I. Human Ventilation Requirements

Ventilation of residential, commercial, and office spaces is now understood to be necessary to control body odors, tobacco smoke, cooking odors, and other odorous impurities, rather than to maintain the required amount of oxygen or remove the carbon dioxide produced by respiration. This is true because standard construction of buildings for human occupancy cannot prevent infiltration and exfiltration of substantial amounts of air, even when all windows, door, roof, or mechanical-ventilation openings are closed. Published data on the amounts of outdoor air normally available by natural ventilation or infiltration indicate that suffocation by deficiency of oxygen or excess of carbon dioxide, as a result of human respiration, is virtually impossible in buildings constructed above ground.

In view of the fact that industrial hygienists are called upon to justify their position to those who are not aware of the background of research and experience upon which present ventilation standards are based, a brief review of the effects of respiration on atmospheric air is in order at this point.

A. AIR COMPOSITION

The approximate composition of air under three conditions is given in Table 1. Simple calculations will demonstrate that human beings do not require more than a few hundred cubic feet of air per hour to satisfy their demand for oxygen and to dilute to a harmless concentration the carbon dioxide produced. A man, even at heavy work, breathes only about 40 liters (1.4 cu. ft.) of air per minute, consumes about two liters (0.07 cu. ft.) of oxygen, and produces about 1.7 liters (0.06 cu. ft.) of carbon dioxide.

TABLE 1

Composition of Air
(Volume per cent)

Component	Outdoor air, dry	Indoor air, 70° F. (RH 50)	Expired air, 97° F. (RH 100)
Inert gases (nitrogen, argon, etc.)	79.00	78.00	75
Oxygen	20.97	20.69	16
Water vapor	0.00	1.25	6
Carbon dioxide	0.03	0.06	3
Total	100.00	100.00	100

[1] *Heating, Ventilating, Air Conditioning Guide, 1957*. American Society of Heating, Air-Conditioning Engineers, New York, 1957, ch. 11.

Mackey[2] offered an interesting hypothesis on the physical and chemical changes occurring in indoor air as a result of human occupancy. His analysis was somewhat as follows (modified after communication with Mackey):

An adult at rest uses in one minute about 20 cubic inches of oxygen and produces about cubic inches of carbon dioxide. At 70° F., he loses in one hour about 300 Btu of sensible and about 0.1 pound of water vapor. Assuming for simplicity that these rates remain (which they would not do in fact), if such an adult were confined in an airtight, insulated space of 1000 cubic feet, initially at 70° F. (ignoring humidity), the dry-temperature would increase to 100° F. in less than two hours, while about 75 hours would required to reduce the oxygen to 16 per cent and increase the carbon dioxide to 5 per cent. extreme case, the physical change is seen to be much more dangerous than the

B. CARBON DIOXIDE AS AN INDEX OF VENTILATION REQUIREMENTS

Measurement of carbon dioxide concentrations in spaces occupied by human been standard procedure among ventilating engineers for many Yaglou, Riley, and Coggins[3] reported in 1936 their results from a experiments on ventilation requirements. They concluded that the carbon concentration "in the air of occupied rooms proved to be an unreliable of ventilation, from the standpoint of both outdoor air supply and odor and suggested that "a great deal of unjustified effort would be saved continuing the usual measurements of CO_2 in ordinary ventilation work, perhaps in instances in which the air flow is well under 10 c.f.m. per person."

Many research workers and writers during the present century have recog- that existence of 0.10 to 0.50 per cent CO_2 in spaces occupied by human not of itself dangerous. Some still express the belief, however, that such in carbon dioxide, from a normal outdoor level of 0.03 to 0.04 per cent, the presence of unhealthful constituents as a result of *vitiation of air* human respiration. This question has not been settled to the satisfaction of the The current use of odors as indexes of ventilation requirements is still by some as neglect of a fundamental hazard to life and health. Never- public health workers and ventilation engineers are now generally con- that oxygen and carbon dioxide concentrations in air at normal barometric are not of concern to health in the absence of more substantial dis- of air composition, as might be caused by industrial processes that oxygen or generate carbon dioxide.

The extended use of odor-controlling processes for air conditioning will bring further revisions in the standards of quantities of outdoor air per capita for health or comfort.[4] In some situations it may be possible to approve mechanical system of 100 per cent recirculation of indoor air, on the strength

[2] A. O. Mackey, *Air Conditioning Principles*. International Textbook, Scranton, 1941.

[3] C. P. Yaglou, E. C. Riley, and D. I. Coggins, *Trans. ASHVE*, **42**, 133 (1936).

[4] H. E. McCord and W. N. Witheridge, *Odors: Physiology and Control*. McGraw-Hill, 1949.