

FILTRATION, LOADING AND FACESEAL LEAKAGE CHARACTERISTICS OF FILTERING FACEPIECES

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ABSTRACT

The filtration and loading characteristics of filtering facepieces have been measured and analyzed, and a new fit testing technique has been developed that measures the aerosol penetration at high and low flowrates and derives from that the size of the leak.

KEYWORDS

Filtration; loading; face seal leak; filtering facepiece; disposable respirator; fit test.

INTRODUCTION

When wearing air purifying respirators, the breathing resistance is highest with HEPA filters. Whenever possible, the chosen respirator tends to have lower breathing resistance and, therefore, higher aerosol penetration. At this time, the least is known and regulated about filtering facepieces (disposable respirators). Therefore, all data shown in this article are on filtration and fit test aspects of filtering facepieces. Several of our recent publications on respirators are pertinent to the discussion of the new data shown here (Chen et al., 1990; Willeke and Krishnan, 1990; Xu et al., 1991; Chen and Willeke, 1992a,b; Chen et al., 1992a,b).

FILTRATION

Figure 1 shows the filtration efficiencies of eight surgical masks used in the U.S. today. Four of the masks are of the flat type, the other four are molded-cone shape. The latter are similar to filtering facepieces used in industrial work environments. The filtration performance of surgical masks is shown because many new procedures in operating rooms and clinical areas aerosolize bloodborne pathogens in the submicrometer size range, thus putting at risk patient and healthcare worker alike. As seen, the worst-performing mask

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(A1) has an aerosol filter penetration of approximately 100% for the particle sizes of 0.2 to 1 μm ; hence, most of the submicrometer-size particles will reach the breathing zone of the wearer of this respirator. Even the best-performing mask (A4) penetrated 20% of 0.15 μm particles at a steady flowrate of 32 lpm.

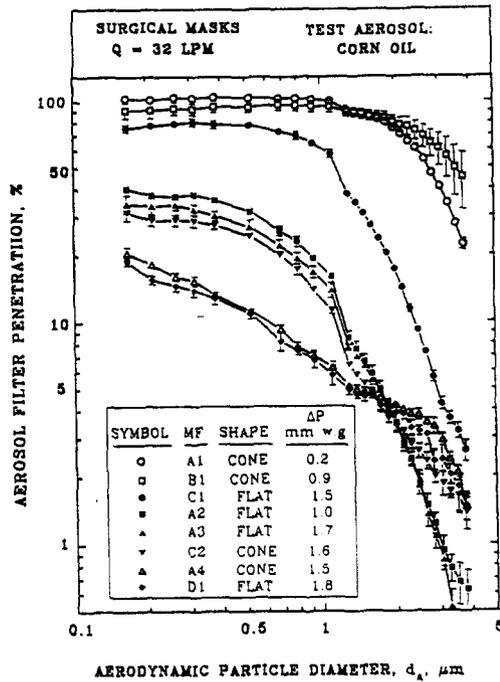


Fig. 1. Filtration performance of eight surgical masks.

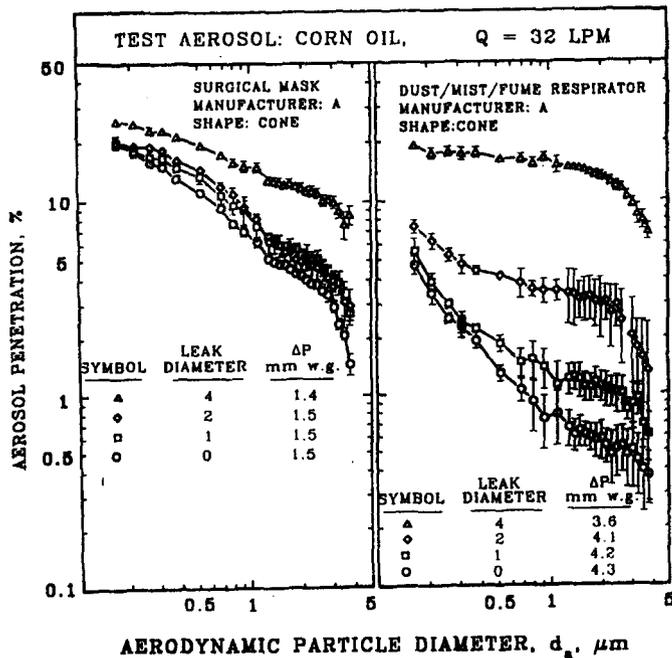


Fig. 2. Aerosol penetration through combination of filter medium and face seal leak.

FACE-FIT

Aerosol particles present in the air environment may also reach the breathing space of the respirator wearer through face seal leaks. In conventional respirator fit testing with elastomeric respirators, the cartridges are replaced by HEPA filter cartridges so that the aerosol measured inside the respirator can be attributed to face seal leakage only. In the case of filtering facepieces, the two aerosol paths are not readily differentiated.

The left side of Fig. 2 shows the aerosol penetration of the best-performing cone-shaped mask (A4) of Fig. 1 with simulated face seal leaks added. For comparison, the performance of an industrially-used dust/mist/fume (DMF) filtering facepiece from the same company with the same leak is shown on the right side. With no leak, the DMF respirator has a percent penetration of 0.15 μm particles of 5% compared to 20% for the best-performing surgical mask. When leaks are added, aerosol penetration increases. This increase is more dramatic for the DMF respirator than for the surgical mask because the DMF respirator has an approximately three times higher pressure drop, Δp , than the surgical mask. The higher the pressure drop, the more important a leak becomes in allowing particles to enter into a mask.

FIT TEST

Fit testing filtering facepieces to the face of a wearer becomes more important as better respiratory protection is needed. As seen in Fig. 2, the combined penetration through the filter material and a large leak by particles larger than 1 μm is higher for the DMF respirator than for the surgical mask although the DMF filter material is less penetrating. We have utilized these differences in aerosol penetration change with leak size and flowrate (Fig. 2) for fit testing filtering facepieces. Traditionally, the fit factor (FF) is given by the inverse of the aerosol penetration (P). We have introduced a fit index (FI) as the numerical difference between the FF at a low flowrate ($Q_L = 10$ lpm) and the FF at a high flowrate ($Q_H = 90$ lpm), as shown in the box above Fig. 3. The FI depends on the flow ratio (FR) which relates the flow through the leak (Q_{LEAK}) to the flow through the filter (Q_{FILTER}). FR is also a measure of fit. However, the theoretically- and experimentally-determined relationship between FI and FR is different for a dust/mist (DM) respirator from that of a DMF respirator.

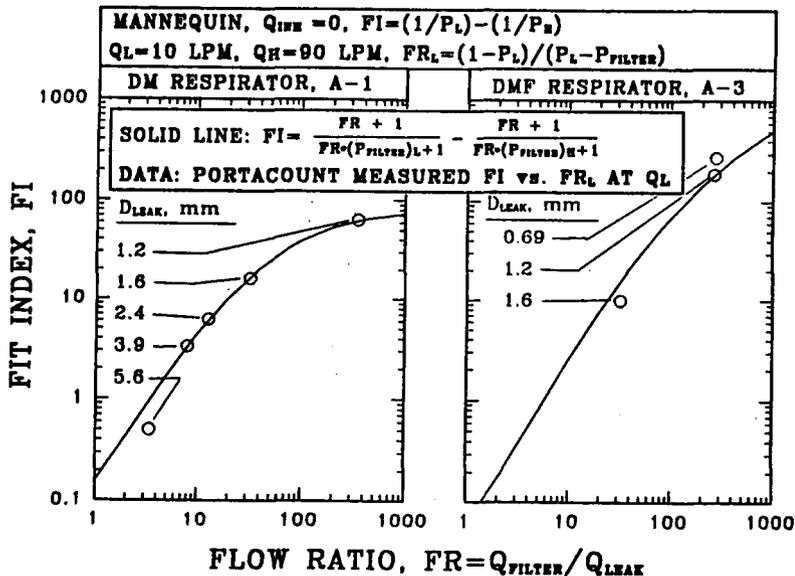


Fig. 3. Theoretically- and experimentally-determined fit index.

We have, therefore, taken this a step further and have normalized the fit index by dividing the FI with a leak by the measured FI without a leak. As seen in Fig. 4, this normalized FI relates quite well to leakage and pressure difference for all of the respirator types tested.

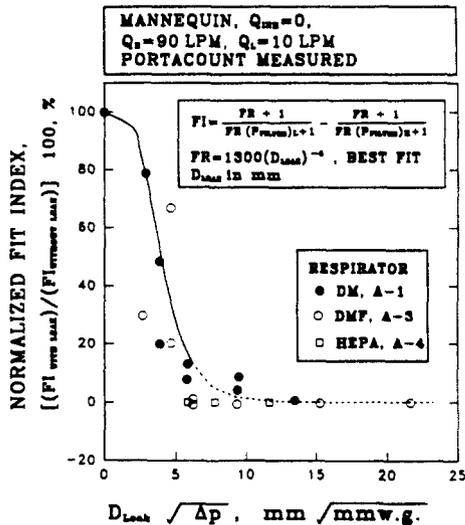


Fig. 4. Normalized fit index.

We, therefore, propose to fit test a filtering facepiece by measuring the aerosol penetration at high and low flowrates while wearing the respirator. By referring to the filtration characteristics of the respirator, the equivalent circular hole size of the face seal leak is determined as a measure of face seal fit.

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