J. Aerosol Sci., Vol. 19, No. 7, pp. 1445 - 1448, 1988
Printed in Great Britain
0021-8502/88 $3.00. + 0.00
Pergamon Press plc

AEROSOL PENETRATION CHARACTERISTICS FOR DISPOSABLE RESPIRATOR FACEPIECES

Ruuskanen, J.*, Chen, C.-C., Carpenter, D. R.,
Sherman, A. and Willeke, K.
Department of Environmental Health, University of Cincinnati
Mail Location #056, Cincinnati, Ohio 45267-0056, USA

INTRODUCTION

Disposable air purifying respirators are widely used in industry with many applications for respiratory protection against aerosols, such as dust, fume, and mist. With nuisable aerosols, the function of a disposable respirator is to reduce the total amount of aerosols entering the respiratory system. To evaluate the protection characteristics, the penetration dependence of aerosols through the filter system should be known. The protection of a disposable respirator is controlled by two primary ways of the inhalation exposure for the wearer, filter penetration and facial seal leakage. The situation dealing with disposable respirators is quite complicated because a respirator mask will allow penetration of small aerosol through the air purifying element and, also, aerosols can traverse facial seal leaks.

In a quantitative respirator fit test the concentration of an aerosol in the air surrounding the respirator wearer and the concentration of that same substance inside the mask are measured. Although the important concern is the mass concentration inside and outside the mask, particle size is a major determinat of particle behaviour and for that reason the penetration through filter material and leakage as a function of particle size should be known (Holton et al.(1987),Holton and Willeke (1987)). This investigation examines the effect of filter material on particle size distribution in a dummy test and , also, the effect of leakage on particle size distribution measured with a human test subject.

EXPERIMENTAL DESIGN

The experimental set-up is shown in figure 1. The test aerosol was produced with a ultrasonic atomizing nozzle device from undiluted corn oil. The number concentration inside the mask and inside the chamber were measured by an optical particle counter (OPC) and an aerodymanic particle sizer (APS). The OPC measured optical particle sizes between 0.78 um and 6 um and the APS measured aerodynamic diameters between 0.6 um and 15 um. The sample flow rate was 10 Lpm (the APS required a sample flow rate of 5 Lpm and the OPC also used a sample flow rate of 5 Lpm). The both instruments were calibrated with monodisperse polystyrene latex particles.

Penetration measurements of filter material were made by mounting a mask on a filter holder in the chamber and measuring inside and outside concentrations. Measurements were made for six different suction

---

*During this study J. Ruuskanen was on leave from the University of Kuopio, Finland

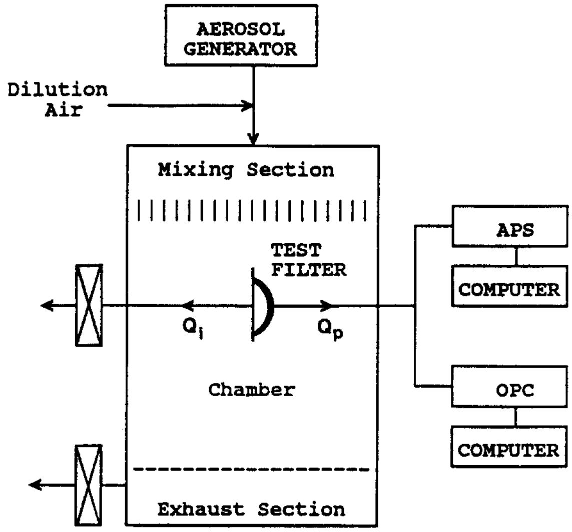

Figure 1. Schematic of test system: APS - aerodynamic particle sizer; OPC - optical particle counter; Q_i- suction flow; and Q_p- samling flow.

flow rates. In these measurements the mask was totally sealed. During the testing with human subjects, the test subject breathed through the nose and sat inside the chamber without moving the head or changing facial expressions. Sampling was performed with the sealed case, normal use (small leak) and normal use with artificial leak (large leak). In the sealed case, petroleum jelly was applied around the faceseal of the mask to block leakage through the leak site. In all of testing, one type of disposable respirators (3M 8715) was used.

RESULTS AND DISCUSSION

The data shown in figure 2, and subsequent figures show the measured penetration inside the mask for size range connected by lines that designate the measurement system. In the filter material test, the penetration is influenced by suction flow rate (figure 2). The results show an increase in penetration with increasing suction flow rate. The reason would be that, in the filtration, the diffusion is dominated, and interception and sedimentation mechanisms are less effective (Hinds and Kraske (1987)). Impaction has a minor role because of the low face velocities used.

In the comparison tests between dummy and human test subjects, a significant result is that the penetration of the sealed mask tested on a human matches with filter material penetration at the suction flow rate of 20 Lpm (figure 3). This result is in quite good agreement with the theoretical values of the human inhalation and exhalation rates.

In order to demostrate the effect of different leakage condition on the size distribution, the penetration at three different leakage rates (sealed, normal use, and normal use with artificial leak) were measured (figure 4). The results show that the shape of the penetration as a function of the particle size is similar in the cases of the dummy measurements and the measurements with the sealed mask on a human. Penetration of aerosols varied quite little with leak condition for particles having physical diameters less than 1 um. In the size range larger than 1 um, penetration indicated a different size-dependent effect between the sealed mask and the mask in the normal use. This result indicates that the large particles can enter through facial leaks.

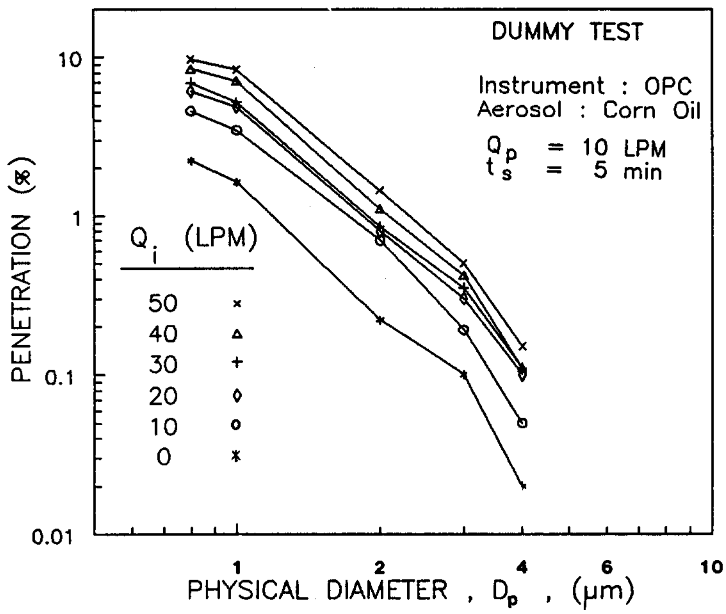

Figure 2. Aerosol penetration through the filter material of a disposable respirator mask at different suction flow rates Q_i.

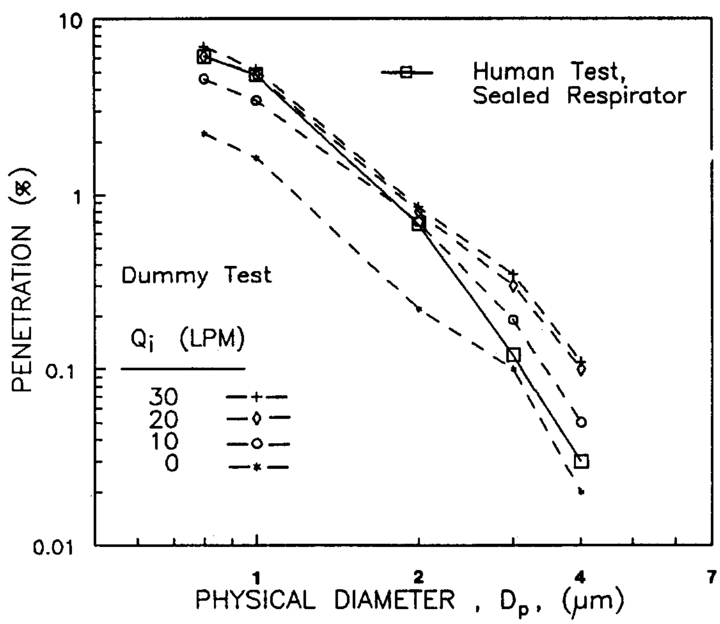

Figure 3. Comparison of a human test with a dummy test, based on measured aerosol penetrations into a respirator mask.

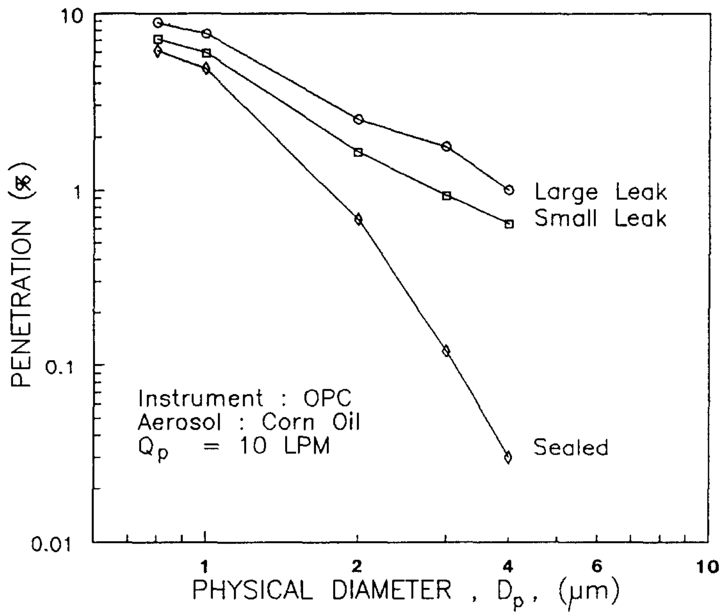

Figure 4. Aerosol penetration into a respirator mask measured on a human test subject.

The partial support of this study was provided by the Center for Aerosol Processes at the University of Cincinnati.

REFERENCES

Hinds, W. C. and G. Kraske (1987) Performance of Dust Respirators with Facial Seal Leaks: I. Experimental. Am. Ind. Hyg. Assoc. J. 48, 836-841.

Holton, P. M., Tackett, D. L., and Willeke, K. (1987) Particle Size-Dependent Leakage and Losses of Aerosols in Respirators. Am. Ind. Hyg. Assoc. J. 48, 848-854.

Holton, P. M. and Willeke, K. (1987) The Effect of Aerosol Size Distribution and Measurement Method on Respirator Fit. Am. Ind. Hyg. Assoc. J. 48, 855-860.