EVALUATION OF THE PROTECTION FACTOR OF HALF-MASKS WITH RESPIRATOR FITTING TEST APPARATUS

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It is important to evaluate the protection provided by a respiratory protective mask when worn. To select good performance masks and improve them, a knowledge is necessary of the variation of performance of the masks with wearers and their exercises. The authors constructed a respirator fitting test apparatus with some improvement, which essentially duplicates that developed by Hounam (1) and Hyatt (2), and measured the protection provided by half-masks used in a radioactive dust atmosphere. Described in this paper are the modified man-test apparatus and the test results. Emphasis was placed on quantitative evaluation of the effects of exercises on the protection.

MAN-TEST APPARATUS AND TEST PROCEDURE

Man-test apparatus: Sodium chloride aerosol was used as a test aerosol because of its low toxicity and ease of generation. As shown in Fig.1, the test aerosol was generated from a 1 per cent sodium chloride solution using a Wright design nebulizer operated with a pressure of 1.25 atm. The air from the nebulizer was diluted with dry air to produce an aerosol of dry sodium chloride. The aerosol was fed into a test hood at 50 l/min. Concentration and diameter of the aerosol particles were 10^{-2} µg/cm^3 and 0.47 µm (MMD), respectively. Air from inside the facepiece was continuously sampled at 4 l/min with a diaphragm pump through a lightweight flexible tube, permitting the subject to move his head freely. Filtered air at 6 l/min was added to the sample just behind the pump in order to dry the sample air, minimize deposition loss of the particles and quicken the response. The concentration of sodium chloride in the air was measured with a flame photometer. The minimum detectable leakage rate (MDL) of the apparatus was limited to 0.03 % due to deposition loss and aerosol dilution.

Test procedure: The subject put on a respirator and ensured its fitting by the negative pressure method before entering the hood. The sampling probe on the facepiece was connected to a sampling tube within the hood, leading to the measuring system, as shown in Fig.1. While the subject performed scheduled exercises, described later, an air sample was taken continuously from inside the facepiece to measure the concentration of sodium chloride.

The concentration was first measured without the canisters, and then with the canisters secured to the facepiece. The ratio of the second concentration (C_i) to the first concentration (C_0) was taken as the penetration. The protection factor PF was evaluated from PF = C_0/C_i. The effect of loss of particles by deposition in the respiratory tract was minimized by this test procedure, with comparative measurements. The exercises were normal breathing, moving head, talking, and smiling. Each exercise was continued during the respective measurement.

The subjects were 44 adult men who had experiences in wearing the respirator. Four types of Japanese mask and two types of U.S.A's were tested. The canisters attached to the masks had filtering efficiencies of over 99.97 % for the sodium chloride aerosol under pulsating flow at a minute volume of 30 litters (3).

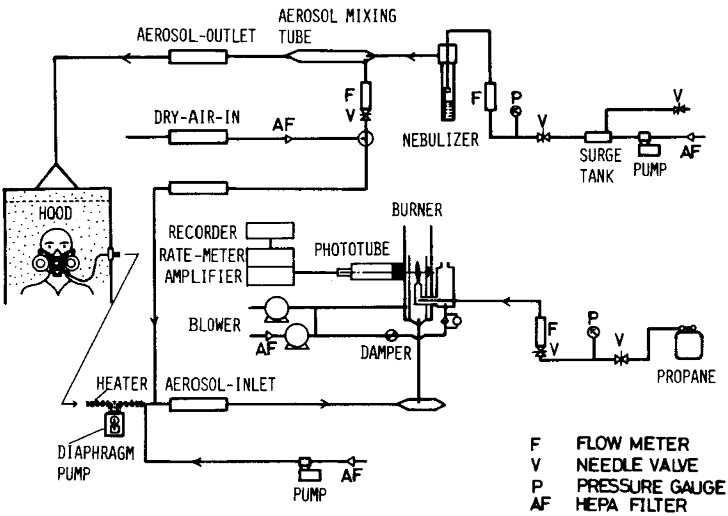

Fig.1 Flow sheet of the respirator fitting test system.

RESULTS AND DISCUSSION

Table 1 shows geometric means, geometric standard deviations, maxima, and minima of the protection factor (PF) for the masks in the exercises by the subjects. When a measured leakage was less than the MDL (0.03 %), the PF was calculated for the MDL of leakage. PFs of the masks for the various exercises are as follows.

Normal breathing: The geometric mean of PFs ranged from 340 to 600 for all masks and particularly 500 to 600 for the masks C,D,E and F. A maximum of PF is 3300 for the masks C,D and E which correspond to the MDL of 0.03 %. This maximum was obtained for 3 % of the subjects. The geometric standard deviation (σg) of PFs ranged from 2.1 to 3.2 in the normal breathing. The largest value of 3.2 for mask B represent large variation of the leakage in the mask with subjects, as compared with other masks. For masks A and B, σgs are 2.3 and 2.4, respectively, and for masks C,E and F the σg is from 2.1 to 2.2. As seen in the table, the performance of the masks A and B is worse because of the small values of geometric mean, maximum and minimum of PF, and in B, large σg of 3.2. On the other hand the masks C,E and F have good performance due to the large values of the geometric mean, maximum and minimum of PF, the minimum values exceeding 100.

Table 1 Summary of the values characterizing the distributions of protection factor(PF).

Mask	Number of subjects	PF,geometric mean				PF,standard deviation			
		NB*	S*	MH*	T*	NB	S	MH	T
A	44	340	120	85	82	2.3	2.9	3.0	2.3
B	44	390	68	120	98	3.2	4.1	3.0	2.4
C	42	530	250	250	240	2.2	3.1	2.1	2.1
D	44	500	97	100	120	2.4	4.1	2.4	2.3
E	42	600	190	300	240	2.1	2.7	2.0	2.0
F	42	470	230	260	230	2.2	2.6	2.2	1.9

Mask	Number of subjects	PF,maximum				PF,minimum			
		NB	S	MH	T	NB	S	MH	T
A	44	2900	900	750	400	17	3	3	3
B	44	1400	720	870	440	8	6	4	5
C	42	3300	1700	1200	1700	100	11	39	34
D	44	3300	3300	830	1000	68	5	6	11
E	42	3300	970	980	1100	120	19	39	64
F	42	2200	1700	1700	1200	100	29	25	35

* NB: normal breathing, S: smiling, MH: moving head, T: talking

Moving head, and talking: As seen in Table 1, these two had similar effects on the variation of PF. The PFs for these exercises were very low, compared with those for normal breathing. The mean of PF markedly decreased to 1/5 those of normal breathing in moving head for mask D. The mean PFs for masks A,B and D decreased to 1/3 to 1/5 . This is in accord with the fact that these masks have rather large σ_g of PFs even in the normal breathing. Mean PFs of the masks C,E and F were 1/2 to 1/3 those in the normal breathing, and were larger than those of A,B and D. This is consistent with the small σ_g values of masks C,E and F in the normal breathing. The minima of PFs markedly decreased with these exercises, to less than 10 in masks A,B and D particularly. Nevertheless, the minima in masks C,E and F are relatively high between 25 and 64; the masks are thus superior in this respect.

Smiling: This exercise led to relatively large drops of mean,maximum and minimum of PF compared with the other exercises, and increased the scatter of data (σ_g). This is probably caused by the leakage through wrinkles of the cheek in smiling. Even in this exercise the masks C,E and F showed good performance, e.g. means 200 and minima more than 10.

Distribution of PFs: The masks C,E and F had similar performance for different exercises. Fig.2 show plots of cumulative percentage of PF for masks C,E and F on log-normal probability paper. As seen in the figure, the values of PF for the exercises are approximately distributed in log-normal form. The data for the normal breathing fit well to a log-normal distribution.

It is seen from Fig.2 that moving head and talking influence the PFs to almost same extents and that smiling raises the scatter of PFs. The expected values of PF for an exercise most liable to leakage, i.e. smiling, is about 30 in reliability of 95 %. Solid lines in the figure are drawn based on statistics of the measured values.

Shape of masks vs. fit: Fig.3 shows external appearance in fitting contour with the face of the tested masks, viewed from the direction of the wearer and from the side. The masks C,E and F with good performance possess the following features. (1) The mask is long in the part in contact with nose bridge. (2) The length of vertical line is about 120 mm. (3) In the side view, the part in contact with the upper nose bridge is curved and the other part is nearly straight. Of the tested masks, mask C and D have the same shape, the D having metalic lining.

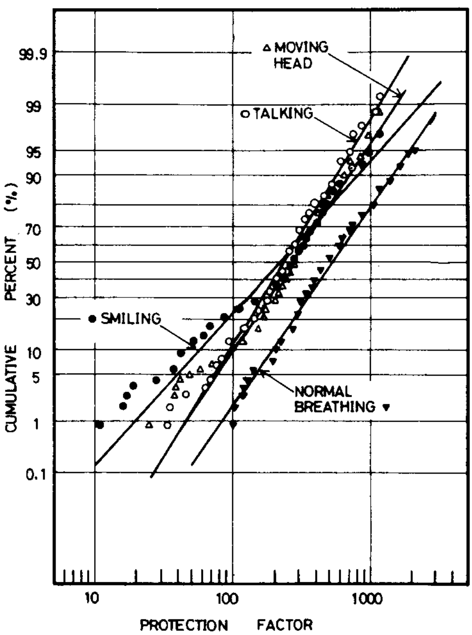

Fig.2 Plots of protection factor of masks C,E and F on the log-normal probability paper.

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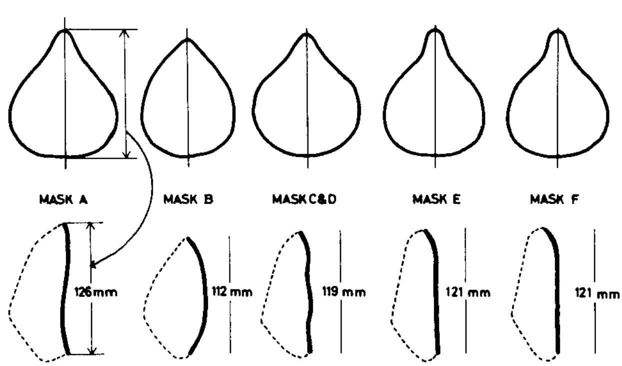

Fig.3 The contours of the half-masks used in the test.