CONTRIBUTIONS TO PRACTICAL RAILROAD INFORMATION.

No. XXVI.—The Ventilation of Passenger Cars.

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It seems not improbable that if a vote of the general traveling public could be taken on the question as to what improvement or change in passenger cars at the present time would most conduce to the comfort of passenger travel, a very large majority of the ballots would be in favor of an improvement in car ventilation. It is to be confessed, we think, that the discomfort attendant on riding a number of hours in a stuffy, over-heated passenger car, and especially the annoyance and discomfort from spending the night in an over-heated, ill-ventilated Pullman car, are so great that it is not at all surprising that not only individual passengers but also the technical papers, and, indeed, the general press of the country, should from time to time break out into a tirade against the present condition of the ventilation of passenger cars. It is claimed that there are cases on record, where passenger car windows are fastened down, of passengers deliberately breaking the glass and paying for the same, in order that they might enjoy the benefit of fresh air. We think it fair to say, on the other hand, in justice to railroad officers, that the condition of affairs is not and has not been in the past entirely ignored by them. They are entirely conversant with the fact that the present passenger coach, and especially the Pullman car, is not properly ventilated, and it is not because of indifference, but because of the extreme difficulty of the problem that no more decided action has been taken in the past. If we succeed in what we have planned in this article, we think the difficulties to be overcome in the proper ventilation of passenger cars and the reasons for the present state of affairs, will be better understood by the general public, than they are at the present time.

The question of car ventilation has been studied more or less for a number of years. Under the auspices of the Railroad Commissioners of the State of Massachusetts, some fifteen or twenty years ago, quite a number of analyses of the air from passenger cars were made by Professor Ripley Nichols, of the Massachusetts Institute of Technology, Boston. Furthermore, not less than fifteen years ago a number of analyses of air from the cars of the Pennsylvania Railroad were made, and in 1893 or 1894 a committee of the Master Car Builders' Association made a long report on car ventilation, accompanying that report with analyses of air from Pullman cars, together with the analyses of air from other cars of passenger equipment. Still further, the records of the Patent Office show a very large number of devices which have been suggested from time to time by inventors for accomplishing this desirable end. It should not be overlooked that most passenger cars have some appliances by which fresh air is introduced, or an approximation at least toward a system of ventilation. Some of these are apparently inefficient and poor, and some are better, so that the subject has certainly not entirely escaped attention. In addition to what has preceded it may be stated that for not less than ten years past very careful and systematic study has been put on this problem by the experts of the Pennsylvania Railroad Company, and while it is not proposed in this article to show completely what has been accomplished, it is fair to say that very great encouragement has been met with, and that the outlook for a successful system of car ventilation seems to be very promising.

The first step in the study of any problem is naturally to know what the present state of affairs is. This, so far as car ventilation is concerned, may be briefly stated as follows: Assuming that ventilation means change of air, and that what is desired is to get sufficient fresh air into a car and to remove the foul air, the analyses above referred to indicate that the ordinary passenger coach and Pullman car get from one-sixth to one-tenth as much air per hour through them as is required for good ventilation. There is a fairly close agreement between the analyses from all the sources mentioned above, so that we may, perhaps, be entitled to conclude that a very much larger amount of air than is at present obtained, is requisite for good ventilation in passenger cars.

Perhaps we shall best make clear what follows by asking a series of questions bearing on this subject, and answering these questions to the best of our ability. But before doing this it may not be too much to say that no problem in engineering has, in our judgment, ever been undertaken which is so fraught with difficulties as the ventilation of passenger cars on railroads. A few words will make this point clear.

An ordinary passenger coach contains about 4,000 cu. ft. of space. It is proposed to take into this space sixty persons, to keep them in this space continuously without allowing them a chance to get out, for from four to six hours at a time, to keep these persons warm enough for their comfort in winter and to supply them with the proper amount of fresh air, and at the same time to exclude objectionable material, such as smoke, cinders and dust from them. Certainly here are difficulties enough. The shape of the car itself, being long and narrow, the very small space compared with the large number of people, the question of keeping the people warm, and the exclusion of objectionable matter from them—each one of these items is a problem in itself, sufficiently difficult to tax the skill of the best experts, and when all are combined in one it is little wonder, apparently, that progress has been so slow.

The first question which we will consider is: Is it necessary to ventilate cars both winter and summer? It would naturally be expected that the doors and windows would be sufficiently satisfactory sources of fresh air in the summer season, and that, therefore, it would only be necessary to study the subject of car ventilation for the winter. Unfortunately part of the problem, as already stated, is to exclude objectionable material from without and on dusty roads, it is absolutely essential, even in warm weather, to keep the doors and windows closed on account of dust. Furthermore, smoke and cinders from the locomotive not infrequently are annoying even in the summer season, so that it seems fairly probable that a good system of ventilation should be operative both in winter and in summer, and in the studies above referred to in connection with the Pennsylvania Railroad, this phase of the case has been constantly in mind.

The next question is: Is it possible to have a ventilation system apart from the heating system? It has been urged in the technical press, and in conversation with would-be experts, that it is an easy matter to ventilate cars: simply let air in, and provide places for the foul air to get out. We are compelled to say that we think this is a very unsatisfactory view of the case. In this climate it is simply impossible to let fresh air into the cars in the winter season without warming it, and, consequently, it is perfectly clear that studies on ventilation must at the same time take into account the heating system of the car. Some systems of car ventilation, if they may be called systems, are little more than apertures in the car, and some so-called systems simply attempt to exhaust air from the car, without providing inlets. So far as our knowledge goes, the experience with these systems is that neither of them can be used for any length of time. One can stand a little cold air for a few minutes, but as will be seen a little later, when we come to consider the amount of air required, it is a little short of an absurdity to attempt to ventilate a car without at the same time warming the air.

Just at this point a very interesting question comes in, namely: Is there any means by which we may know when a car is well ventilated or not, and if so what is this means? Upon this point it is fair to say that there does not seem to be agreement among the experts, and it is possible that as time progresses and our knowledge increases, the rule which is given below may not be adhered to, but at the present time the following is accepted as the measure of good ventilation. A space, be it a car, a room, or a theatre, or whatever may be which is chosen, is said to be well ventilated when a person coming into this space from the outside fresh air detects none of the odor characteristic of a badly ventilated space. Unfortunately, we have no means of measuring odors, but there is one of the accompaniments of the odor which is characteristic of badly ventilated spaces that is easily measured.

Let us see if this can be made clear. Three things are continually given off from our bodies, namely, carbonic acid, water vapor and organic matter. Every time we breathe, we breathe out some carbonic acid, we breathe out some water vapor, as everyone knows who has been out on a cold morning; and we also breathe out, or there is exhaled from our bodies, a certain substance, which, for want of a better name, is simply called organic matter, and which is believed to be the source of the odor. Of these three substances, carbonic acid is easily measurable, and it is customary to take the amount of carbonic acid in the air as the measure of good ventilation.

Many years ago, before this latest test already mentioned was introduced, it was customary to place an arbitrary limit on the amount of carbonic acid that should be allowed in the air in spaces which were said to be well ventilated. That is to say, twenty years ago, if the amount of carbonic acid in the air in any given space did not exceed 10 cu. ft. in 10,000 of the air, that space was said to be well ventilated; but later studies have changed this view. A very large number of analyses of air have been made to find the amount of carbonic acid that is characteristic of the air when you can just begin to detect an odor. In Parkes' "Practical Hygiene" there is given a summary of a very large number of such analyses, giving the amount of carbonic acid that is in the air, when one can just begin to detect an odor. The average of these analyses indicates that when two parts, or 2 cu. ft. of carbonic acid that comes from our bodies, or the bodies of animals, in 10,000 of air is found, one can just begin to detect an odor in a closed inhabited space. Therefore, two cubic feet of carbonic acid given off by human beings or animals in a closed space, in 10,000 cu. ft. of air, is taken as the test or measure of good ventilation. It should be said for information, perhaps, that the air in different parts of the world, and from many different places, has been analyzed a good many times for carbonic acid. From these it is found that there is a certain normal amount of carbonic acid in almost any air. The air in any room, even if the windows were wide open and the room vacant, would contain a small amount of carbonic acid. The averages of these analyses—they vary somewhat, in towns the amount is larger than in the country—is about 4 cu. ft. in 10,000; that is, 10,000 cu. ft. of air contains normally 4 cu. ft. of carbonic acid. If we add to that the two that come from our bodies we would find in a well ventilated space an amount of carbonic acid not exceeding 6 cu. ft. in 10,000. The various analyses referred to in the early part of this article show carbonic acid varying from about 15 to 25 parts per 10,000 in the air of cars. If we deduct the four parts which are characteristic of normal air, this leaves from 11 to 21 parts per 10,000 furnished by the passengers, and since good ventilation, as already stated, should only show an increase of carbonic acid of two parts in 10,000 over the normal, it is evident that, as already stated, the passenger and Pullman cars of the country are apparently getting approximately from one-sixth to one-tenth the amount of air that is required for good ventilation.

The point which we are leading up to, and which we will discuss in the next paragraph is: How much air is actually required per car per hour in order to give satisfactory ventilation? Before taking up this question, however, there is another question that must be discussed, and that is: How much carbonic acid do human beings give off per person per hour? A good many experiments have been made on this point by different investigators. It is found, if we are right, that men give off more than women, and children less than either, and that a man at vigorous work gives off more than a man in idleness. The studies show, so it is stated, at least in Parkes' "Practical Hygiene," that the average of a mixed community, men, women and children, as they occur, give off 6/10 of a cubic foot of carbonic acid per person per hour, part of this coming from the lungs and part from the skin. Since the people traveling on cars may be fairly regarded we think, as representing a mixed community, that is to say, men, women and children, it will, perhaps, be safe for us in our calculations to use this figure, 6/10 of a cubic foot of carbonic acid per person per hour.

This brings us to the discussion of the question just previously stated, namely: How much air per car per hour is needed to properly ventilate a car? It is apparent that if each person gives off 6/10 of a cubic foot of carbonic acid per hour, and there are 60 people in the car, there would be generated or given off in the car per hour, 36 cu. ft. of carbonic acid. The problem then becomes: How much air is it essential to mix with these 36 ft. of carbonic acid in order that the resulting mixture shall contain 2 cu. ft. of carbonic acid in 10,000 of the mixture in addition to the 4 cu. ft. which are characteristic of the normal air? This is a very simple proportion, namely, if 10,000 cu. ft. contain 2, how many thousand cubic feet will be required to contain 36 cu. ft. on the same ratio? Making the calculation and we reach the astounding figure that in order to have a passenger car well ventilated, in accordance with the tests and data that have already been given, it actually requires that 180,000 cu. ft. of fresh air per hour should be taken through the car. We fancy most railroad operating officials, as well as the general public, who have not given the subject careful consideration, will be astonished at this figure. It actually means that the air in a car must be changed about 45 times an hour or once in about 80 seconds.

It is fair to say that in the best information which we can get hold of on ventilation, this is the figure adopted, namely, 3,000 cu. ft. of fresh air per person per hour are requisite for good ventilation of closed spaces. In other words, the best authorities that we can consult on the subject lead up to this figure. Two points, however, may be mentioned as possibly modifying these requirements. First, some studies were conducted a few years ago in Washington, the results of which were published by the Smithsonian Institution, the object of which among other things was to find out to what the drowsy feeling that we have noticed when in ill-ventilated places was due. These studies did not reach any definite conclusion as we read them, but seem to point to the conclusion that 3,000 cu. ft. of air per person per hour was a large figure. The authors of the paper were, however, very cautious, and while their studies did not succeed in isolating any poisons given off from the bodies of human beings that would produce drowsiness, and possibly more serious consequences, they finally say in so many words that their experiments do not entitle them to change the ordinarily accepted figure.

Other points bearing on this question are the experiments made with the human calorimeter, in connection with the Middletown University, by Professor Atwater. In conversation with him on the experiments made with this calorimeter, it was stated that there seemed to be no complaint from the inmates of the calorimeter, due to an increase in the amount of carbonic acid. The analyses of the air taken out of the calorimeter might indicate very much larger amounts of carbonic acid than any figures given above show, and yet the inmates did not complain of drowsiness or of any unpleasant feeling. If, however, the amount of moisture in the air got much above the normal, drowsiness and unpleasant feelings, with occasional headache, seemed to result. With the present state of our knowledge, the best that can be said is perhaps that the question as to the absolute amount of air required for good ventilation is in a moderately uncertain condition, and that there is need for much more definite work on the subject than has yet been done. For information it may be stated that so high a figure as 180,000 cu. ft. of air per car per hour has not been attempted in the experiments referred to above on the Pennsylvania Railroad. To get such an amount of air as this through a car per hour, and to warm it in severe weather, is a more difficult problem than we have ever attempted to solve. The experiments on the Pennsylvania Railroad have been confined to at attempt to get 60,000 cu. ft. of air per car per hour, or 1,000 cu. ft. of fresh air per person per hour through the car.

Questions in regard to the amount of heat and heating surfaces required to heat 60,000 cu. ft. of air per car per hour, questions in regard to the appliances made use of in accomplishing the results thus far obtained, questions in regard to the details of the experiments, questions in regard to the exclusion of objectionable matter from without, the method of obtaining control of the system, the analyses of the air from cars, with and without the system, etc., will have to be deferred to another article. Two points farther may perhaps be reasonably touched upon in this article.

The first of these has a bearing on the attempts made so often by those who have not apparently sufficiently studied the problem, to get ventilation by putting on ventilators. In one of our experiments as many as 20 Globe ventilators were put on the deck of a car, proper appliances having been made use of, as was supposed, to admit sufficient air to the car. It was found as the result of these experiments that the ventilators on the front end of the car, especially when the wind was ahead, acted so vigorously in producing a vacuum in the car that actually the Globe ventilators on the rear portion of the car took in air instead of exhausting it, as it would naturally be supposed they would do. In other words, this experiment, we think, most conclusively proves that there must be a proper relation between the supply of air and the exhaustion of air. It may be worth mentioning that the peculiarity found when the car was running was that the rear of the car was a great deal colder than the front end, and in the attempt to find why this was so, the point mentioned above, of the cold air coming in through the Globe ventilators in the rear of the car was developed. We are very firmly convinced that exhaustion of air from any space is not ventilation. There must be fresh air supplied as well as the removal of all polluted air from the space that it is sought to ventilate.

One question further: How is it possible to measure the amount of air that goes into and out of a car per hour? We have already spoken about the enormous amount of air required, according to present ideas, for successful ventilation, and also that the attempt had been made in the experiments on the Pennsylvania Railroad to get 60,000 cu. ft. of air required through the car, but how do we know, or what means is there for telling whether we get 60,000 or 40,000 or 100,000 cu. ft. of air per car per hour through the car? This problem is not so simple as it looks. Obviously, with the leakages and the friction of the air in the ventilators, any attempt to measure the amount of air by taking the velocity of the current issuing from the Globe ventilators would be fallacious. The air issues not only from the Globe ventilators which are put on for the purpose, but also from the ventilators over the lamps. Furthermore, any attempt to measure the velocity of the current from the intakes would probably result in failure, owing to the fact that around doors and windows there are constant leakages; so it is obvious that some means of measuring the air other than by taking the sizes of the apertures and velocities through these apertures must be made use of.

The data already mentioned, we think, gives us a means of getting at what we are seeking. It has already been stated that the average of a mixed community gives off 6/10 of a cubic foot of carbonic acid per person per hour. If now we have a definite number of people in the car, and can safely assume that on the average a certain amount of carbonic acid is given off per person per hour, it is obvious that we can very readily calculate how much carbonic acid per hour we have to deal with: and this being known, a very simple calculation, as already shown above, will give the amount of air required to dilute this to any given figure. What was actually done in our experiments was, the cars were loaded with men from the shops, in charge of a foreman, so that the doors and windows could be kept closed, and a trip of 30 or 40 miles made. Toward the end of the run, samples of the air in the car were taken, which were analyzed for carbonic acid. If, for example, it was found that the amount of carbonic acid in the sample showed 11 parts in 10,000, we have the data to calculate how much air passes through the car per hour, as follows: It has already been stated that the air normally contains four parts of carbonic acid in 10,000. If we diminish the 11 by 4, it is obvious we have 7 parts of carbonic acid per 10,000 of air as given off from the passengers. There being, say, 60 men in the car, and since they are full grown laboring men, the amount of carbonic acid given off being stated by the authorities as somewhat higher than the average of a mixed community, say 0.72 cu. ft. per person per hour, instead of 0.60 cu. ft., it is obvious that we have 43.20 cu. ft. ($60 \times 0.72 = 43.20$) of carbonic acid to deal with, and our problem really is, How many cubic feet of air are required, in order to dilute 43.20 cu. ft., so that the amount will be 7 parts in 10,000 of the air? Now, by a very simple proportion, if 10,000 cu. ft. of air contain 7 parts of carbonic acid given off by the passengers, how many thousand cubic feet of air will be required to dilute 43.20 cu. ft. to the same ratio? Making the calculation, we get, under the conditions supposed, a trifle over 61,700 cu. ft. It will be understood that in this calculation extreme accuracy to the amount of a few cubic feet is not aimed at, and also that since the cubic feet of space in a car is so small, and the air in the car changed so frequently, the amount of air in the car to start with has been ignored.

It is, perhaps, not premature to say that the system worked out on the Pennsylvania Railroad has been in use on five cars for considerably over a year. It may be too soon to speak positively farther in regard to the success of the system, and it is possible that additional experimentation will be needed before it can be called satisfactory. It is not too much to say, however, that the outlook is hopeful.

Mr. R. H. Soule, Member A. S. M. E., recently resigned as Western Representative of the Baldwin Locomotive Works, and has opened an office at 71 Broadway, New York, as Consulting and Designing Engineer. He will make a specialty of plans and specifications for locomotives, cars, shops, machinery, power plants, mechanical and electrical equipment, investigations and reports, also appraisals and valuations. We know of no one better able to bring so varied and extensive an experience to bear upon such questions, and doubtless many railroad officers will be glad to avail themselves of his opinions and advice. Mr. Soule is splendidly equipped for the greatest motive power responsibilities, and while no single corporation will now enjoy his exclusive attention, his work will remain in the line of transportation subjects, but his field is widened. He graduated from Harvard College in 1870, and from the Massachusetts Institute of Technology in 1872. After spending two and a half years in machine shops, such as the Southwark Foundry, Philadelphia, he entered railroad service in the Mechanical Engineer's office of the Pennsylvania. After passing through the grades of Signal Engineer and Assistant Engineer of Tests, he was made Superintendent of Motive Power, successively, at Baltimore, Williamsport and Columbus, Ohio. After that he served two and a half years as Superintendent of Motive Power of the West Shore, then for one and a half years in the same capacity on the Erie, and held the position of General Manager of the Erie for one year. Following this he was General Agent for the Union Switch and Signal Company, and for six years was Superintendent of Motive Power of the Norfolk & Western. For the past two and a half years he has represented the Baldwin Locomotive Works in Chicago.

We are informed by Mr. J. H. Hadley, President of the International Power Company, that Mr. Joseph Lithgoe, Superintendent of the Locomotive Works at Providence, R. I., has not resigned as has been stated.