

A proposed method of measuring the rate of air change in factories

by R. I. NORONHA, G.I.Mech.E.

SUMMARY

The known methods for measuring the rate of air change in houses cannot be applied to factories because of the large quantities of tracer gases required.

A method is proposed for measuring the rate of change of air in factories by the use of a small quantity of commercial concentrated ammonia solution. It is cheap, easy to use, reasonably accurate and unobjectionable to the occupants.

INTRODUCTION

In naturally ventilated shops in factories part of the ventilation is uncontrolled, e.g. leakages into and out of buildings. Because of the size of shops in factories an increase or decrease in the number of air changes due to this uncontrolled ventilation can cause a correspondingly large waste or saving in heat.

There is therefore a need to measure the rate of air change shop by shop quickly and accurately, and so ensure that an expensive decision is not taken to insulate a shop where the same quantity of heat could have been saved by stopping a few gaps or cracks.

In this paper a method is proposed for doing this.

LIMITATIONS OF PRESENT METHODS

All methods of air change measurement are based on introducing a tracer gas not previously present into the atmosphere and measuring its diminution of concentration with time. Two types of tracers can be used:—

- (1) hydrogen or helium
- (2) radioactive gases.

1. Hydrogen or helium

These are detected by measuring the change of conductivity of the air which they produce: a katharometer is used. For reliable and accurate results an initial concentration of not less than 0.3% of hydrogen is required in the shop.² For an average factory shop 200ft x 50ft x 30ft high, approximately 1300 ft³ or the contents of 12 normal cylinders would have to be released in fifteen minutes to achieve this minimum concentration. Such large quantities of helium would be difficult to obtain and hence the possible choice would have to be hydrogen.

2. Radio-active gases

These are detected by means of a Geiger counter and ratemeter.

The choice of radio-active tracers is limited since they must have a suitable half-life and produce no harmful

radio-active decay products. The most suitable are the inert gases Argon A⁴¹ and Krypton Kr⁸⁵. For reliable and fairly accurate results a concentration of 0.025 microcuries/ft³ of A⁴¹ or 0.1 microcuries/ft³ of Kr⁸⁵ is required².

The above quantities of tracer gases are required for one shop only and since factories consist of a number of shops, correspondingly larger quantities of tracer gases will be required. For factory use, therefore, neither of these tracers is satisfactory. They are expensive and in addition the high concentration of gas near points of release leads to explosion hazard in the case of hydrogen, and radiation hazard in the case of radio-active gases.

PROPOSED METHOD

In the proposed method a small quantity of ammonia is used as a tracer gas and its rate of decay is measured by a colorimetric method. The advantage of this method is that extremely small concentrations can be detected (the minimum initial concentration required is 0.0002% by volume). This could be achieved in an average shop (200 x 50 x 30ft) by spraying 180cm³ of commercial concentrated ammonia solution into the air.

The following is an account of an experiment using this method in a shop with dimensions of 45 x 195ft; height to eaves 29ft, height to ridge 37ft 6in (total volume 295 000ft³).

The schematic layout of the apparatus for air sampling is shown in Fig. 1. The rate of flow of air through the sampling bottle was regulated by the control valve; closing the valve increased the flow, opening it decreased the flow. The sampling bottles A, B, C & D each contained 75ml of dilute sulphuric acid (0.1gm/100ml).

180cm³ of concentrated ammonia solution was sprayed in every part of the laboratory. This operation took fifteen minutes. 10 litres of air was then passed through bottle A at the rate of 2 litres/minute. Bottle A was then replaced by bottle B and a second sample taken ten minutes after the first. This process was repeated with bottles C & D.

50ml of the solution from each bottle was placed in four Nessler's tubes marked A, B, C & D. 1ml of Nessler's Reagent was added to each and they were allowed to stand for ten minutes. Depending on the quantity of ammonia absorbed, the tubes developed a yellow colour of different strength.

50ml of sulphuric acid (0.1gm/100ml) were then placed in each of a number of Nessler's tubes. 1ml of

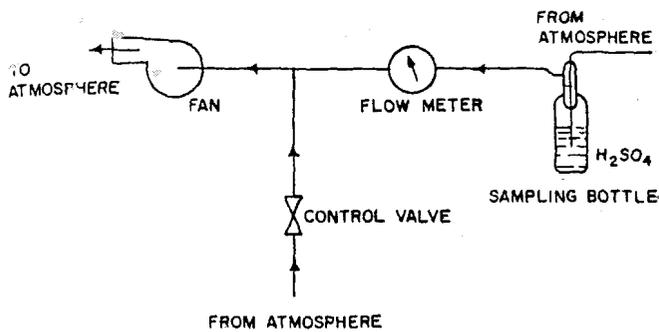


Fig. 1.—Schematic layout of apparatus for air sampling

Nessler's Reagent was added to each. A standard ammonium chloride solution (0.01mgm/ml) was added to each of these tubes. The volume of this solution varied in each tube and the quantities added were marked on it. On standing for ten minutes each of these tubes produced the characteristic yellow colour, depending on the quantity of solution added to it. The colours in these tubes were then matched to the colours in the samples A, B, C & D.

The experiment took less than three hours.

Although ammonia is toxic, the concentration of 0.0002% by volume required is so low (1/50 of that allowable for prolonged exposure) that there is no danger so long as care is taken during the actual process of spraying the solution into the air. No complaints were made by the occupants of the laboratory who continued their normal activities.

TEST RESULTS

The test results are given in Table 1, and shown graphically in Fig. 2.

Time in minutes from start of sampling	Sample	Matching quantity of ammonium chloride solution in ml
0	A	1.2
10	B	0.85
20	C	0.65
30	D	0.5

The theoretical formula for the decrease of concentration due to air change is given by

$$x_t = x_0 e^{-Nt} \quad (1)$$

where x_0 = initial concentration of the tracer gas which in this case would be proportional to the matching volume of ammonium chloride,

x_t = concentration after time 't' also proportional to the matching volume of ammonium chloride,

N = number of air changes per hour,

t = time in hours.

If T is the time in hours required for one air change then $T = 1/N$ and $x_t/x_0 = e^{-1} = 0.368$.

The time taken for one air change is, therefore, the time required for the concentration to fall to 36.8% of its initial value.

In Fig. 2 this occurs at a concentration of 0.442 ml, i.e. after 32.7 minutes.

$$\therefore \text{number of air changes/h} = 60/32.7 = 1.83.$$

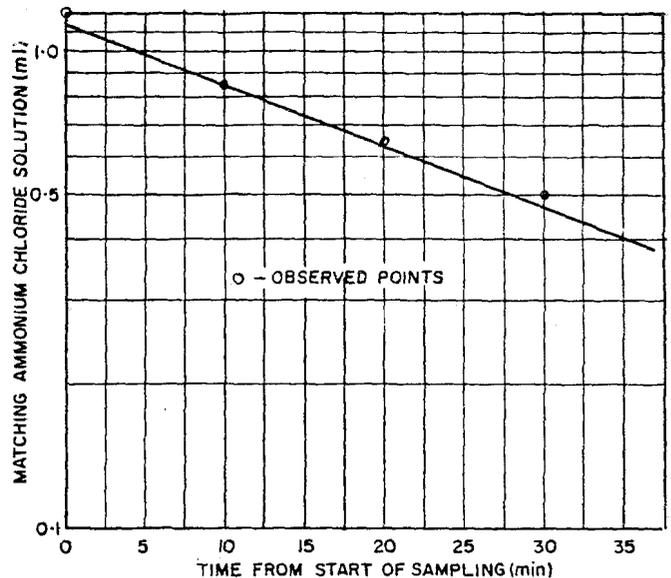


Fig. 2.—Decay of ammonia in air

DISCUSSION OF RESULTS

The Research Laboratory has 14 fan-blown unit heaters, 7 on each side along its length placed approximately midway between the roof and the floor. These were in operation during the experiment. The air in the laboratory was, therefore, in a constant state of agitation. Because of this, and the time taken to release the ammonia, it was assumed that the ammonia was diffused throughout the laboratory. From this assumption, it follows, that any decay in the concentration of ammonia in the air would be due to the air changing because of ventilation.

In Fig. 2 the best line through the points is also the line obtained from formula (1) for an air change of 1.83/h. The error involved in the above assumption is not greater than 4% and is therefore small.

Greater speed could be obtained by measuring the colours in the sample on a calibrated photo-electric absorption-meter. This would also make it unnecessary to make up the tubes of standard concentration. Such a procedure would certainly be justified should the rate of air change in a number of shops be required.

CONCLUSIONS

A method for measuring air change in factory shops using commercial ammonia solution as a source of tracer gas has been developed. It is cheap, easy to use, reasonably accurate, and unobjectionable to the occupants.

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