Some 15 or 20 years ago analyses of the air from passenger cars were made by Prof. Nickols, for the Board of Railroad Commissioners of Massachusetts. In 1894 a committee of the Master Car Builders' Association made a report on the subject of car ventilation, and with it submitted the results of several analyses of air from cars (see Table II.).

In 1904, Dudley* reported on analyses of the air of cars of the Pennsylvania Company, which were ventilated by the excellent system which he devised. He found from 10 to 18 parts of carbon dioxid per 10,000 in running cars, and 20 to 21 parts in cars standing still for 20 mins. The 52 people in the cars are assumed to have produced 0.72 cu. ft. of carbon dioxid each per hour; from which it is estimated 26,000 to 62,000 cu. ft. of air-supply per hour for the moving and 22,000 to 23,000 for the still cars.

The ventilation device upon which this report is based is designed to remove air by exhaustion from the upper portion of the car, and its operation is dependent on train motion.† Anemometer readings, have shown that each such exhaust ventilator will remove an average of about 15,000 cu. ft. of air per hour at a train speed of 40 m.p.h., and proportionately more or less for faster or slower speeds. While there is considerabe variation under apparently simiconditions, the outward flow is constant. One ventilator is placed over each alternate section of a sleeping-car, while two are applied to the smoking-room and one to the stateroom.

It is readily seen that a very large volume of air leaves the car through these openings; it must enter somewhere. The question was, does it enter at such places and take such courses as to cause a free dilution of the air at the breathing level in the occupied car? There seems no adequate answer to this question except by determining the carbon dioxid in such air, from which the amount of dilution may be computed as already indicated.

Nearly 3,000 carbon dioxid determinations were made for all purposes in connection with this work; about 2,000 of these were of the air from over 200 sleeping-cars. [Table I gives a summary of the author's tables of records of observations in sleeping cars; Table II. shows the comparison of observations made in various places, and includes the figures of the Master Car Builders' Association, mentioned above.—Ed.]

TABLE II.—COMPARATIVE RESULTS OF TESTS OF CARBON-DIOXID IN AIR.

Place	No. of observations	CO_2 per 10,000. Ave.	Max.	Min.	Equiv. hourly air supply per person. cu. ft.
Sleeping cars (body)	294	6.20	10.0	....	2,727
Sleeping cars (berths) ..	690	6.96	13.5	....	2,027
Day coaches (32 pass.) ..	43	9.38	21.0	....	1,100
Street cars	45	15.10	29.0	....	541
Elevated cars	17	13.90	26.5	....	674
Suburban coaches	47	14.30	38.0	....	583
Stores	23	8.80	10.0	....	1,250
Restaurants	51	16.10	26.0	....	496
Offices	26	13.91	19.0	....	670
Sleeping cars (12 pass.)	...	18.0	22.0	11.3	M.C.B.
Chair cars (17 pass.)	...	10.7	15.5	7.0	re-
Sub'n cars (½ full)	...	13.8	21.7	6.9	port

* "The Passenger Car Ventilation System of the Pennsylvania R. R.," C. B. Dudley.

† The Garland Ventilator; Eng. News, Dec. 23, 1909.

Before proceeding to an analysis of the findings it is necessary to know the amount of carbon dioxid in the air surrounding trains in order to have some basis for computing air-supplies to cars. The locomotive emits an enormous total volume of this gas, which, it is easily conceived, might play a considerable part in the amount of carbon dioxid found in the air of the cars. According to Leissner the air surrounding trains contains from 18 to 22.8 parts carbon dioxid per 10,000. My results are at variance with this; 46 determinations averaged 4.04; the highest was 10, the lowest 3.

Of course, the smoke and condensed steam do not diffuse as do the invisible gases; but with these is mixed a quantity of sulphur dioxid. My observation has been, in the examination of tunnel air, that where flue gases have contaminated the air, with 15 to 20 parts of carbon dioxid in 10,000, sulphur dioxid is readily detected. It occasionally happens that sufficient gas is carried into a train running in the open to render sulphur dioxid noticeable. It seems that my determinations of carbon dioxid in the surrounding trains have not dealt with the conditions that could bring this about. Consequently I concluded that this is a relative rarity, and that 4 in 10,000 is a proper average to deal with in considering the air outside of moving trains.

Adding to the open deck windows by opening one or both end doors to the vestibule (the outside vestibule doors remaining closed) would be expected to cause a greater air-supply. Such is the case, as shown by the records. [Table I.] Observations were made also where both doors and all the deck sash were closed. Whatever amount of the outside air enters the car under these conditions must find its way in through natural crevices and is driven in and out by the pressure of the wind and the suction effects produced by the motion of the train. As would be expected under these conditions, the average carbon dioxid is greater than in either of the preceding groups and the computed air-supply is smaller.

The air-supply to sleeping-cars, as computed from 555 carbon dioxid determinations, is (for all but that of the completely closed car depending upon natural ventilation) a large one relative to the number of passengers, and would not allow the average carbon dioxid to go above 10 in any but this one condition unless the cars were crowded beyond their natural capacity. Such overcrowding in sleeping-cars is prevented by the assignment of space and refusing further applicants when this is all taken. It very rarely happens that sleeping-cars carry more than 25 passengers.

It should be understood that all of the above observations apply to the main compartment of the standard sleeping car in motion; and in setting down the number of passengers only those persons were counted who were actually in this compartment, and who had been there for a period of at least ten minutes at the time the samples of air were being collected. The smoking-room, the drawing-room, and other small rooms constitute separate problems.

In order to test the consistency of the results obtained, and to find if the carbon dioxid actually does go up in proportion to the number of passengers, the 555 observations were divided into four groups, according to the number of passengers (Table III.). It is seen that it increases with the number of passengers:—