in 10,000 parts a room would be considered close For general considerations of ventilation, the limit should be placed at 6 to 7 parts in 10,000, thus allowing an increase of 2 to 3 parts over that present in outdoor air, which may be considered to contain 4 parts in 10,000 under ordinary conditions.

### ANALYSIS OF AIR.

The amount of carbonic acid present in the air may be readily determined with sufficient accuracy for practical purposes, in the following manner:

Six clean, dry, and tightly corked bottles, containing respectively 100, 200, 250, 300, 350, and 400 cubic centimetres, a glass tube containing exactly 15 cubic centimetres to a given mark, and a bottle of perfectly clear, fresh limewater, make up the apparatus required. The bottles should be filled with the air to be examined by means of a hand-ball syringe. Add to the smallest bottle 15 cubic centimetres of the limewater, put in the cork and shake well. If the limewater has a milky appearance the amount of carbonic acid will be at least 16 parts in 10,000. If the contents of the bottle remain clear, treat the bottle of 200 cubic centimetres in the same manner; a milky appearance or turbidity in this would indicate 12 parts in 10,000. In a similar manner, turbidity in the 250 cubic centimeter bottle indicates 10 parts in 10,000; in the 300, 8 parts; in the 350, 7 parts; and in the 400, less than 6 parts. The ability to conduct more accurate analyses can be attained only by special study, and a knowledge of chemical properties and methods of investigation.

### AIR REQUIRED FOR VENTILATION.

The amount of air required to maintain the standard of purity can be very easily determined provided we know the amount of carbonic acid given off in the process of respiration. It has been found by experiment that the average production of carbonic acid by an adult at rest is about 6 cubic foot per hour. If we assume the proportion of this gas as 4 parts in 10,000 in the external air, and are to allow 6 parts in 10,000 in an occupied room, the gain will be 2 parts in 10,000; or, in other words, there will be $\frac{2}{10,000}$ = .002 cubic foot of carbonic acid mixed with each cubic foot of fresh air entering the room.

Therefore, if one person gives off .6 cubic foot of carbonic acid per hour, it will require .6 — .002 = 3,000 cubic feet of air per person to keep the air in the room at the standard of purity assumed —that is 6 parts of carbonic acid in 10,000 of air.

The following table has been computed in this manner, and shows the amount of air which must be introduced for each person in order to maintain various standards of purity:

### AIR REQUIRED FOR VENTILATION.

| Standard Parts of Carbonic Acid in 10,000 of Air in Room | Cubic Feet of Air Required per Person. | |
|---|---|---|
| | Per Minute | Per Hour |
| 5 | 133 | 8,000 |
| 6 | 67 | 4,000 |
| 7 | 44 | 2,667 |
| 8 | 33 | 2,000 |
| 9 | 27 | 1,600 |
| 10 | 22 | 1,333 |
| 11 | 19 | 1,151 |
| 12 | 17 | 1,000 |

While this table gives the theoretical quantities of air required for different standards of purity, and may be used as a guide, it will be better in actual practice to use quantities which experience has shown to give good results in different types of buildings. Authorities differ somewhat in their recommendations on this point, and the present tendency is toward an increase of air.

The following table represents good modern practice and may be used with satisfactory results:

### AIR SUPPLY FOR VARIOUS CLASSES OF BUILDINGS

| Air Required per Occupant in | Cubic Feet per Minute | Cubic Feet per Hour. |
|---|---|---|
| Hospitals .. .. | 50 to 80 | 3,000 to 4,000 |
| High Schools .. | 50 | 3,000 |
| Grammar Schools | 40 | 2,400 |
| Theatres and Assembly Halls.. | 25 | 1,500 |
| Churches .. .. | 20 | 1,200 |

### FORCE FOR MOVING AIR.

Air is moved for ventilating purposes in two ways—first, by expansion due to heating; and second, by mechanical means. The effect of heat on the air is to increase its volume and therefore lessen its density or weight, so that it tends to rise and is replaced by the colder air below. The available force for moving air obtained in this way is very small, and is quite likely to be overcome by wind or external causes. It will be found in general that the heat used for producing velocity in this manner, when transformed into work in in the steam engine, is greatly in excess of that required to produce the same effect by the use of a fan. Ventilation by mechanical means is performed either by pressure or suction. The former is used for delivering fresh air into a building and the latter for removing the foul air from it. By both processes the air is moved without change in temperature, and the force for moving must be sufficient to overcome the effects of wind or changes in outside temperature. Some form of fan is used for this purpose.

### MEASUREMENTS OF VELOCITY.

The velocity of air in ventilating ducts and flues is measured directly by an instrument called an *anemometer*. It consists of a series of flat vanes attached to an axis, and a series of dials. The revolution of the axis causes motion of the hands in proportion to the velocity of the air.

### AIR DISTRIBUTION.

The location of the air inlet to a room depends upon the size of the room and the purpose for which it is used. In the case of living-rooms in dwelling houses, the registers are placed either in the floor or in the wall near the floor; this brings the warm air in at the coldest part of the room and gives an opportunity for warming or drying the feet if desired. In the case of schoolrooms, it is best to discharge air through openings in the wall at a height of 7 or 8 feet from the floor. This gives a more even distribution, as the warmer air tends to rise and hence spreads uniformly under the ceiling; it then gradually displaces other air and the room becomes filled with pure air without sensible currents or drafts. The cooler air sinks to the bottom of the room, and can be taken off through ventilating registers placed near the floor. The relative positions of the inlet and outlet are often governed to some extent by the building construction; but, if possible, they should both be located in the same side of the room.

The vent outlet should always, if possible, be placed in an inside wall, else it will become chilled and the air-flow through it will become sluggish. In theatres or halls, which are closely packed, the air should enter at or near the floor, in finely divided streams, and the discharge ventilation should be through openings in the ceiling.

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