

Evaluation of a Ceiling-Mounted Low-Impulse Air Inlet Unit for Local Control of Air Pollution

Ing-Marie Andersson,^A Gunnar Rosén,^A and Jan Kristensson^B

^ANational Institute of Occupational Health, Sweden; ^BAirSon AB, Sweden

In many cases, control of exposure to air pollutants has not been successful using local exhaust and general ventilation. Other measures, such as breathing protectors, must be used by the worker. Another solution is to provide the area around the worker with clean air. Different solutions for that purpose are available on the market. One of them has been evaluated with reference to its ability to reduce exposure originating from a local source handled by the worker or a high background concentration. The equipment has been evaluated both in a laboratory experiment and in a field study. The results show that the studied inlet air unit is able to reduce the worker's exposure to air pollutants in situations where he/she is handling the source and when the background concentration is high. The factor of protection with different inlet air flow, different work situations, etc., has been analyzed.

Introduction

Air pollution problems at workplaces are often complex and cannot always be resolved with general ventilation. The damage solvents are capable of inflicting shows just how important it is to keep exposure on a low level.⁽¹⁾ In most instances, especially in the reinforced plastic industry in which large objects are handled, there is need for separate, carefully devised ventilation facilities for each workplace. The design of workplace ventilation must also be combined with staff training if good results are to be achieved with respect to exposure reduction.

A ventilation solution based on the AirSon device has been developed to solve this type of problem. The device has been evaluated with respect to properties and exposure reduction in laboratory trials and at a lamination workstation in a factory making reinforced plastic products.

Material and Methods

Air Inlet Unit

The examined AirSon low-impulse air inlet device from AirSon AB is illustrated in Figure 1. One or more of the air inlet devices were mounted in a suspended ceiling which also included a light ramp. The device delivered 640 m³/hr of air at a velocity of about 1 m/sec. to the work area. The temperature of this air was 1°–3°C lower than the room's air. The surface of the device consists of a porous material with an outer, highly permeable, load-bearing shell and an inner layer with a high air resistance to air flow. The device also contains a vane-type grill making it possible to adjust the distribution pattern. The shape of the device is very important from the point of view of air preparation. The

device was located 0.3 to 0.4 meter above the worker's head. The device weighs 1.5 kg and is 0.34 m in diameter.⁽²⁾

PIMEX Method

The air inlet device was mainly evaluated with the PIMEX method. In this method, the worker is filmed on video film at the same time as her/his exposure is measured with a personal, direct-reading instrument. The measurement signal is transmitted by telemetry to a receiver. The video image and measurement signal are merged into a composite image with a video mixer and subsequently displayed on a TV monitor. Exposure is then designated as a bar on the left side of the video frame. The composite image is recorded on a video tape recorder.⁽³⁾

Laboratory Trials

Laboratory evaluation was performed in a 3-m by 3-m by 2.36-m experimental chamber (Figure 2) with a volume of 21 m³. Air to the chamber was delivered by the device and extracted through an exhaust at floor level or mounted on the table.

Additional experiments were performed in which four air inlet devices were mounted in a suspended ceiling at each corner of a square with 1.1-m sides (Figure 3). The suspended ceiling was set up inside a larger room. Air for the workplace was delivered by the four inlet devices and then distributed into the larger room.

The source of pollution in both instances was an in-

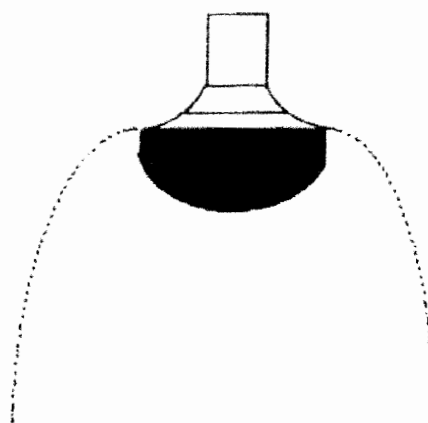


FIGURE 1. The AirSon low-impulse air inlet. The dashed lines designate the approximate area the inlet device supplies with clean air.

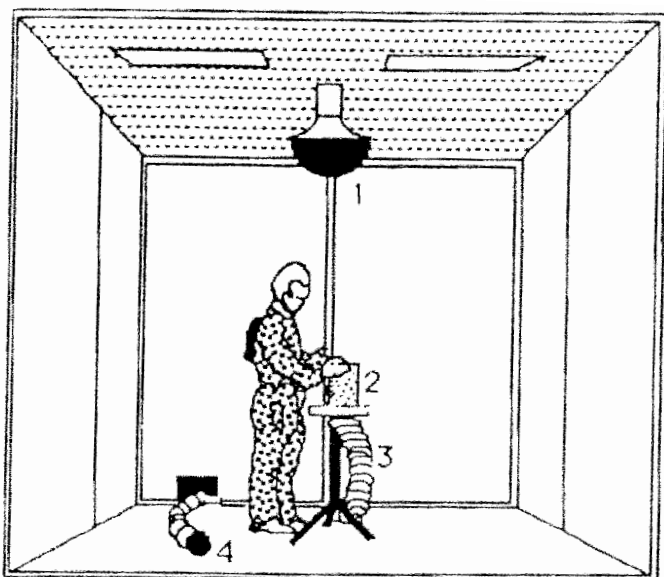


FIGURE 2. The experimental chamber in the laboratory. LEGEND: 1, Air inlet device; 2, Trace gas release; 3, Air exhaust hose mounted on the table; 4, Air exhaust hose at floor level.

verted pail placed on the table. A tracer gas consisting of toluene vapor in air was pumped through holes in the pail. The tracer gas was made by the injection of toluene into an aluminium laminate bag containing about 100 L of air. The concentration in the bag was about $20,000 \text{ mg/m}^3$ and the flow 2 L/min . The subject performed simulated work in which he applied a roller by hand to the surface of the pail.

Two experimental series were performed. The experimental setup in one was as illustrated in Figure 2; the other experimental setup is illustrated in Figure 3. In both series, exposure to toluene was measured according to the charcoal tube method.⁽⁴⁾ In most instances, exposure measurement was made with a personal monitor in the subject's breathing zone; however, a stationary monitor was employed for some measurements. The sampling time was 5–20 min. The concentration of tracer gas was also measured. In addition, studies using the PIMEX method were

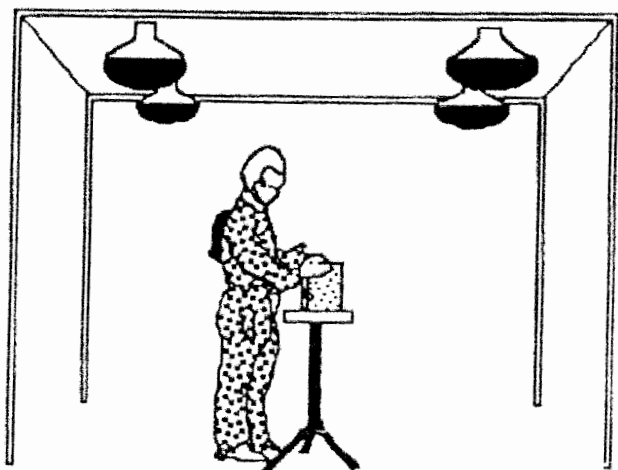


FIGURE 3. Laboratory setup with four air inlet devices mounted in a suspended ceiling.

performed. One photo-ionisation instrument, a Photovac TIP, was used. Data from measurements were stored every 2-seconds in an AAC data logger.

Field Experiments

Field measurements were performed in a spray booth at a factory manufacturing bathroom furnishings made from laminated, reinforced plastic. The spray booth and the investigated workplace were inside a large factory room. A group of three people performed the spray lamination and post-spray rolling of bathroom fixtures, e.g., bath tubs. Post-spray rolling entailed the application of a roller to a fiberglass and polyester laminate on the mould so as to expel any pockets of air trapped in the material during spraying. A suspended ceiling with four air inlet devices was installed outside the box in which rolling was performed. The devices were located with the same mutual relationship as in the laboratory study. The air flow to each device was $640 \text{ m}^3/\text{hr}$. After spraying, the work object was moved to a location under the middle of the ceiling with the four air inlet devices. Two people carried out the post-spray rolling of the fiberglass and polyester laminate. The workplace is illustrated in Figure 4.

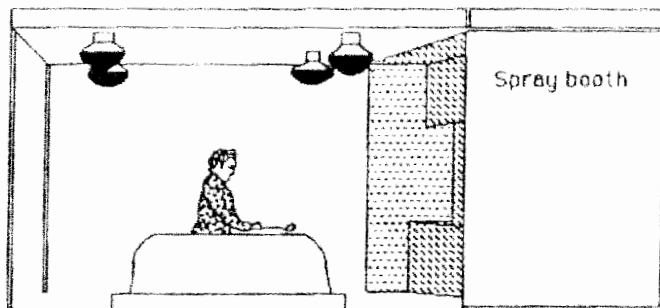


FIGURE 4. The experimental set up at a workplace with four air inlet devices installed in a suspended ceiling. The work comprised post-spray rolling of a standard bath tub.

Exposure measurements were performed on a worker with personal measurement equipment according to the charcoal tube method, with the studied air inlet devices turned on and off. The same worker's exposure was also determined with the PIMEX method. A Photovac TIP photo-ionisation instrument was used. Data from the measurements were recorded every 2 seconds with an AAC data logger. One stationary reference measurement point was located outside the suspended ceiling with input air. The objective was to measure the background concentration of styrene. An HNU photo-ionisation instrument was used. Data from the measurements were recorded every 2 seconds with an AAC data logger.

Results

Laboratory Experiments

The purpose of the laboratory experiments was to study, under controlled conditions, the ability of an air inlet device to protect the worker from exposure to an adjacent

TABLE I. Set Up and Results of a Five-Experiment Series (input and exhaust air were constant 500 m³/hr and 300 m³/hr, respectively)

Experiment No.	Location of Exhaust	Temperature Gradient Δt (°C)	Heat (W)	Protection Factor S*
1	Table	-2	100	3.1
2	Floor	-2	100	2.8
3	Table	0	0	4.0
4	Floor	0	0	0.5
5	Floor	0 to -1.5	100	—

*Protection factor calculated according to Equation 1.

source of pollution. Table I shows the setup and results of the experimental series. The temperature gradient (Δt) is the ambient temperature minus the input temperature.

The protection factor, S, was calculated according to Equation 1.

$$S = C_0/C_1 \quad (1)$$

where:

C_0 = exposure in work without separate workplace ventilation

C_1 = exposure in work with separate workplace ventilation

Figure 5 shows exposure as a function of time in two work phases with different input temperature gradients (Δt). The experiments were performed in the experimental chamber.

Figure 6 shows how exposure changed when the temperature gradient (Δt) increased from 0 to -1.5°C in the same experiment. Figure 7 shows exposure as a function of time in stationary and personal measurement. Experiments were performed with and without a worker under a ceiling with four air inlet devices.

Field Experiments

The purpose of the workplace experiment was to check

whether the results measured in the laboratory studies agreed with true conditions at the workplace. Table II shows the results of the experimental series performed during the lamination of a standard bath tub.

Figure 8 shows exposure as a function of time during two work phases with different temperature gradients. The experiments were performed at a workplace during the lamination of bath tubs.

Discussion

The purpose of the study was to investigate a new inlet device for delivering low-velocity clean air to a workplace. The air inlet device was used to reduce exposure to styrene at a workplace in which large objects were laminated. Solutions entailing the capture of styrene vapor at its source were not practical here. The idea was to study the device's ability to protect the worker from exposure.

Five experiments were performed in an experimental chamber in the laboratory where air input and exhaust, the temperature gradient, heat loading, the location of the exhaust, the type of work performed, and exposure conditions could be carefully controlled. All the parameters were selected so as to lie within the range of recommended settings when the air inlet device is used.

In the laboratory experiments, in which the input temperature gradient was 2°C less than the ambient tem-

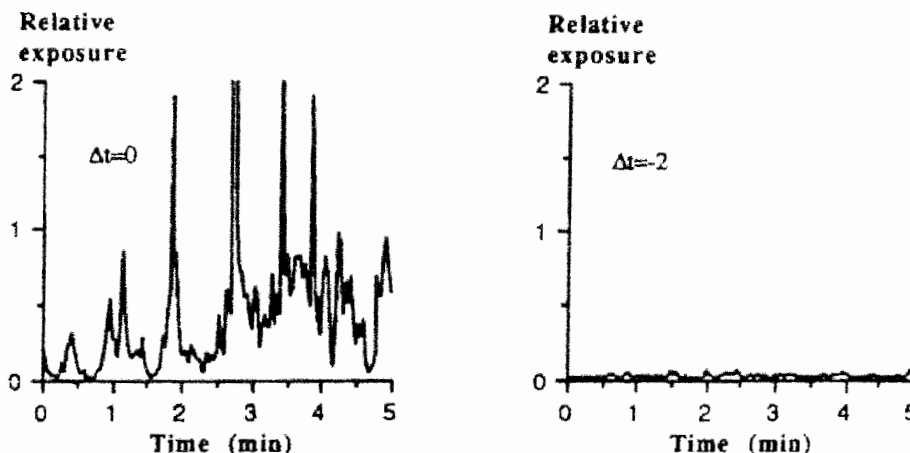


FIGURE 5. Exposure as a function of time in an experiment in the chamber. The temperature gradient for input air was 0°C and -2°C. The exhaust was located at floor level.

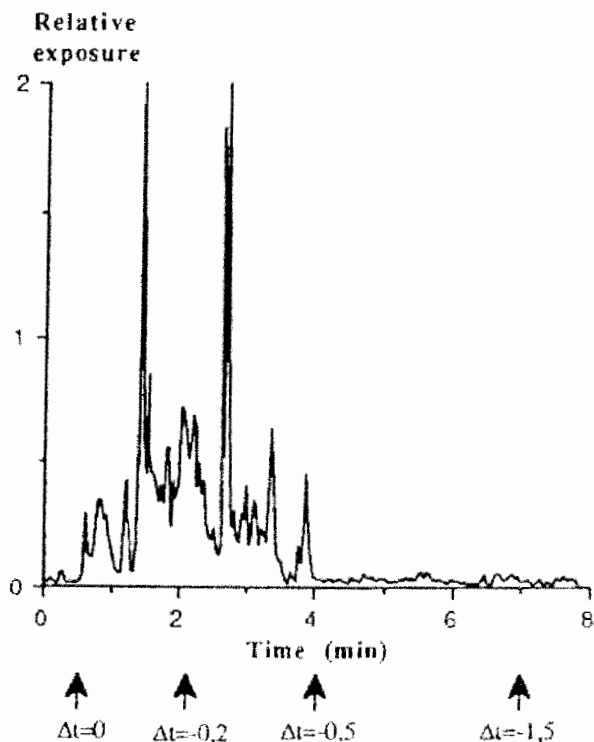


FIGURE 6. Exposure as a function of time in experiments in the chamber. The temperature gradient of input air was varied from $\geq 0^\circ$ to -1.5°C during the course of the experiments.

perature, the location of the exhaust had no decisive impact. The protection factor may have been slightly lower when the exhaust was at floor level. Exposure was almost eight times greater when input air was at room temperature and the exhaust at floor level. The best effect is achieved when the pollution is captured at its source. Exposure was very slight and stable in the workplace under an air inlet device with an air temperature gradient of -2°C and the exhaust at floor level. Exposure was varied and

heavy in the same conditions when there was no temperature gradient for input air. A large number of heavy exposure peaks also occurred. There was a pronounced drop in exposure at -0.5°C when the temperature gradient increased from 0 to -1.5°C . The laboratory experiments showed that capturing pollutants at their source is always best. But if this is not possible, a good protective effect can still be achieved when work is performed under an air inlet device with a temperature gradient exceeding -0.5°C .

The evaluation of a measure's ability to reduce exposure to an air pollutant cannot be made solely with stationary measurements at the workplace. This is clearly illustrated by the results of our measurements made in the laboratory with measurement equipment in the breathing zone of a subject performing work and in measurements made at the corresponding location without any subject present. The results of stationary measurements suggest that input air has only a slight impact on concentrations in a worker's breathing zone. However, the results from measurements in the breathing zone of a person performing work disclosed a great drop in exposure. The major differences in results, mainly composed of considerably higher concentrations in the breathing zone when the air inlet device was turned off, are ascribable to disruptions in the air currents produced when a person performs work and by the transport of pollution from the source to the breathing zone by convection currents close to the body.

One experimental series, composed of nine trials, was performed at a workplace in order to verify laboratory results. The results of these trials confirmed the laboratory results. The difference found consisted of somewhat higher protection factors in the field experiments. This was probably due to the circumstance that work in the field is more active, i.e., a worker bends more and is more frequently forced to work close to the wet surface of the workpiece, thereby increasing exposure when no protective input air was being supplied. The difference in exposure in work performed with and without input air was then greater, increasing the protection factor accordingly. This was probably because the worker was forced to perform lamination

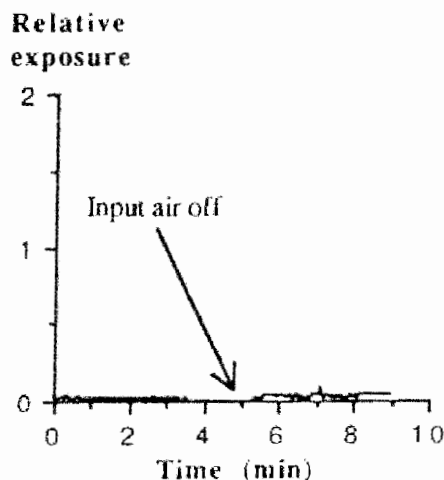
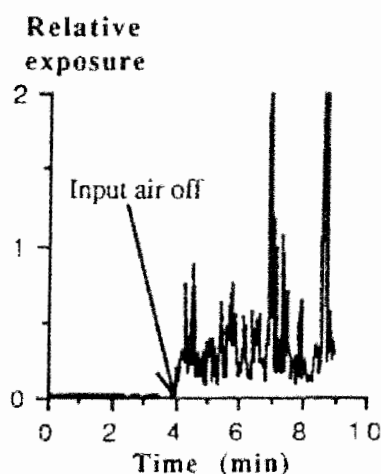


FIGURE 7. Exposure as a function of time in personal and stationary measurement. The measurement was performed with a subject performing simulated work or stationary with no work. The input air flow was $600\text{ m}^3/\text{hr}$ and the temperature gradient was -1°C .

TABLE II. Measured Factors and Calculated Protection Factor

Experiment No.	Input Air On/Off	Temperature Gradient Δt ($^{\circ}\text{C}$)	Air Flow (m/s)	Exposure (ppm)	Protection Factor S^*
10	Off	0	0	44.6	—
11	Off	0	0	23.4	—
12	Off	0	0	16.0	—
13	On	0	1.15	22.6	1.2
14	On	-0.5	1.15	28.5	1.0
15	On	-2.1	1.33	3.2	8.8
16	On	-2.5	1.33	5.7	4.9
17	On	-1.8	1.27	3.3	8.5
18	On	-1.8	1.05	3.1	9.0

*Protection factor calculated according to Equation 1.

at the ends of the bathtub, thereby ending up outside the protection zone provided by the air inlet device. Occasional exposure peaks could occur even when input air was supplied.

The investigated air inlet device makes it possible to reduce exposure considerably at workplaces where workers handle the source of pollution. The results are valid, provided pollution is emitted from the source at a low velocity. One prerequisite for preventing secondary exposure through the spread of pollutants into the workroom is general ventilation capable of efficient evacuation of these pollutants.

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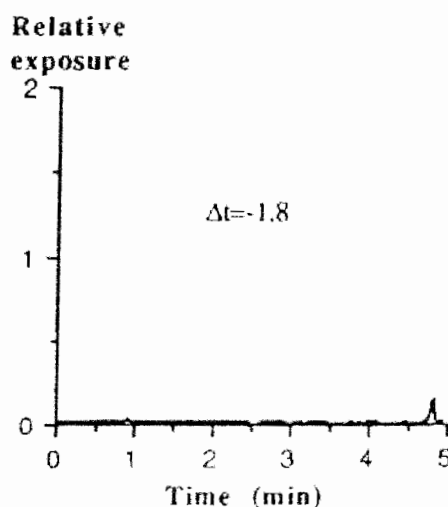
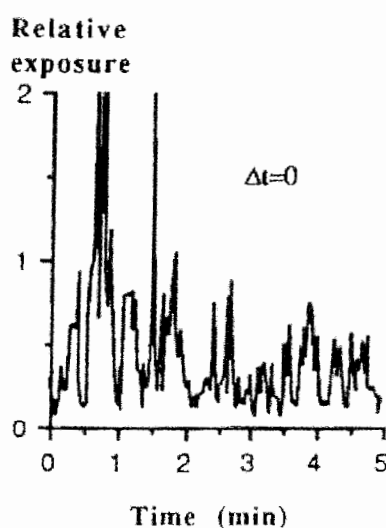


FIGURE 8. Exposure as a function of time in lamination work. The input air flow to each inlet device was $640 \text{ m}^3/\text{hr}$, and the temperature gradient was 0° and -1.8°C , respectively.