#2218 AIVC 1842 2218

Ventilation '85, edited by H.D. Goodfellow, 1986 291
Elsevier Science Publishers B.V., Amsterdam — Printed in The Netherlands

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A TRACER-GAS SYSTEM TO EVALUATE THE EFFICIENCY OF VENTILATION SYSTEMS OR SIMULATE THE CONSEQUENCES OF AN ACCIDENT

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ABSTRACT

The tracer technique can be used in ventilation and contaminant spreading investigations. We have choosen sulfur hexafluoride. We have constructed a specific instrumentation to perform indoor and outdoor tests. All components are portable and battery operable. We use generators with remotely controlled flow, real-time chromatographs as analysers, continuous SF6 monitors and field-use calibrators.

We have performed numerous tests, in the nuclear industry (Laboratories, reprocessing facilities and PWR), in conventional industries and in hospitals. The goal was as well hygiene problems as the improvement of an industrial process.

INTRODUCTION

Sulfur hexafluoride has been first used in the laboratory for atmospheric diffusion experiments. A home-made instrumentation was developped, allowing the direct determination of SF6 in tracer studies. Several real-time, portable and battery-operated chromatographs were constructed.

The same analyzers were then used for the evaluation of the efficiency of ventilation systems. Owing to the sensitivity of outdoor designed chromatographs, we only had to adapt the flowrate of the generator. The accuracy required for air infiltration measurements led us to construct field use calibrators and generators with an electronically controlled discharge flow. This set was called the "SF6 System".

METHODS

The "SF6 System"

Chromatographs (SFX 83). The home-made chromatographs are packed in rugged aluminium cases. A rechargeable battery for up to 10 hours operation and a bottle of high purity nitrogen gas are built-in. The case includes also the chart-recorder.

The conception is very classical. All temperature and contamination sensitive elements are mounted in a cylindrical block, that can be easily removed and decontamined.

The detector operates in the linear range (0.1 - 20 vpb).

The time delay between two consecutive samplings can be reduced to values as low as 30 seconds.

SF6 continuous monitors (SFD 84). For some applications, as the determination of the transfert time to a specific detector, a time resolution of 30 seconds is not sufficient. Available monitors, as leak detectors, are not suitable: the drift has generally the same order of magnitude as the expected signal.

We have designed and constructed SF6 continuous monitors, without drift and with a time resolution of nearly 1 second. For short-range experiments, sensitivity may be very poor (useful range : 10 vpb - 600 vpb), if time resolution is sufficient. For this purpose, air is driven into the apparatus at a high flowrate to reduce transfert time. A small part is continuously taken off, mixed with Argon gas and passed into an electron capture detector. All flow rates are regulated.

All components, battery operated, are disposed in the same case as the chromatographs.

Generators. For most applications, we need a precise control of the flowrate of the discharge of SF6. For contamination transfert simulations, the source has to be remotely actuated, because the operator may carry traces of SF6 in his clothes after he has actuated the valve.

We use two generators.

The first one is designed for industrial applications and large rooms. SF6 is passed through mass flowmeters (0 - 10 $cm^3.min^{-1}$ or 0 - 100 $cm^3.min^{-1}$) and the flowrate is regulated. The control signal is either a gate signal (known flowrate during a known period), or any other law available from the output of a FM recorder. It is also possible to get impulses (discharges from small pressurized volumes).

The second generator, designed for small rooms, uses air with 1 % SF6 gas and is identical to the previous one.

Field use calibrator. Periodic calibration of simplified chromatographs is necessary, at least at the beginning or the end of a study day. Known standards of SF6 in compressed gas cylinders are not reliable, so we have designed and constructed a field use calibrator.

The apparatus includes two parts :

- a permeation tube system, disposed in a well-insulated oven, releasing pure SF6 at a constant rate of 0.95 $ng.min^{-1}$.

- a dilution system, with mass flowmeters, that enables us to obtain any concentration in the useful range to calibrate simultaneously all our chromatographs. In some applications (accurate flowrate measurements), the calibrator is used for the indirect measurement of SF6 concentrations, as chromatographs are used only for comparison between the unknown concentration in the duct and the known standard delivered by the dilution system.

The useful data (Flowrates, ...) are available on a LED display. The calibrator is disposed in the same aluminium case, is battery operated and is self sufficient (power, sweeping gas) for 48 hours.

Auxilliary equipments. We use also temperature recorders (for the continuous monitoring of the vertical temperature gradient), anemometers and a home made bubble generator ("HELIBUL"), which delivers calibrated bubbles with a nul apparent weight.

Composition of the "SF6 System". Actually (July 1st, 1985), the "SF6 System" includes 6 chromatographs, 1 continuous SF6 monitor (soon 4), a field use calibrator and 2 generators.

Some applications of the "SF6 System"

Principles and limitations. SF6 System was designed with respect to the following principles :

- We use several analysers, operating simultaneously and with results available in real time for direct interpreting.
- Accuracy is guaranteed by frequent calibration and by extensive use of mass flowmeters.
- All components are portable and battery operated.

The tracer technique is a powerful tool. The limitations result from two facts :

- The phenomenon to be studied must be in the concentration of the tracer : we can measure leaks in buildings or glove boxes in the nuclear energy, where safety occurs from depression and leaks create a fresh air entrance. The same is not possible in the space industry, where confinment is obtained by overpressure.
- SF6 in an inert gas, whereas contaminants, dust and toxic gases are trapped on filters.

Tightness measurements. We have used tracer techniques to evaluate the dynamic confinment in nuclear buildings. The test is a simulation of the transfert of contamination.

A puff of SF6 is released instead of the contaminant (from the reactor pool, from the fuel pool for example). We use continuous SF6 monitors (SFD 84) to measure the transfert time in the reactor building (in the fuel building ...) to the detectors or to the airlocks. Chromatographs (SFX 83) control the lack of tracer outside the building and in the neighbouring cells. This procedure may include several parameters, as the effects of traffic, the opening of the doors of the airlock, and the transient effects in case of a partial failure in the ventilation system.

Capture efficiency of local exhaust ventilation systems. Capture efficiency is generally easily measured using tracer techniques. Capture efficiency is related directly to the resulting airborne contaminant concentration, whereas capture velocity is only an useful information on the ability of the system to prevent contaminants to escape to the work place.

The theoritical model for a capture efficiency measurement is quite simple. Capture efficiency is defined to be the fraction of the airborne contaminants generated by the source that is captured by the local exhaust ventilation system. According to that, measurement can be performed by a single chromatograph connected to the exhaust duct, and a mobile generator. Capture efficiency can be shown to be the ratio of the concentrations measured when the generator is placed at the real source and when it is placed in the hood (efficiency set to unity).

In some cases, especially when intense crossdrafts and recirculation occur, such a measurement has no physical meaning. SF6 is first dispersed in the room environment, and measurements in the exhaust duct agree rather with the values of the ambiant concentration than the values connected with the directly collected fraction. Simultaneous measurements in the exhaust duct and around the hood, and transfert time considerations may reduce the risk of such a misunderstanding.

Evaluation of the ventilation efficiency. Tracer techniques, and the ability of simultaneous measurements, are a powerful tool to evaluate the efficiency of ventilation systems, and specially the existence of short circuiting or dead zones. This can be revealed by simultaneous measurements of the air change rate per hour at different places in the room (at work place, near the outlet, under the ceiling...). An alternative method is to measure the effective decay rate of SF6 with respect to time, and to compare it with the theoritical value drawn from the exponential law. Any discrepancy may be assigned to transfert time problems and to the existence of dead zones.

Simulation of accidents. One of the major interests of tracer studies is the ability to simulate accidental situations.

We have for example studied the consequences of the release of an argon-gas/méthane gas mixture from a particle detector in the CERN near Geneva. We used and Ar/air mixture, marked with SF6 to represent density effects. In fact, we have shown that density differences were completely cancelled by the intense thermal effects around magnets and electronic equipments.

We have studied anoxia risks due to leaks occuring in the nitrogen gas supply circuitry in the reactor building of a PWR. Air releases, marked with SF6, enable us to evaluate the size of the danger zone and to optimize the configuration of the oxygen monitoring network.

We are now studiing risks resulting from use of toxic gases (phosphin, arsin and phosgen gas) in the electronic industry and in pharmaceutical plants. We have first simulated a breaking of the coupling to the supply cylinders outside. We have measured the concentrations at the neighbouring houses, and we have also shown that the toxic cloud could reach the make-up air inlets of the ventilation system of the clean rooms. We have also considered the case of a leak inside the clean rooms. The goal was to know if gases could reach the neighbouring rooms of the personnel corridor used to escape.

CONCLUSION

Tracer techniques are a powerful tool to evaluate the performances of ventilation systems. The choice of a peculiar tracer is unimportant. We preferred SF6 for the ease with which it can be monitored and used.

SF6 System is an operational set, characterized by accuracy, mobility, self sufficiency and real time and simultaneous measurements.

We have performed numerous and various tests, and we are still finding new applications. For that purpose, we are continuously improving the technology or the performances of our system. The actual trend is towards continuous systems withe the same mobility and self sufficiency as chromatographs.