A STUDY OF THE VENTILATION OF SLEEPING CARS.*

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For the purpose of securing a suitable exchange of air in railway cars many types of ventilators have been suggested and not a few have been given practical tests. About three years ago I was asked to report on the efficiency of one of these. It became evident that it would be necessary to establish some basis of comparison, since it does not seem to have been estimated in exact figures to what degree natural ventilation of a railway car is effective. As the problem is of lasting importance and is likely to recur, it seemed advisable to make a fundamental study of the question and to place the results within reach of those who might have occasion to make use of them.

All air contains carbon dioxid as a normal constituent. The average amount in pure air is commonly stated to be 4 parts in 10,000.

The carbon dioxid in the expired breath averages more than 4 per cent. (400 in 10,000). The amount excreted hourly varies according to age, sex and the degree of bodily activity. In a mixed community of persons at rest it will average about 0.6 cu. ft. per person per hour.

If there were no ventilation whatever the air of an ordinary railway coach, containing 4,000 cu. ft. of space and occupied by 20 people, would have 34 parts of carbon dioxid per 10,000 of air at the end of one hour. This would continue to increase indefinitely in a direct ratio to the time, since carbon dioxid continues to be produced by the respiration of the occupants at a practically constant rate.

It is plainly impossible to measure directly the amount of air flowing into a car, since it enters at many points and at constantly changing velocities. But the amount of the interchange may be readily computed from the actual amount of carbon dioxid found from time to time by applying the figures given above to a simple mathematical procedure. Suppose a car contains 20 people and its atmosphere is found to have an average of 10 parts of carbon dioxid per 10,000. The incoming fresh air contains 4 parts, hence the respiratory contamination of the car air is represented by only 6 parts.

The 20 people produce 20 times 0.6 cu. ft., or 12 cu. ft. of carbon dioxid per hour. With what amount of air must the 12 cu. ft. be diluted so that the air will contain 6 parts of carbon dioxid in 10,000? The simple proportion, 6 : 10,000 : : 12 : × gives 20,000 as the answer (or 1,000 cu. ft. per hour for each person present.) The computation is better represented by the general formula:—

$$A = v\,p \div (x - N)$$

v = the CO_2 produced by one person (cu. ft. per hour),
p = the number of persons in the room,
x = the proportion of CO_2 in the air of the room,
N = the proportion of CO_2 in the outside air (0.0004)
A = the air-supply to the room (cu. ft. per hour).

TABLE I.—SUMMARY OF THE RESULTS OF NUMEROUS TESTS TO DETERMINE THE CONDITION OF THE AIR IN SLEEPING-CARS.

(Normal carbon-dioxid in air; 4 parts per 10,000.)

Cars with natural ventilation:	Ave. No. of people in car.	Carbon-dioxid per 10,000 parts of air Ave.	Min.	Max.	Necessary air to maintain ave. carb. diox. cu. ft. per hr.
1. Decks open; doors and windows closed	15	7.19	3.5	13.0	28,300
2. Ditto, but one or both doors open to vestibule	10	5.40	3.5	8.5	40,700
3. All decks, doors and windows closed	13	8.33	5.5	15.0	18,500
4. In lower berth (A)	16	8.32	5.0	18.0	1,389 per berth
5. In aisle opposite lower berth (B)	16	7.32	4.5	10.0	.....
6. In upper berth (C)	21	9.17	4.5	18.5	1,161 per berth
7. In aisle opposite upper berth (D)	21	8.37	6.0	13.0	.....
(4 to 7; windows and doors closed).					
Cars with Exhaust Ventilators:					
8. Decks open; doors and windows closed (day)	13	6.01	4.5	10.0	38,400
9. Ditto; for aisle only (night)	16	6.33	4.5	10.0	41,300
10. One or both doors open to vestibule	14	5.50	3.5	9.0	57,900
11. In lower berth (A)	16	6.96	4.5	13.5	2,027 per berth
12. In aisle opposite lower berth (B)	16	6.33	4.5	10.0	.....
13. In upper berth (C)	17	6.70	4.5	10.5	2,222 per berth
14. In aisle opposite upper berth (D)	17	5.95	4.5	9.5	.....
(11 to 14; windows and doors closed)					
Berth Tests.					per berth
15. Cars with natural vent; lower berth	..	8.45	...	....	1,354
16. Upper berth	..	8.85	...	....	1,237
17. Cars with exhaust vent; lower berth	..	6.51	...	....	2,391
18. Upper berth	..	6.70	...	....	2,222
19. Berth with one person	..	7.36	...	....	1,785
20. Berth with two persons	..	9.91	...	....	2,027

Note.—Observations (A) and (B) and observations (C) and (D) were made at the same level (lower and upper respectively) but on opposite sides of the berth curtains.

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