MIRAN® SapphIRe Analyzer for Ventilation Studies Using Tracer Gas

INTRODUCTION

With today's energy efficient buildings, measurement of ventilation has become important. Since little natural ventilation exists in a building, mechanical ventilation is critical for the removal of many indoor air pollutants such as volatile organic compounds, dusts, allergens, micro-organisms, and naturally occurring gases such as carbon dioxide.

Condensation, which promotes the growth of bacteria, and radon are also components that need to be "flushed" out of buildings by either mechanical or natural means.

The need for make-up air to flush out potentially hazardous chemicals is also critical. Predicting the actual air exchange rate in all areas of a room during actual operations is vital for understanding the dynamics of the air flow pattern and determining the ability of the ventilation system to flush out the contaminants

Ventilation is typically quantified as either the outdoor air supply requirement or the outdoor air exchange rate. We will discuss the outdoor air exchange rate.

This value is defined as the volume of outdoor air entering the room per hour compared with the volume of the room. For example, if the room is 16,000 ft^3 and the ventilation system is supplying 24,000 ft^3/h, the air exchange rate would be 1.5 changes/hour.

Ventilation is also quantified as the outdoor air supply requirement. The value is defined as the recommended volume of outdoor air each person in the enclosure should receive per unit of time. Typical values in hospitals range from one to four changes per hour - operating room should have four outside air changes per hour.

AIR EXCHANGE RATE METHODS

There are two basic methods that accurately define air exchange rates. In each method the basic equation is:

Change in the amount of tracer in the room	=	Amount of tracer introduced into room	Amount of tracer which has left room

CONCENTRATION-DECAY METHOD

This method, the simplest to perform, involves introducing a fixed quantity of gas into the room at time 0. The gas is then shut off and removed, and fans are used to ensure good mixing of the tracer. Before starting the test, spot measurements should be taken throughout the room to ensure that the mixing is complete.

The concentration is then measured several times over the test duration. Once the measurements are complete, a plot of the natural log of concentration versus time is made. The slope of the line is the air exchange rate. If the plot is not a straight line, the air is considered not well mixed and the results are invalid.

The equation for computing exchange rate is

$$N = In(C_s) - In(C_t)$$

where

N = Air exchange rate

C_s = Concentration of tracer gas at start time

C_t = Concentration of tracer gas at t1

T = Elapsed time in hours

PROCEDURE

The procedure for the concentration-decay method is as follows:

1. Determine the volume of the room. This is done to identify the amount of tracer gas to eject into the room. It is important to introduce gases that are not beyond the calibrated range of the equipment. The starting concentration should be targeted at about 1000 times the detection limit of the analyzer. With the SapphIRe analyzer, this will result in values about 10 ppm. Going to a higher concentration is not a problem, however.

2. Shut down the air intake system in the room being tested. A simple means to accomplish this is to simply block off the air intakes with paper. This is important because if the intake is open, it will be difficult to get a stable concentration to begin the test.
3. With the SapphIRe warmed up and measuring the tracer gas, begin to eject the gas into the room. You immediately notice the concentration rising. A mixing fan can now be used to ensure that the tracer gas is equally distributed. For a room of about 200mf3 this should take only a few minutes.
4. Take spot measurements of the tracer gas at ALL areas in the room to ensure that there is even distribution of the gas.
5. Remove the paper coverings over the air intake and begin to record the values. Logging data via the SapphIRe analyzer's internal logging memory or simply recording a value every minute is acceptable.
6. Record data for a minimum of 3-5 minutes. A maximum of 20 minutes worth of data is enough to prove a completely linear relationship between the Natural Logarithm of the concentration versus time.

EXPERIMENTAL EXAMPLE

A SapphIRe was calibrated for 0-30ppm Sulfur Hexafluoride. In the first run, gas was ejected from a cylinder for about 30 seconds. After equilibration, the concentration in the room was approximately 60 ppm. We then removed the paper covering from the intake to evacuate the tracer from the room. In about 10 minutes the tracer concentration fell within the range of the analyzer (starting concentration 28 ppm). At this point we began to collect the data from the center of the room. We repeated these experiments two other times at different locations. The concentration of tracer gas at the start of the other two experiments was 20 ppm and 23 ppm. Each run was conducted for 20 minutes with the following final concentrations of 4.5 ppm, 3.0 ppm and 3.4 ppm, respectively. See Figures 1, 2, and 3 for data describing the experiments.

In our example three separate runs yielded virtually identical room air exchange rates. Analyses were conducted at table height at the farthest point from the air intake, the center of the room, and directly below the air intake system.

In the second and third runs we ejected Sulfur Hexafluoride at a pressure of 5 psi for about 5 seconds into a room about 200 m3 in size. This resulted in a concentration of about 20 ppm. Theoretically, ejecting 3 liters of the pure gas in this room would yield 15 ppm. This is an ideal concentration to start the analysis.

Although the data was collected over a 20-minute period, the room air exchange rate was stable after about 10 minutes. Even after 2 minutes the Room Air Exchange Rate was yielding values that were within 10% of the final value.

CONSTANT EMISSION METHOD

This method is used for long term air exchange rates or for measurement of air flow through ventilation ducts. It requires the introduction of a constant amount of the tracer gas for the duration of the test. This method is similar to the concentration-decay method that the gas should be evenly distributed throughout the room with fans and should be uniform throughout the room. An accurate means of ensuring that the flow is evenly delivered, such as a flow meter, is required. The equation is as follows:

$$N = \frac{F}{VC}$$

where

N = Air exchange rate (changes/hour)
F = Introduction rate of the tracer - ft^3/h
V = Volume of room - ft^3
C = Concentration of tracer gas in room

CHOOSING A TRACER GAS

Several criteria should be examined when choosing a tracer gas - density, toxicity, detectability, and explosivity. The following table shows how the various gases meet the requirements above.

Gas	Density compared to air	Maximum Concentration		SapphIRe detection limit (ppm)
		Tracer test	Safety levels	
CO_2	1.53	640	5000	0.40
SF_6	5.11	83	1000	0.02
N_2O	1.53	640	25	0.06
R-13B1	5.13	83	100	0.12

* This value defines the concentration above which the air/tracer mixture would differ by 0.03%. This density difference is not expected to affect the air flow.

CONCLUSION

The advantages of measuring air flow by tracer gas techniques via an infrared analyzer are as follows:

- Air exchange rate is measured instantaneously.
- The equipment is very simple
- The user has the ability to identify air flow patterns in real life setups; i.e. with personnel and equipment present.
- The user can investigate specific locations of an exchange as opposed to simply measuring CFM at the air intake.

The MIRAN SapphIRe Portable Ambient Air Analyzers are ideal for determining air flow patterns in buildings. They are easy to use, sensitive, and accurate. MIRAN Ambient Air Analyzers have long been used by government agencies and private companies to study air flow patterns. Their ease of use, sensitivity, and accuracy make them the industry standard for air flow measurement.

Time (min)	SF6 (ppm)	ln (ppm)	AER-calc* (hours)
0	28.0	3.33	--
1	26.0	3.26	4.4
2	23.6	3.16	5.1
3	22.0	3.09	4.8
4	20.7	3.03	4.5
5	18.8	2.93	4.8
6	17.0	2.83	5.0
7	15.4	2.73	5.1
8	14.0	2.64	5.2
9	12.6	2.53	5.3
11	10.2	2.32	5.5
12	9.6	2.26	5.4
13	8.8	2.17	5.3
14	7.9	2.07	5.4
15	7.1	1.96	5.5
16	6.4	1.6	5.5
17	5.9	1.77	5.5
18	5.3	1.67	5.5
19	4.8	1.57	5.6
20	4.5	1.50	5.5

*AER-calc = Air Exchange Rate calculated per period

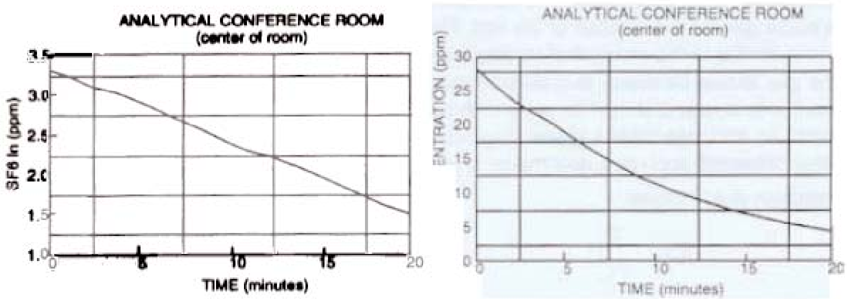

Figure 1

Time (min)	SF6 (ppm)	ln (ppm)	AER-calc* (hours)
0	20.5	3.02	
1	18.6	2.92	5.8
2	17.1	2.84	6.4
3	15.6	2.75	5.5
4	14.3	2.66	6.4
5	12.7	2.54	5.7
6	11.8	2.47	5.5
7	11.2	2.42	6.2
8	9.6	2.26	5.7
9	8.9	2.19	5.6
10	8.2	2.10	5.5
11	7.2	1.97	5.7
12	6.8	1.92	5.5
13	6.1	1.81	5.6
14	5.4	1.69	5.7
15	4.9	1.59	5.7
16	4.5	1.50	5.7
17	4.2	1.44	5.6
18	3.7	1.31	5.7
19	3.3	1.19	5.8
20	3.0	1.10	5.8

*AER-calc = Air Exchange Rate calculated per period

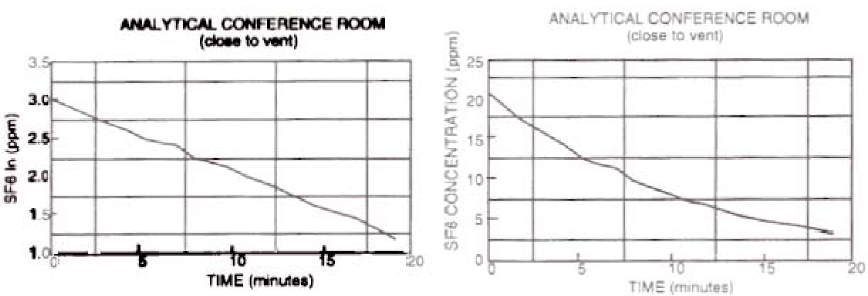

Figure 2

Time (min)	SF6 (ppm)	ln (ppm)	AER-calc* (hours)
0	22.9	3.13	--
1	20.5	3.02	6.6
2	17.1	2.84	5.8
3	15.4	2.73	6.0
4	14.3	2.66	5.7
5	12.6	2.53	6.0
6	11.8	2.47	5.7
7	9.8	2.28	6.4
8	9.1	2.21	6.2
9	8.8	2.17	5.7
10	7.9	2.07	5.8
11	7.1	1.96	5.9
12	7.1	1.96	5.9
13	6.2	1.82	6.0
14	5.7	1.74	6.0
15	5.5	1.70	5.7
16	5.0	1.61	5.7
17	4.3	1.46	5.9
18	4.0	1.39	5.8
19	3.7	1.31	5.8
20	3.4	1.22	5.7

*AER-calc = Air Exchange Rate calculated per period

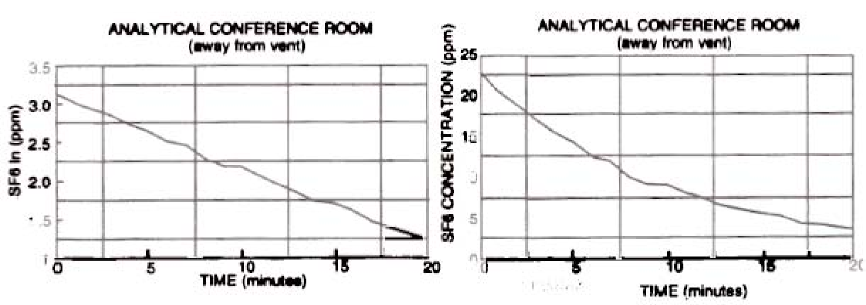

Figure 3.

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