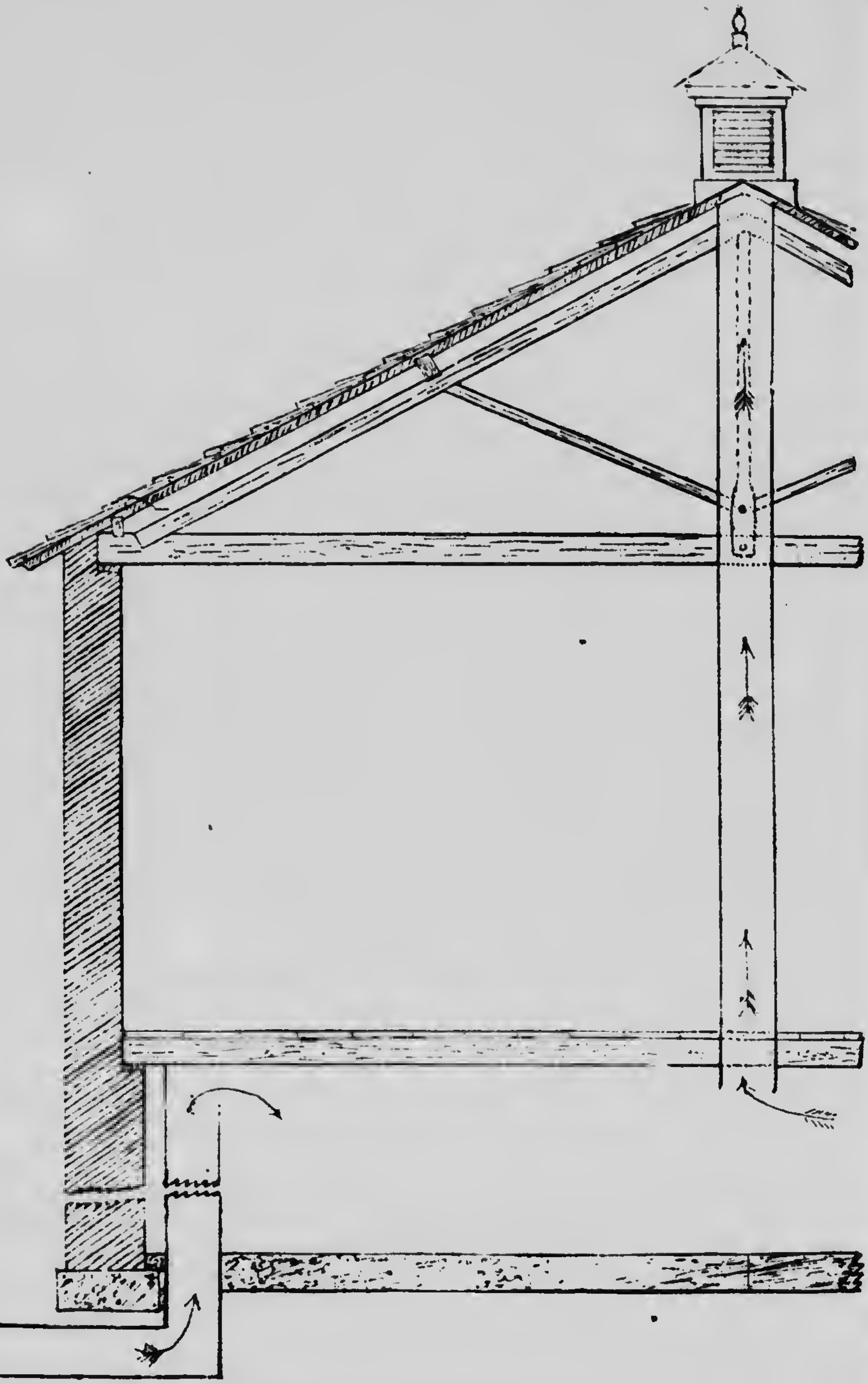

Fig. 8. Dr. Rutherford's plan of ventilatian—U pipes.

fresh air sucked in through the U pipes or boxes. By closing the damper, the inrush of air through the lower pipes is at once checked, while a partial closure has a corresponding partial effect on the action of these inlets. In this way, the whole system is under easy control, and can be adjusted to suit the weather or the number of animals in the stable. . . . This plan has stood a fair trial, having been in operation for upwards of seven years. I may say that I would not exchange it for any system of winter ventilation I have ever seen. . . . By this plan a stable can be kept free from odors, and at a temperature during the coldest weather of from 35 to 40 degrees Fahrenheit, which is quite warm enough for healthy animals of any kind."

By way of further note on this plan of ventilation, it may be added that the outer arm of the U pipe may be of any length that seems advisable, while the inner arm should terminate near the ceiling, or may rise to the ceiling and extend horizontally for some length. Of course, it is understood that this system is not confined to one inlet pipe. The number of U pipes put in will depend upon the number of animals in the stable.

Figure 9 represents an inexpensive system of ventilation that is in operation at Dentonia Park Farm, of the late Mr. W. E. Massey, of East Toronto. The cowl, which revolves so as always to face the wind, is made of galvanized iron, and stands immediately above the peak of the barn, so as to catch the full force of the wind. The wooden box (or iron-pipe, as in the figure), which is the continuation of the cowl inlet, extends down through the floor of the barn to the stable beneath. The joints of the box or pipe should be practically air-tight. At the floor, the inlet shaft may be of wood, but land tile cemented at the joints will make a better and more lasting job. The outlet shafts, of which there should be two at least, in opposite parts of the stable, should extend up into the barn well above the hay and straw, if not quite through the roof. An excellent plan for the outer terminal of the outlet shaft is to provide a cowl that points away from the wind, thus increasing the driving power of the wind by giving it an aspirating effect at the mouth of the cowl. These outlet shafts might be used also as feed shafts for carrying hay or meal from the barn floor to the stable below.

By way of comment, there is given below a report of the working of the system, kindly furnished by Mr. J. B. Ketchen, superintendent of the Dentonia Park Farm. The report was written March 17th, 1900:—

TEMPERATURE. "I should think we had our supply shut off half a dozen times probably during the last winter. We rarely shut the outlet, and by careful watching the temperature can be regulated. In both the outlet and intake shafts there are revolving doors that can be shut by an attached string."

EFFICIENCY. "It is quite satisfactory. A horse stable is the most difficult part to ventilate properly, but in our stables I will guarantee that you could work all day, and your clothes would not have the smell of stables on them."

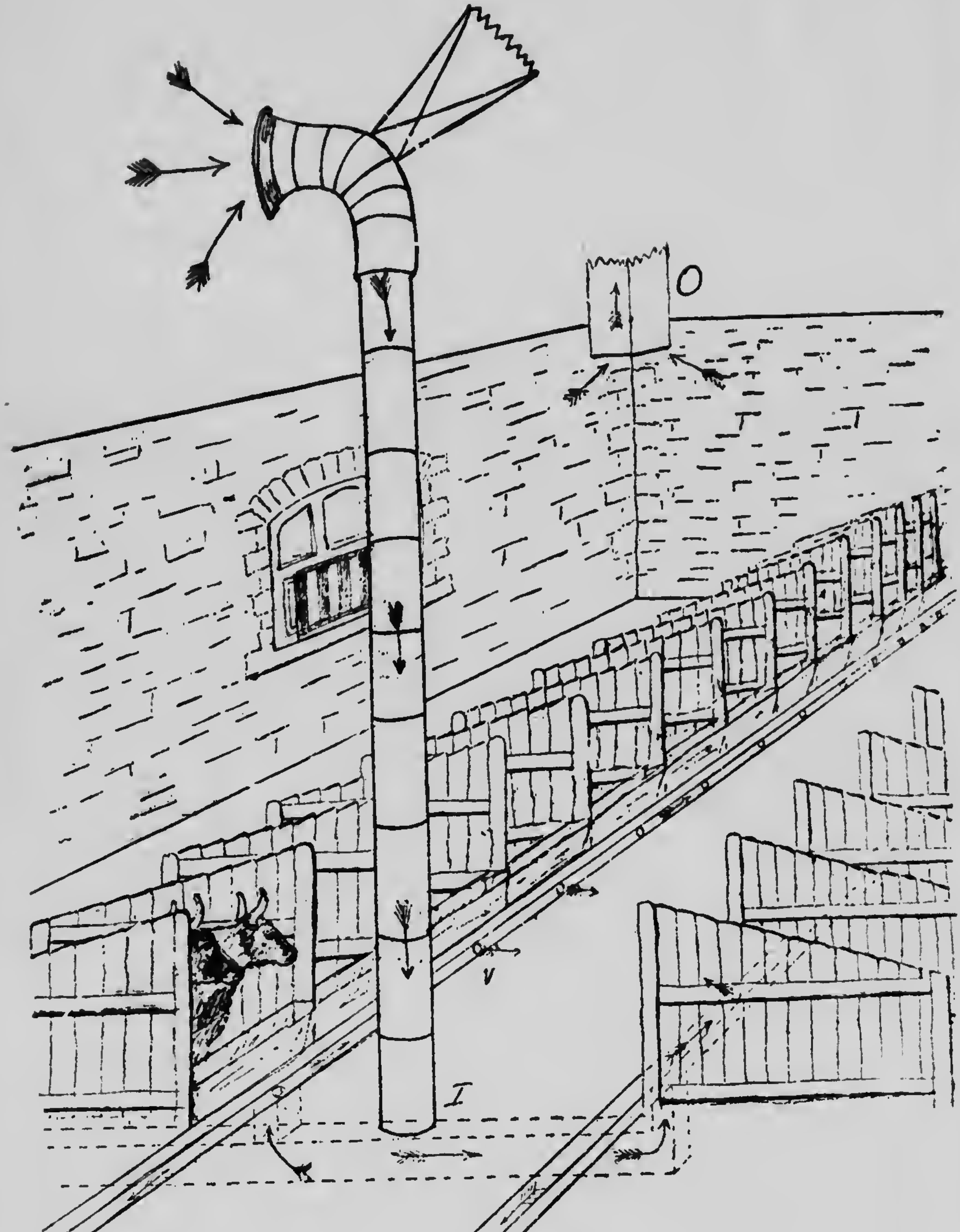

Fig. 9. Mr. Massey's plan of ventilation.

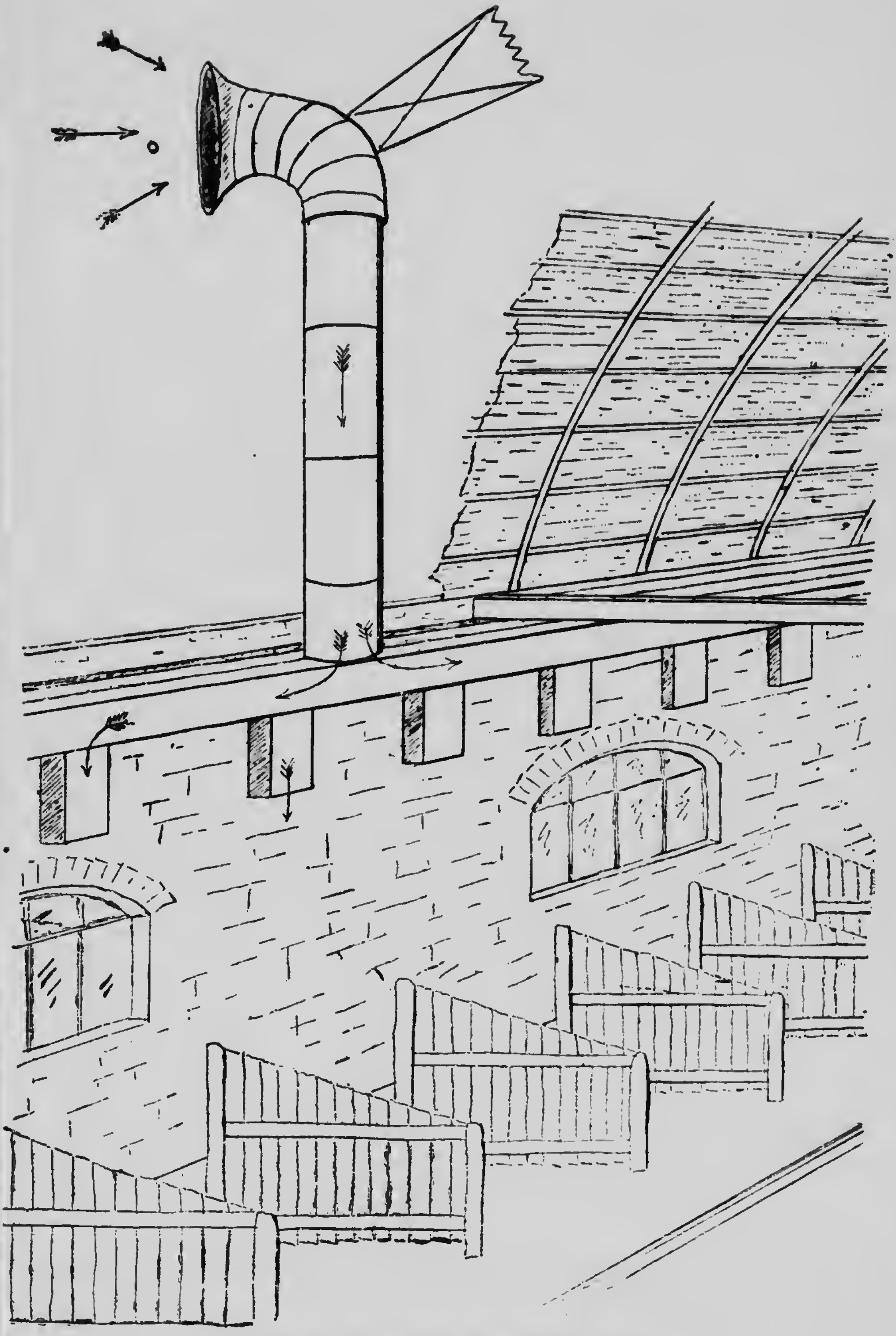

Fig. 10. Ventilation for stables already built.

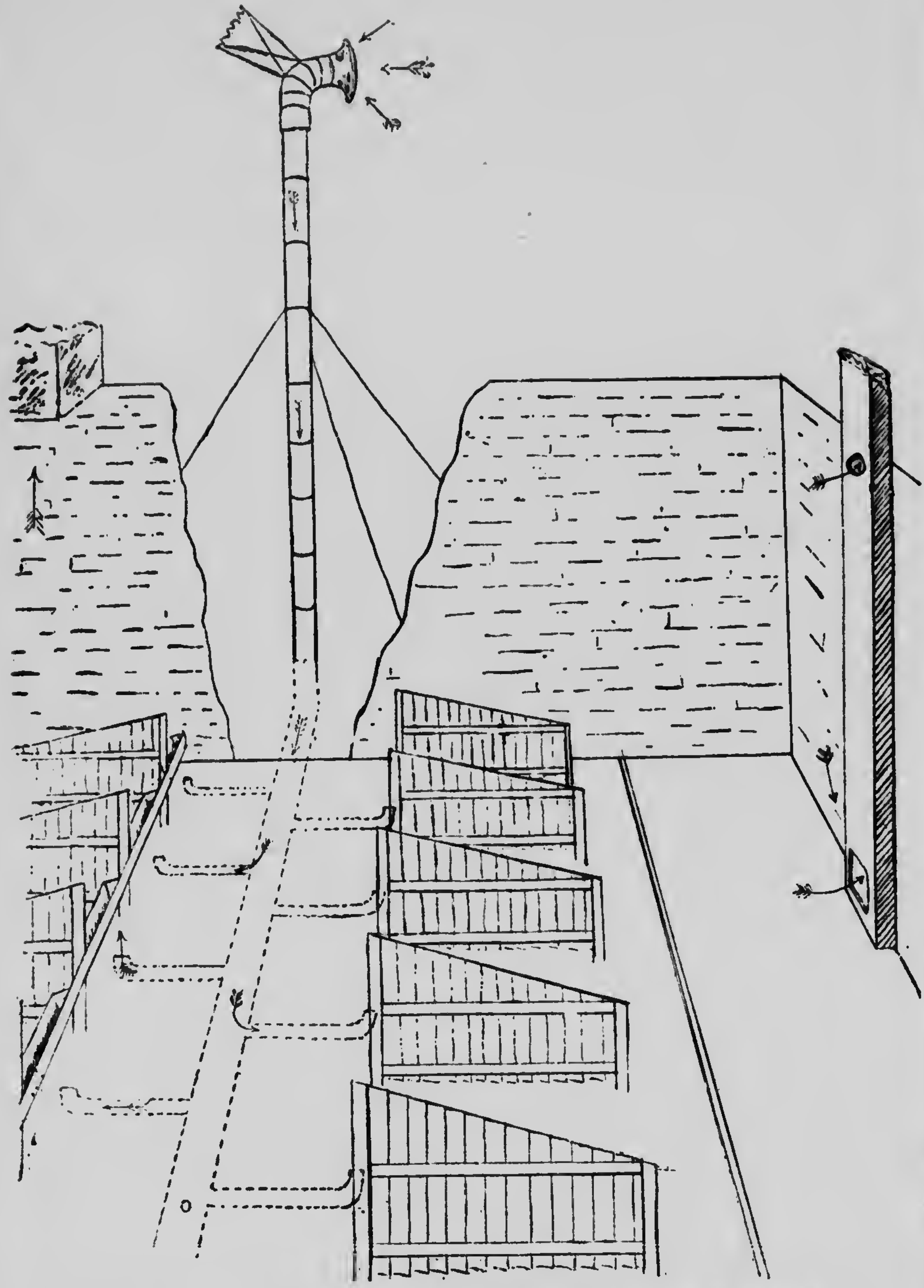

Fig. 11. System of ventilation u[illegible]ng cowl, sub-earth duct, and flue in wall for foul air.

Fig. 10 shows a system on the same principle as that of Fig. 9, except that the air is distributed at the side-wall, instead of at the floor. This plan is suitable for old stables in which the pipes cannot be laid along or under the floor.

Fig. 11 shows the system of ventilation in Mr. Tillson's stables at Tillsonburg. It differs from that shown in Fig. 9 in the following particulars:

1. The inlet pipe, instead of being placed immediately above the roof, stands by itself at some distance from the barn, and the horizontal pipe lies eight (8) feet below the ground until it enters the stable, when it passes just below the floor of the passage. In this way, the air before entering the stable is warmed in winter and cooled in summer. At 8 feet below the ground, the earth temperature varies but slightly through the year, and the sub-earth duct brings the air nearly to a constant temperature.

2. The air is distributed by lateral pipes 9 inches in diameter and 8 feet apart, alternately on opposite sides of the main, and opening out at the floor level just in front of the mangers.

3. The foul-air shafts at the ceiling are supplemented by flues built into the wall about 20 feet apart. Each flue has a square or oblong opening near the floor, and a similar opening near the ceiling. This addition, while it increases the cost, increases the efficiency of the ventilation.

SIZE OF PIPES, SHAFTS, ETC. The inlet pipe is 24 inches in diameter, and is made to do duty for 40 cattle—an area of 11 square inches for each animal. This is less than half the area that has been mentioned as desirable. In this particular case, the amount of air might be doubled with but slight additional expense, by erecting a cowl at each end of the horizontal pipe, and sealing the latter at the middle, so as to virtually make two inlet pipes.

The *laterals* are 9 inches in diameter, and supply air to four animals, which is equivalent to a 4½ inch pipe for each. Such a provision is ample on a cold day, but not so on a calm mild day. It is best to supply sufficient space for the lowest rate of supply, since on a windy day, when the rate of supply is greater, the area can be diminished by shut-offs.

The *ceiling outlets* represented in Fig. 11 are in the original 4 feet square,—much larger than is necessary for ventilation, but convenient for the secondary use to which they are put, namely, to serve for feed-chutes. Mr. Tillson informed us that on account of the large size of these ventilators, a down draft was sometimes felt coming from them. In order to prevent this, and at the same time to allow of their use as feed-chutes, it would be a good plan to build them the size required for the second purpose, to a sufficient height, and then reduce them to about 18 inches or 2 feet square.

The *flues* are built in the wall and extend like chimneys well above the eaves. They are not essential to stable ventilation, but undoubtedly improve it, especially in large crowded stables. The openings near the floor provide a way of escape for disagreeable odors from the gutters, at points remote from ceiling shafts. Also any heavy gases that have settled to the floor are best got rid of by this means.

The *sub-earth duct* is to be recommended for winter stabling, but is less desirable in summer. In summer the outside air after passing through the underground duct rises in relative humidity, and becomes somewhat damp. Where summer stabling is practised, the sub-earth duct may be an undesirable feature.

Improved Ventilation of Farm Stables at the College.

When the present barn and stables at the College were built, a system of ventilation was devised and put into operation. The plan included three large louvred ventilators on the roof, connected with 10 boxes 2 ft. by 1 ft. passing down through the barn to the ceiling of the stable below. These ten boxes, 20 square feet of space in all, were intended as outlets, no inlets for fresh air being provided. It was found, especially in the winter, as a consequence of lack of inlets, that the outlet pipes were frequently converted into inlets, and cold, disagreeable down drafts were felt coming from the ceiling openings Also, when the pipes consented to act as outlets, they returned part of their cargo in the form of condensed moisture, and there was a constant dripping. The result was, the outlets were kept stuffed with straw in the winter, and there was no ventilation.

The improved plan was built in the summer of 1901, and conbined the two schemes represented in Figs. 9 and 10 above. Where possible, the air was carried to the floor of the stable, and distributed as in Fig. 9. In certain parts of the stable, however, it was impracticable to lay boxes along the floor ; in such cases the air was distributed as in Fig. 10.

Prof. Day's report on the working of the scheme is appended. The report was written on Feb. 14th, 1902 :—"The system of ventilation put in last autumn has been in operation about three and one-half months, so that we are in a position to judge of its efficiency. Unfortunately, our carpenter had not time to finish the work, and there are several important details yet to attend to. Chief among these are the outlets for foul air, which we purpose locating at intervals along the walls of the stable. They were to consist of shafts running from near the floor of the stable to the ceiling, and out through the side of the barn just above the stone wall of the basement. Each shaft was to have an opening at the floor and also one at the ceiling, the one at the ceiling having a trap door so that it could be opened and closed at will. In mild weather the upper outlets would be opened, but in very cold weather these would be closed, and only the colder air from the floor would be removed. In this way the temperature of the stable would be well under control. At present we have simply the original straight ventilating shafts running from the ceiling up through the centre of the barn to the roof. In very cold weather these shafts carry off the warm air too rapidly and we are forced to almost close the inlets to prevent freezing.

"In spite of the disadvantages mentioned above, there is a wonderful improvement in the air of the stable compared with previous conditions. Before we put in our present system, the air was close, clammy, and foul smelling. Now, it feels dry and healthful, though on the cool side. A somewhat cold, dry air, however, is much preferable to the damp, stifling warm air encountered in so many stables. Our cattle, including small calves, appear to suffer no inconvenience from a temperature of 40° because the air is dry. The same animals in a temperature of 55° to 60°, where the air is damp and foul, would suffer much more discomfort, to say nothing of the danger to health.

"There is no doubt that the system of ventilation is a success, even in its incomplete form and when the outlets are properly arranged the results will be eminently satisfactory."

Ventilation of Houses.

For the same cubic space, the number of occupants is usually much less in a house than in a stable. Nor does the contamination of the air in houses, for reasons not necessary to mention, proceed so rapidly as in stables. In addition, doors and windows are usually more plentiful, and chimneys, stoves, furnaces, and fire places aid materially in keeping up a ventilation without effort or extra cost to the occupants. To keep houses tolerably well ventilated should therefore be comparatively easy. And yet most houses are badly ventilated even in summer, and still worse in winter. The reasons for this state of things are manifold: First, many people have a horror of fresh air in the house, it being often associated in the mind with dampness and drafts; secondly, open windows and doors provide a way in for flies, and when it comes to a choice between two evils, the immaculate housekeeper prefers to keep her house closed up tight rather than admit flies; thirdly, in winter, changing the air of a room frequently means more fuel, since the incoming air has to be warmed. In spite, however, of this combination of circumstances and prejudices operating against a thorough and perfect ventilation, a partial and irregular ventilation is [illegible]ation in

Fig. 12. House ventilation, showing lower sash raised and a board under.

all dwellings. The plans and suggestions given below, will, it is believed, aid in giving a more regular ventilation, in some cases to single rooms that are most constantly occupied, in some cases to the whole house.

VENTILATION OF SLEEPING ROOMS. It is undoubtedly a safe principle to lay down, that for persons in health, at least, it is more wholesome to have the air of the sleeping room pure, even if it is chilly, than impure, fetid and warm. Of course, many persons who have been accustomed to

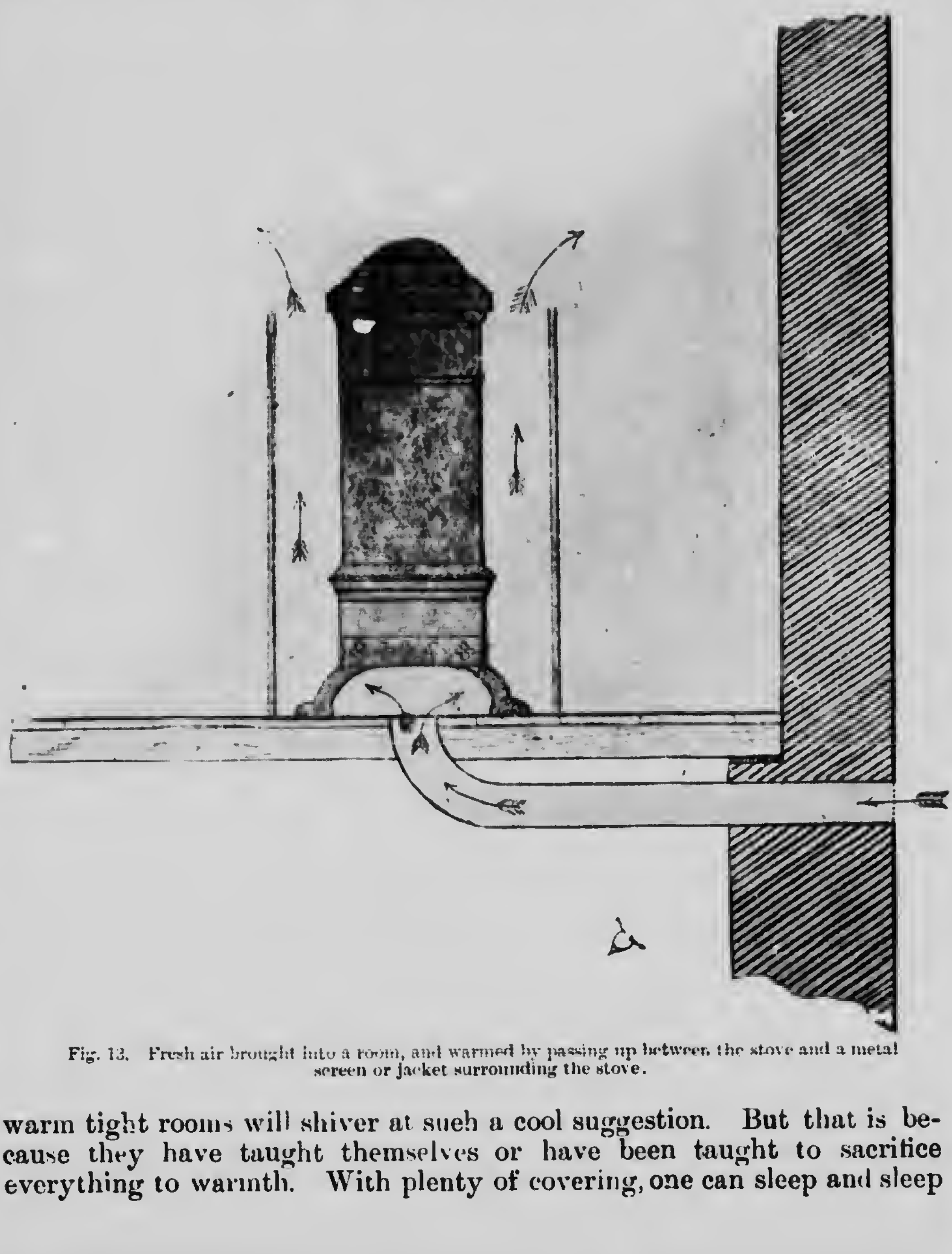

Fig. 13. Fresh air brought into a room, and warmed by passing up between the stove and a metal screen or jacket surrounding the stove.

warm tight rooms will shiver at such a cool suggestion. But that is because they have taught themselves or have been taught to sacrifice everything to warmth. With plenty of covering, one can sleep and sleep better in a fresh cool atmosphere than in an atmosphere that is hot and stagnant. And there is no comparison between the healthfulness of the two conditions. With a window and a door in a room pretty good ventilation can be secured at almost any time. Even a draft is not objectionable if one does not lie directly in the draft But drafts can be avoided by opening the lower sash and placing under it a board of the same width as the sash, as in Fig. 12. The air will find its way in between the sashes, and will stream upwards and spread without creating a draft. The impure air will find its way out of the doorway, the fanlight, or even under the closed door, if a small space is left below the door. Two windows in the room, raised as in Fig, 12, will give very good ventilation.

VENTILATION OF LIVING ROOMS. Any room that is occupied by the family during the day may be ventilated in winter with the aid of the stove or stove pipe. A valuable adjunct to all stoves used principally for heating is a *metal screen* or *jacket*, fastened to the floor and surrounding, or almost surrounding, the stove. This screen serves as a protection from the intense heat of the metal, and at the same time presents a larger radiating surface than the stove itself would do. But it is chiefly as an aid to ventilation that the metal screen is introduced here.

Fig. 13 illustrates a simple and efficient means of ventilation by use of the screen The fresh air is brought in from the outside by a pipe under the floor, and passes into the room under the stove, and within the jacket space. The heat of the stove warms the air, and causes it to ascend, until finally it emerges from the jacket and spreads over the room. By such a device a circulation of the air is kept up, and a more uniform and comfortable temperature maintained throughout the room. This plan is especially to be recommended for school-rooms heated by stoves.

Fig. 14 illustrates a method of making use of the heat from the stove-pipe to provide fresh warm air for an upper room, or, if desired, for the room in which the stove stands. The fresh air is introduced as in the preceding illustration, the pipe rising through the ground floor and up through the floor above, widening out just after it leaves the lower floor so as to contain the stove-pipe, and at the same time to carry the required volume of air. The heat from the stove-pipe warms the air, and thus causes a current to ascend continually. By this means a constant stream of fresh (warm) air is passing into the bedroom above.

REMOVING FOUL AIR. The foregoing suggestions on House Ventilation relate to fresh air and to methods of bringing it into rooms. But in order to be able to bring in fresh air, the air which is already in the room must be drawn off. To this end, in addition to the ordinary means that require no care or contriving, there are certain devices of a special nature, yet simple and inexpensive. The best contrivance for removing foul-air is the *chimney flue.* With two or more flues built in the same stack, one of which is used as a smoke flue, when the latter is in use the smoke ascending warms the adjacent flue. If between this flue and the room through which it passes, openings are made for air, the warming of the air in the flue will create a draft upward. the air will be drained out

NOTE.—Illustrations Nos. 13, 14 and 15 are taken from Billings' Ventilation and Heating.

of the rooms and up the chimney, and thus the latter will serve the purpose of a ventilator. For this purpose, and also for the purpose of insuring a good draft for stoves, *all chimneys should be built in the interior of the house* and not in the outside wall. For good draft, either for smoke or foul air, the chimney requires to be kept warm, and there is much less loss of heat from an inside chimney than from one built on the outside.

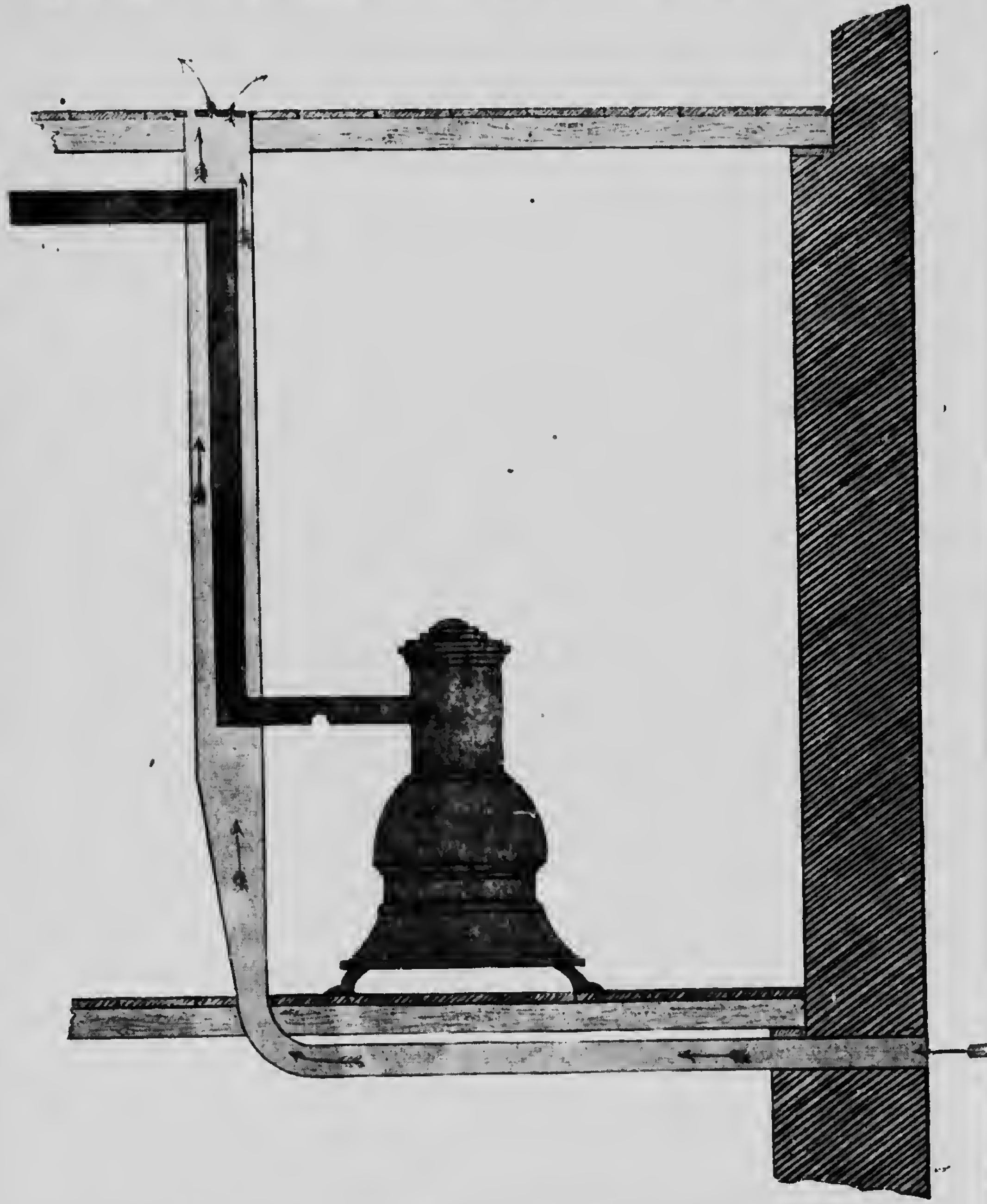

Fig. 14. Using heat from stove pipe to warm the air and to create a convection current. Furnishing warm fresh air for an upper room.

Fig. 15. Using heat of stovepipe to create a convection current for removing foul air.

All methods of removing foul air, though they may differ in detail, are identical in principle with the foregoing. In large city buildings and in schools of the more modern type, the flue is heated by means of a steam-pipe situated at its base, or, instead of the coil, a small coal-heater, called the auxiliary. The important thing to emphasize here is the *principle* by the operation of which a draft from a room is continually kept up. Knowing the principle, anyone interested can work out his own details; for each house, especially one that is already built, is a separate and distinct problem, the requirements of which could not be anticipated by even the fullest details.

One method whereby in the absence of the chimney flue, the latter may be successfully imitated, is given in the accompanying illustration, Fig. 15. In this case, it is supposed that the house is a two-story one, and that the chimney comes down only a short distance below the ceiling of the second story. The opening in the chimney is enlarged so as to admit a jacket for the stove pipe, much larger than the enclosed pipe. The jacket may be extended, as in the illustration, to the ceiling of the room below, and may thus be used to ventilate both rooms.

SUMMARY.

All plans of ventilation, to be effective and satisfactory, should possess in a greater or less degree, the following properties :

1. A motive force, by means of which the air is introduced and withdrawn.
2. A means of tempering the air before it enters the room.
3. A means of distributing the air uniformly over the space where it is required, and avoiding drafts and strong currents.
4. Sufficient provision for drawing off the foul air.
5. Automatic action.

The combination of all these properties, in the right degree, makes perfect ventilation, and no ventilation is perfect without this combination. Yet without all of these, very satisfactory ventilation may be had. If the external force is dispensed with, such a force as is represented in Figs. 9 and 11, there is still the heat from the bodies and the warm air from the lungs keeping up a constant upward motion of the air. If it is impossible to distribute the air as uniformly as seems desirable, then let the distribution be as good as possible, and it will be a long way ahead of no ventilation at all. If the plan cannot be made automatic, then it simply means more or less constant attention, and the time thus spent will be well spent.

With the preceding plans of ventilation, and the accompanying comments and instructions, the stockmen or householder may choose for himself, whether he wants the best and is prepared to pay for it, whether he will be satisfied with a fairly good system that yet has some disadvantage, or whether he will be content with an apology for ventilation, or with none at all.