

# Some Observations on Aerodynamic Types of Laboratory Fume Hoods

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This paper describes the measurements of fume hood containment performance and discusses some consequences of the results. Both the tracer gas technique and the KI-Discus method were used for the same fume hood to measure containment values at different inlet air velocities at constant aperture height. Two newly designed hoods with "different" inside air patterns are described. The tracer gas method has been used to evaluate these hoods. These results are compared with the results from a conventional hood of the most common type used in Sweden.

## INTRODUCTION

In a laboratory fume hood, a very complex flow configuration can arise and pollutants in the hood can be discharged outwards through the aperture into the operator's breathing zone. Such an outward discharge can be caused by stationary or non-stationary vortices or by a very large turbulence in an unstable wake region in front of the operator caused by the air flow into the hood being drawn past the operator. These outward discharges have been visualized by using smoke tests in the presence of a person and are described in the literature.<sup>(1-3)</sup>

There is currently much interest in producing a containment test to characterize the overall performance and operator safety of fume hoods. Tracer gas techniques have traditionally been used for this work to measure protection quantitatively and to differentiate between "good" and "bad" hoods.<sup>(4-8)</sup> In addition, there is an established method for measuring operator protection in open-faced microbiological safety cabinets. This technique, the KI-Discus method, has now been successfully applied in the assessment of protection factors for fume hoods.<sup>(9-12)</sup>

In this paper, the measurements are described in two parts. In the first part, tests were performed with the tracer gas technique and the KI-Discus method on the same fume hood at different inlet air velocities. In the second part, two newly designed fume hoods are described and, with the aid of tracer gas technique, are compared with the most common fume hood employed in Sweden, the KBS-type.

## TEST METHODS

### Tracer Gas Technique

In the tracer gas method, nitrous oxide ( $N_2O$ ) is used as the tracer. The gas is emitted at a constant flow rate ( $0.13 \text{ m}^3/\text{hr}$ ) at one of four positions 0.016 m, 0.15 m, 0.3 m, and 0.7 m above the base of the fume hood and 0.15 m back from the plane of the aperture. The tracer gas outlet is a specially designed line source producing an almost momentum-free outflow of gas into the working area of the hood.<sup>(6,13)</sup> Concentrations of  $N_2O$  are measured using an infrared gas analyzer (URAS) at several points over the aperture opening in a plane 0.01 m outside the sash at different heights.

Effects of disturbances at the front aperture can be determined when measurements are made with an operator standing still in front of the fume hood and also with the operator moving his hands in a "calm" manner within the hood. Because the tests were made to evaluate the safety of the fume hoods, the maximum values (ie., worst case) were always used.

The Escape Safety Value (E), described by Ljungqvist and Malmstrom,<sup>(7)</sup> is used:

$$E = \frac{C_x}{C_x + C_{\max}} \quad (1)$$

Where:

$C_x$  - tracer gas concentration in exhaust air (mean value)

$C_{\max}$  = maximum recorded concentration just outside the fume hood

The tracer gas method, as it is used here, takes into consideration the disturbances from a moving operator. However, the violent, pulsating concentrations measured must reflect the response time of the measuring equipment and how the operator is moving.<sup>(7,8)</sup>

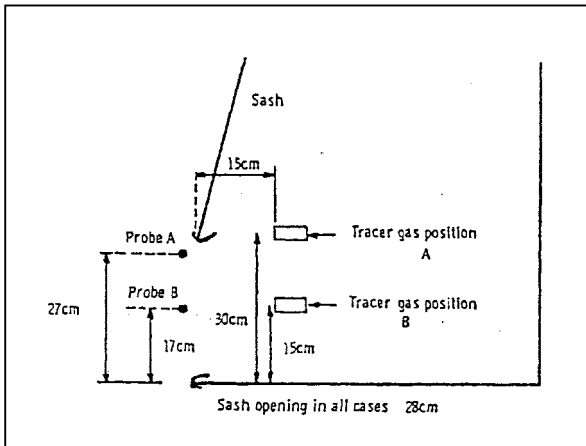


FIGURE 1. Position of the test equipment for fume hood containment measurements using the tracer gas technique.

## KI-Discus Method

The KI-Discus method was developed by the Medical Research Council in the United Kingdom to evaluate microbiological safety cabinets. In this test method, a spinning disc generator produces a fine mist or spray of potassium iodide particles (mean diameter 7  $\mu\text{m}$ ) to constitute a challenge to the hood aperture. Any potassium iodide particles that escape into the laboratory are sampled and collected on filter membranes housed in high-efficiency air samplers. The filters are subsequently treated with palladium chloride and "developed" to show the deposited potassium iodide as small, well-defined grey/brown spots. <sup>(14)</sup>

Fume hood containment tests have been made with two air samplers, each placed on either side of an artificial arm that was centrally positioned at the cabinet aperture with the base of the arm some 35 mm above the hood floor. Different configurations may be used in order to detect leakage in the center and top parts of the aperture which may be particularly vulnerable to disturbances in the inlet air flow patterns. <sup>(9,10)</sup>

## FUME HOODS TESTED

### Tracer Gas and KI-Discus Methods for the Same Hood

Both the tracer gas technique and the KI-Discus method have been used to evaluate containment values at different inlet air flows at a constant aperture height for the same fume hood. It is an "aerodynamic" hood that has a symmetrical face velocity through the aperture.

Figure 1 shows the position of the test equipment for fume hood containment measurements using the tracer gas technique. Figure 2 shows the results produced by the upper probe (A) and lower probe (B) when the operator was both standing still and moving. From Figure 2, it can be seen that the greatest divergence in containment caused by operator movement occurred at the lower inlet air flow velocities. Leakage from the front aperture tended to be least at an inlet air flow velocity of 0.5 to 0.6 m/s; however, as the velocity increased, there was a tendency for leakage to be greater.

Tests with the KI-Discus method have been made on this hood with the same inlet air flow velocities and aperture height. The test equipment was placed as for a Class I cabinet, according to BS 5726. <sup>(15)</sup> The positions of the aerosol generator and

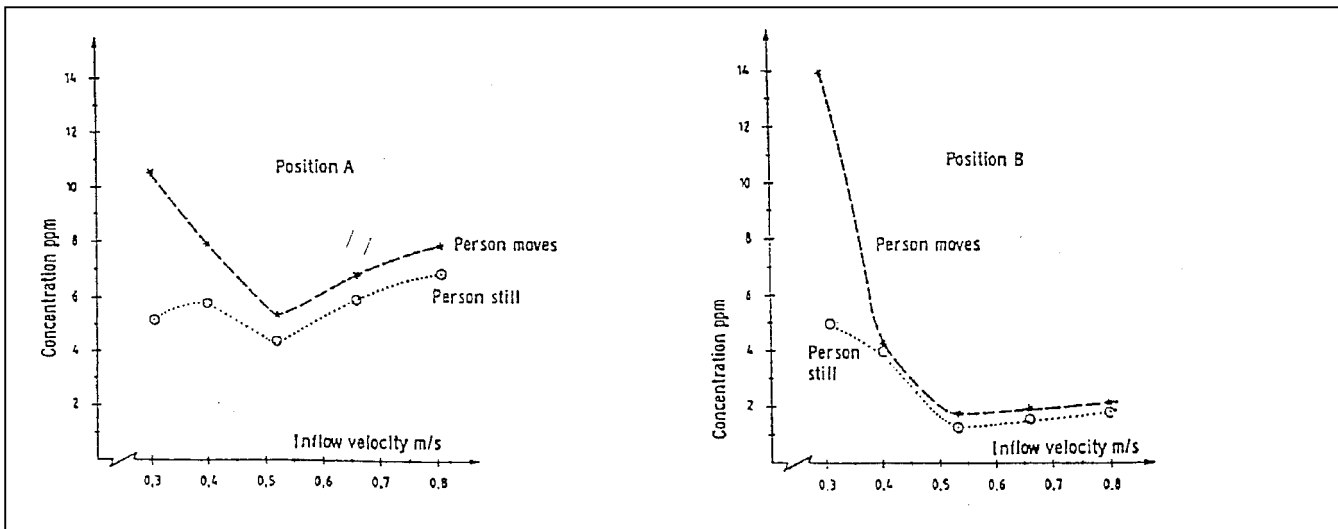


FIGURE 2. Concentration of tracer gas (maximum values) versus inlet air flow velocity measured at the position shown in Figure 1 for an aerodynamic fume hood.

the samplers were 0.1 m behind and 0.1 m in front of the plane of the sash, respectively. Figure 3 shows the results of the potassium iodide tests with the operator protection factor plotted on the vertical axis. The protection factor is "the ratio of the exposure to airborne contamination generated on the open bench to the exposure resulting from the same dispersal in the fume hood." This is evaluated from knowledge of the quantity of potassium iodide particles constituting the challenge and the number sampled on the filter membranes together with the air sampling rate. Figure 3 also shows an envelope of performance for 18 different types of hoods described by Clark et al. (9-11) The best and worst results are shown by the upper and lower lines, respectively.

It is quite possible for simple box-type hoods to achieve operator protection factors in excess of 10s at inlet air flows of some 0.5 m/s. In order to achieve this level of performance, it is important that there is a reasonably uniform air flow (within 20% over the whole front face of the aperture). In such cases, if the inlet air flow velocity is reduced to around 0.3 to 0.4 m/s, it is still possible to achieve operator protection factors greater than  $10^5$ . However, it should be noted that, at these lower inlet velocities, a hood is particularly sensitive to outside disturbances and a large reduction in operator protection factor can occur. Modern, aerodynamic-type fume hoods cannot always be assumed to produce high levels of containment.

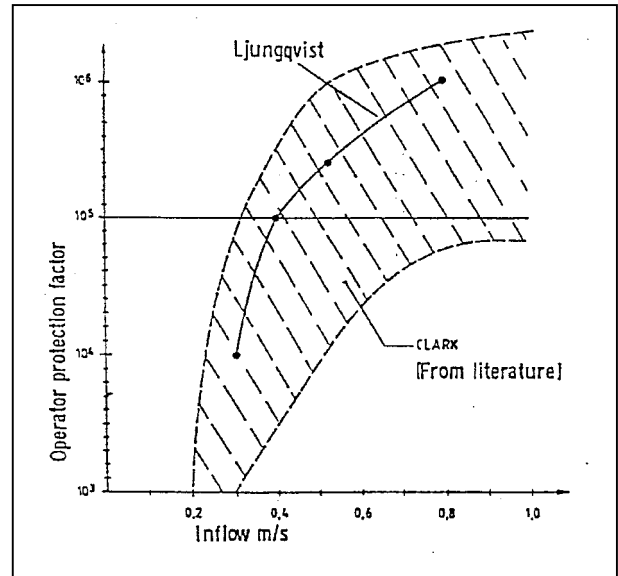


FIGURE 3. Operator protection factor (KI-Discus method) The solid line indicates the same a fume hood on which the tracer gas tests shown in Figure 2 were made. The shaded envelope represents the highest and lowest KI-Discus values measured on a range of 18 fume hoods. The horizontal solid line indicates the hood to be in the upper part of the performance range.

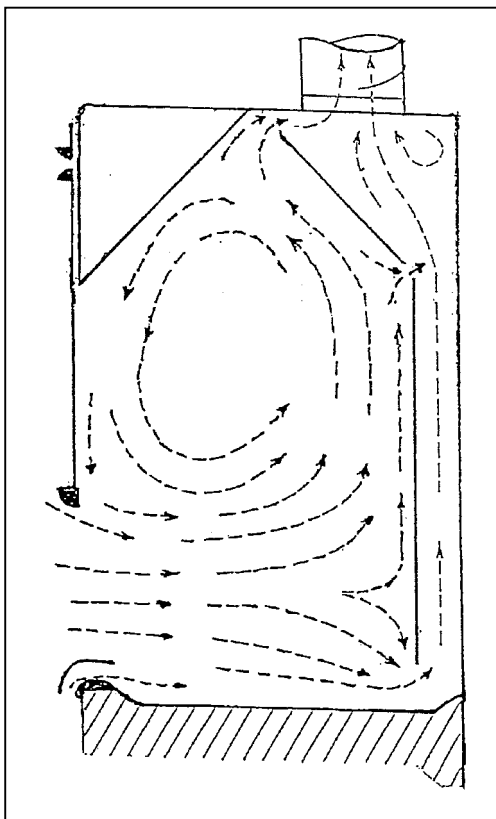


FIGURE 4. Observed main flow pattern in the KBS fume hood.

### COMPARISON AMONG THREE TYPES OF FUME HOODS

Two, newly designed fume hoods have been compared with one of the most common fume hoods (KBS-type) employed in Sweden. The EBS fume hood is an aerodynamic fume hood that has a symmetrical face velocity into the hood. It was designed in the late 1960s in order to save heating energy. The exhaust air flow was set at 600 m<sup>3</sup>/hr which gives the mean face velocity of 0.5 m/s when the sash is one-third open (0.28 m aperture height). The KBS fume hood is described by Olander<sup>(6)</sup> and Ljungqvist and Malmstrom.<sup>(7)</sup> Figure 4 shows the principle of the flow pattern in the KBS hood.

One of the newly designed fume hoods is described as the "Tornado-hood" by Ljungqvist and Waering.<sup>(8)</sup> The hood has a tornado-like vortex (irrotational vortex) at the top edge of the hood. This vortex is created and maintained with aid of supply air via an ejector air diffuser at the working area (see Figure 5). The air flow moves upwards with the rear tornado vortex, which ensures that contaminants are drawn away from the front aperture and the working region of the fumehood. The tornado vortex also has an accumulation facility that can contain additional loads caused by "puffs." The air is exhausted from the ends of the cylindrical vortex.

The second new fume hood has an aerodynamic design and an inlet slot at the top of the front side of the hood. With the aid of exhaust air through the two outlet slots, this design creates air movements that draw the contaminants more directly to the exhaust slots compared with the KBS hood. This direct flow hood is called the DF-type. Its airflow pattern is shown in Figure 6.

In all tests, the exhaust flows were in accordance with the design recommendations: 600m<sup>3</sup>/hr for the KBS-type; 500m<sup>3</sup>/hr for the tornado-type; and 550m<sup>3</sup>/hr for the DF-type. These exhaust flow rates give a mean face velocity of 0.5m/s at one-third sash opening (0.28m aperture height) for all three hoods. Room air velocities were always lower than 0.1 m/s.

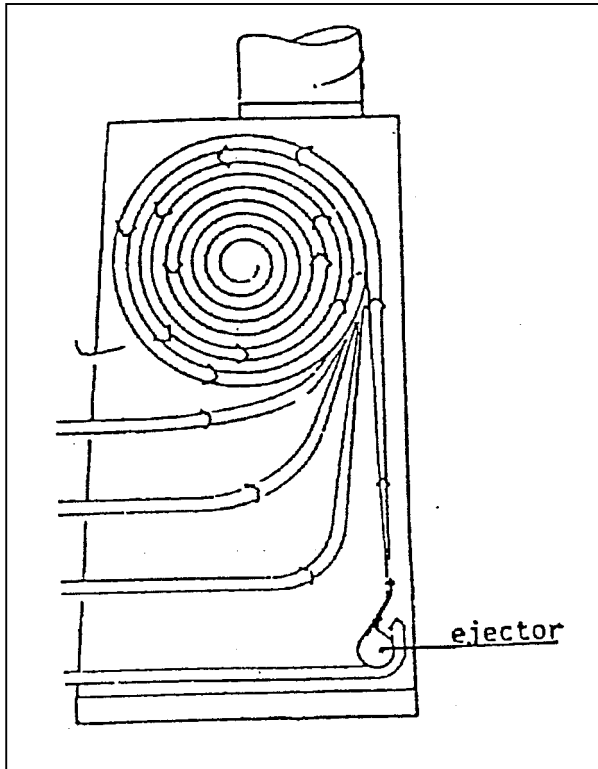


FIGURE 5. Air movements in the tornado-type fume hood.

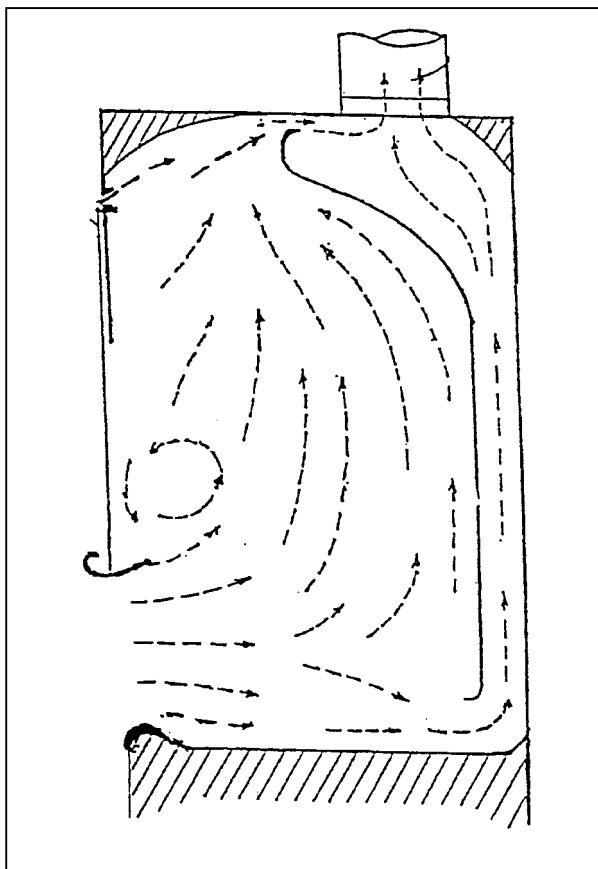


FIGURE 6. Observed main flow pattern in the DF fume hood.

Measurements for the three hood types without an operator positioned in front of the fume hood did not show any significant leakage. In the following discussion, the only values that are examined are those obtained when the operator was in front of the hoods. To limit the quantity of values, only the measurements with the tracer gas source at the position 0.3 m above the bottom of the hood are described here, and these values are used for a comparison.

The Escape Safety Values (E-values) measured with the URAS infrared analyzer are shown in Table I.

## DISCUSSION

Both the tracer gas technique and the KI-Discus method can be used to evaluate and compare the containment performance of general-purpose laboratory fume hoods. For a conventional fume hood with uniform inlet airflow velocity and with well-designed aperture edges, the results show that the inlet airflow velocity should be higher than 0.4 m/s. The results from the tracer gas measurements show that leakage from the front aperture tended to be the least at an inlet air flow velocity of 0.5 to 0.6 m/s; thereafter, as the velocity increased, the tendency for leakage was greater.

Measurements with the URAS infrared analyzer from a large number of workplaces with local exhaust ventilation have shown with experience that E-values > 95% characterize safe working conditions. This means (see Table I) that the fume hoods should not be used with the sash in the fully open position. At two-thirds open, the tornado-type and the DF-type can be used, while the KBS-type should have a lower sash position.

The reasons for the better results with the tornado and DF-types can be explained in terms of well-designed aperture edges with a little leakage and in the hoods' well-arranged internal air patterns. By these means, contaminants are drawn away more directly from the source to the exhaust system with a minimum of recirculation within the working space of the hood. The better results with the tornado hood can also be explained by the high capture efficiency of the tornado vortex. On the other hand, when the sash is fully open, the tornado vortex seems to be disturbed, which gives lower E-values compared with the two other hood types.

Fume hood safety cannot be assumed when hoods are evaluated solely on the basis of an inlet air flow velocity that may well be unrelated to the operator safety actually achieved. The aerodynamic air flow patterns into and within the hood play an important role in any outward discharge, which, in turn, affects operator safety.

TABLE 1. Comparison of the E-Values Measured with URAS for the KBS, Tornado, and DF Fume Hoods

Sash Position	E-Values (%)					
	Operator Still			Operator Moving		
	KBS	Tornado	DF	KBS	Tornado	DF
Full opening	97.8	91.7	98.0	< 70	< 76	80
2/3-opening	97.1	98.8	98.6	86.4	95.5	95.4
1/3-opening	96.4	99.1	99.2	96.4	98.8	99.2

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